Dataquest

MilAero Technology Service

Indispensable information for decision makers in the military and aerospace industries

Dataquest's MilAero Technology Service provides value-added information about the worldwide military and aerospace electronics and semiconductor markets. The service also provides valuable semiconductor supply base information for user organizations.

MilAero research focuses on worldwide markets and issues that link military and aerospace electronic systems to semiconductors. Included are detailed forecasts, market shares for military semiconductor and electronic equipment, technology trend assessments, competitive analyses, and semiconductor procurement issues.

MilAero comprises four comprehensive databases: component, procurement, military and aerospace equipment, and company.

Component Technology Database

Provides forward-looking technology trend and market information about military and aerospace semiconductor technology. Captures trends in the areas of microcomponents and ASICs, digital signal processing, memories, power, and gallium arsenide, as well as the standard product area of logic families, analog, and discrete. Examines product standards such as 1750A and 1553, as well as the enabling technologies such as computer-aided design and packaging. Useful to groups that require information about semiconductor trends in the context of military-aerospace needs.

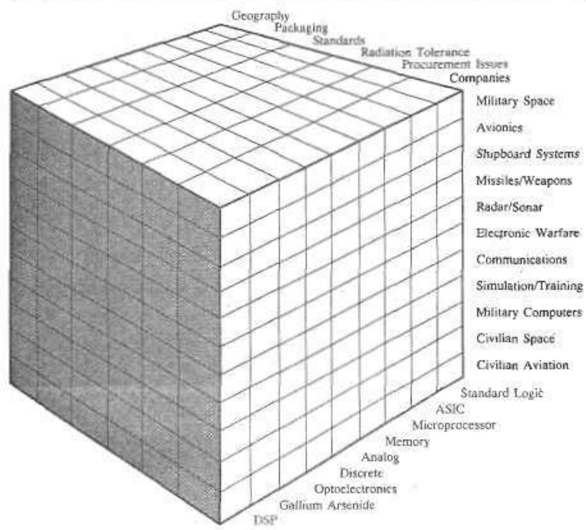
Semiconductor Procurement Database

Offers procurement and engineering organizations analyses and data on all the issues involved in sourcing semiconductor components. Sunrise and sunset sourcing, quality and reliability trends, cost issues, third-party value adding, government standards, supplier assessments, availability and life cycles, and long-term pricing projections are some of the subjects covered. Useful for organizations that need help with negotiating contracts and supplier alliances, those that are trying to be more proactive in planning, or those that are fighting crucial near-term sourcing crises.

Military and Aerospace Equipment Database

Provides value-added overview of worldwide spending budgets, major programs, and specific types of electronic equipment. Includes forecasts,

The EPIS Database Model



assessments of key market dynamics and drivers, technology utilization trends, and profiles of major OEMs. Useful to organizations that need overview information about military and aerospace electronics.

Company Database

Provides essential information about system manufacturers of military and aerospace equipment and semiconductor suppliers of military and aerospace components. Includes detailed profiles of the top companies and lists company backgrounds, product analyses, and competitive analyses. Listings are worldwide and include a mix of equipment vendors and component suppliers.

Methodology

Dataquest's MilAero Technology Service conducts its research via an underlying philosophy that the best data and analysis come from a well-balanced program. The program includes balance between primary and secondary data collection techniques; balance between supply-side and demand-side analysis; balance between focused, industry-specific research and coordinated "big picture" analysis; and balance among the perspectives of experienced industry professionals in Washington D.C., and around the world. These inputs are augmented by an integrated database covering policy budgets, contracts, systems, subsystems, components, and base technology.

Research Coverage

- Political and economic environment
- Electronic systems markets and technology
  - Worldwide military system overview
    - Military space
    - Avionics
    - Shipboard
    - Missiles/weapons
    - Radar/sonar
    - Electronic warfare
    - Communications
    - Simulation/training
    - Military computers
    - Miscellaneous military equipment
    - Research and development
  - Worldwide civilian aerospace overview
    - Aviation
    - Space
- Electronic equipment forecast
  - Worldwide
  - North America
  - Europe
  - Japan
  - Rest of World
- Semiconductor technology
  - Semiconductor market and technology overview
    - Standard logic
    - ASICs
    - Microcomponents
    - Memory
    - Linear
    - Discrete
    - Optoelectronics
    - Digital signal processing
    - U.S. government R&D programs (Sematech, VHSIC, etc.)
    - Emerging technologies (GaAs, etc.)
    - Radiation tolerance
    - Packaging
    - Government standards
- Worldwide MilAero semiconductor consumption forecast
  - Product forecast
  - Application forecast
  - Government standards forecast
  - Radiation hardness forecast
- Semiconductor procurement
  - Pricing and lead times
  - Supply base profile
  - Product lift cycles
  - Quality and reliability
- System manufacturers
  - Competitive analysis
  - Profiles
- Semiconductor suppliers
  - Competitive analysis
  - Supply base assessments

Industry Service Program

Research and decision support are provided to clients under Dataquest's comprehensive Industry Service program. The elements of this program are discussed below:

Database Notebooks Detailed reference sources examine the specific industry covered by your retainer. They are updated annually with market forecasts, annual shipments, market shares, and installed base information. They also include analysis of the industry's key companies, products, and technologies. Time-sensitive sections of the notebooks, such as market forecasts and industry analyses, will be updated throughout the year.

Research Bulletins and Newsletters These event-driven publications provide a continual flow of information, including Dataquest analysis of major industry events and issues. They can also take the form of lengthier newsletters and special reports or facsimiles.

Inquiry Support Direct access to Dataquest's market research staff provides specific answers and unique information—such as clarifications, opinions, and assumptions—on a timely basis. In this way you can target the specific information and analysis pertinent to you and your company's special needs. You can make inquiries in person or by telephone, telex, or facsimile.

Client Inquiry Centers Strategically located Client Inquiry Centers can handle your calls if you're out of the country or simply can't reach your regular contact. Designed to facilitate your access to Dataquest resources, the Client Inquiry Centers are dedicated to answering data- and fact-related questions on a quick-turn basis. The CICs are open during extended hours Monday through Friday and also can be used as a point of first contact to quickly refer more complex inquiries to the appropriate Dataquest analyst.

Information Resource Center Dataquest's library facilities around the world provide access to a wealth of reference material if you want to perform your own specific research or supplement information provided by the other service elements.

Additional Products and Services

Dataquest also offers an extensive list of supplementary products to meet the specialized needs of clients from a wide range of corporate environments. These products include:

- Conferences
- Custom consulting
- Custom surveys
- Multiclient studies
- Product specification guides
- Special reports

Dataquest
a company of The Dun & Bradstreet Corporation

1290 Ridder Park Drive
San Jose, California 95131-2398
(408) 437-8000
Telex: 171973
Fax: (408) 437-0292

© Dataquest Incorporated 5/90
0006856

Dataquest

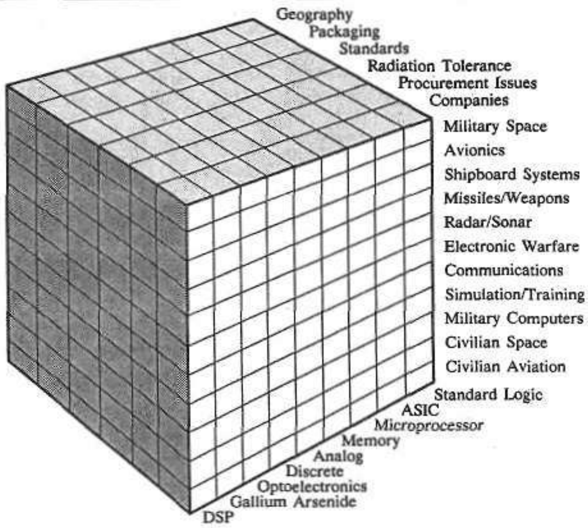
MilAero Technology Service

Indispensable information for decision makers in the military and aerospace industries

Dataquest's MilAero Technology Service provides worldwide, forward-looking, value-added information about electronic technology usage in military and aerospace systems.

MilAero research focuses on worldwide markets and issues that link military and aerospace electronic systems to semiconductors. Included are six detailed forecasts, market shares for military semiconductor and electronic equipment, technology trend assessments, competitive analyses, and semiconductor procurement issues.

MilAero comprises four comprehensive data bases: component, application procurement, military and aerospace equipment, and company financials.



Component Technology Data Base

Provides forward-looking information about commercial and military semiconductor technology. Trends are captured in the VLSI areas of microcomponents and ASICs, digital signal processing, memories, power, and gallium arsenide, as well as the standard product area of logic families, analog, and discrete. Product standards like 1750A and 1553 are examined, as are the enabling technologies such as computer-aided design and packaging. Useful to groups that require information about semiconductor trends in the context of military-aerospace needs.

Semiconductor Procurement Data Base

Offers procurement and engineering organizations analyses and data on all the issues involved in sourcing semiconductor components. Sunrise and sunset sourcing, quality and reliability trends, cost issues, third-party value adding, government standards, supplier assessments, availability and life cycles, and long-term pricing projections are some of the subjects covered. Useful for organizations that need help with negotiating contracts and supplier alliances, those that are trying to be more proactive in planning, or those that are fighting crucial near-term sourcing crises.

Military and Aerospace Equipment Data Base

Provides value-added overview of worldwide spending budgets, major programs, and specific types of electronic equipment. Includes forecasts, assessments of key market dynamics and drivers, technology utilization trends, and profiles of major OEMs. Useful to organizations that need overview information about military and aerospace electronics.

Company Financials Data Base

Provides essential information about system manufacturers of military and aerospace equipment and semiconductor suppliers of military and aerospace components. Includes detailed profiles of the top companies and lists company backgrounds, product analyses, competitive analyses, and financials. Listings are worldwide and include a mix of equipment vendors and component suppliers.

Methodology

Dataquest's MilAero Service conducts its research via an underlying philosophy that the best data and analysis come from a well-balanced program. This includes balance between primary and secondary data collection techniques; balance between supply-side and demand-side analysis; balance between focused, industry-specific research and coordinated "big picture" analysis; and balance between the perspectives of experienced industry professionals in San Jose, Washington D.C., and around the world. This is augmented by an integrated data base covering policy budgets, contracts, systems, subsystems, components, and base technology.

Research Coverage

- Political and economic environment
- Electronic systems markets and technology
  - Worldwide military system overview
    - Military space
    - Avionics
    - Shipboard
    - Missiles/weapons
    - Radar/sonar
    - Electronic warfare
    - Communication
    - Simulation/training
    - Military computers
    - Miscellaneous military equipment
    - Research and development
  - Worldwide civilian aerospace overview
    - Aviation
    - Space
- Electronic equipment forecast
  - Worldwide
  - North America
  - Europe
  - Japan
  - Rest of World
- Semiconductor technology
  - Semiconductor market and technology overview
    - Standard logic
    - ASICs
    - Microcomponents
    - Memory
    - Linear
    - Discrete
    - Optoelectronics
    - Digital signal processing
    - U.S. government R&D programs (Sematech, VHSIC, etc.)
    - Emerging technologies (GaAs, etc.)
    - Radiation tolerance
    - Packaging
    - Government standards
- Worldwide MilAero semiconductor consumption forecast
  - Product forecast
  - Application forecast
  - Package forecast
  - Government standards forecast
  - Radiation hardness forecast
- Semiconductor procurement
  - Pricing and lead times
  - Supply base profile
  - Sunset technology
  - Sunrise technology
  - Quality and reliability
  - Cost issues
  - Distribution
  - Third-party value addition
  - Vertical integration
- System manufacturers
  - Competitive analysis
  - Profiles—top 20 companies
- Semiconductor suppliers
  - Competitive analysis
  - Profiles—top 20 companies
- Budget-program data
  - RI/PI
- Glossary

MilAero clients receive:

Data Base Notebooks The notebook constitutes frequently updated reference source on the military and aerospace industries. Market forecasts and analyses, annual shipments, market shares, and program analysis are provided for each market tracked.

Inquiry Privilege This feature provides clients with access to the MilAero research staff for information on industry topics of specific interest. These inquiries can be made either in person or by telephone, telex, or facsimile.

Research Bulletins These event-driven publications provide a continual flow of timely information and included Dataquest analysis on major industry events and issues.

Research Library Clients have access to Dataquest's extensive libraries in London, Munich, Paris, Tokyo, Boston, and San Jose, should they wish to perform independent research.

Industry Seminar An annual update brings industry participants together to review the state of the military and aerospace industries and to discuss the major issues in an open forum.

As an adjunct to its Industry Service program, Dataquest also offers a full spectrum of custom consulting and survey capabilities. This special service is primarily supported by highly capable professionals, including our primary research staff.

Dataquest

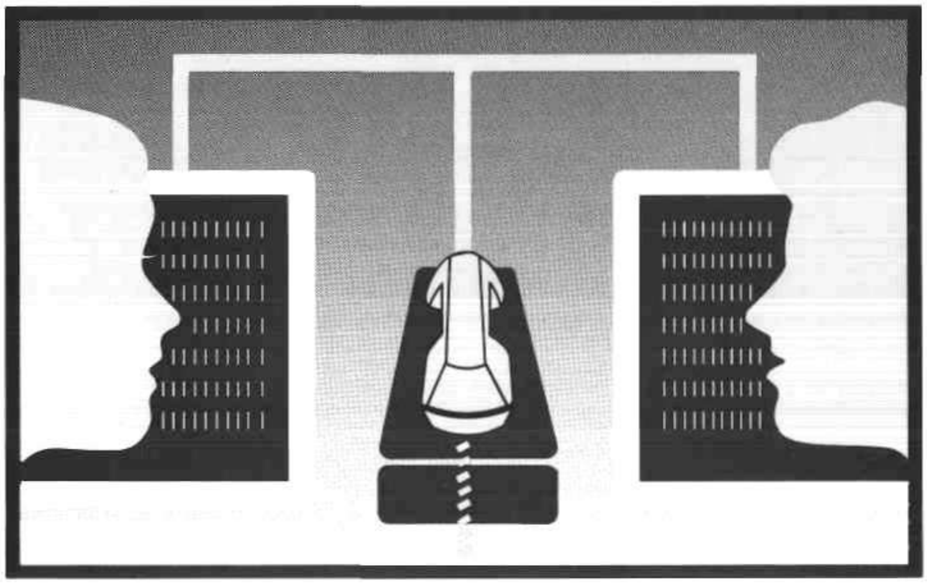
a company of The Dun & Bradstreet Corporation

1290 Ridder Park Drive
San Jose, California 95131-2398
(408) 437-8000
Telex: 171973
Fax: (408) 437-0292

7/88

Dataquest

Components Division
On-Line Supplement



Success in the fast-paced world of semiconductors belongs to companies that have the most accurate information. Industry, product, and market share data change frequently. Convenient access to these important data can mean the difference between a blind guess and an informed decision.

That is why you need Dataquest's Components Division On-Line Supplement. Now, with this easy-to-use feature, you can obtain the most recent forecasts and analyses instantly, from anywhere, any time of the day or night.

Designed to complement and enhance your annual subscription to any Components Division service group, the On-Line Supplement brings you the facts you need, when you need them.

The On-Line Supplement also delivers timely analyses of important industry trends and issues. With the touch of a button, clients receive direct on-line access to the most recent Components Division Research Newsletters and Bulletins.

In addition, the On-Line Supplement features an electronic inquiry service. Questions, clarifications, and correspondence can now be handled with the accuracy and convenience of E-mail.

Be on top of the semiconductor industry. Let Dataquest and the Components Division On-Line Supplement help you turn information into action today.

Here's All You Need:

- A terminal or personal computer
- A telephone and modem with communications software

Here's What You'll Receive:

- Around-the-clock access to Components Division data bases
- Immediate availability of Components Division Research Newsletters and Bulletins
- Accuracy and convenience of electronic inquiry service
- Twenty-five hours of use per year
- A local telephone access number
- A password, an ID number, and a manual

The On-Line Supplement is available only to clients of services within Dataquest's Components Division. Each client is entitled to 25 hours or one year (whichever comes first) of on-line access to the information provided.

A summarized directory of the information available appears below. For further information, please contact your Dataquest representative at the number listed below.

Available to All Clients
- Company Financials
- Consumption Forecast
- *DQ Monday Report*
- Electronic Inquiry Service
- Worldwide Market Share

Asian Semiconductor and Electronics Technology Service
- Assembly
- Consumption/Production
- Demography and Economy
- Distribution
- Electronics Industry
- Equipment and Materials
- Imports/Exports
- Major Semiconductor Users
- Market Share
- Semiconductor End Use

European Semiconductor Application Markets
- Electronic Equipment Data Base
- Exchange Rate Tables
- Input/Output Ratios
- Semiconductor Consumption by Application
- Semiconductor Consumption by Region
- Semiconductor Consumption by Technology

European Semiconductor Industry Service
- Application-Specific Integrated Circuits
- Exchange Rate Quarterly
- Memory
- Microprocessor
- Regional Data
- Semiconductor Market Share
- Services and Suppliers
- Wafer Fabrication

Japanese Semiconductor Industry Service
- Exchange Rates
- Historical Japanese Semiconductor Data Base
- Japanese Activity in Europe
- Japanese Imports into the United States
- Japanese Semiconductor Consumption
- Japanese Semiconductor Forecast Data Base
- Regional Trade with Japan
- U.S. Exports to Japan

MilAero Technology Service On-Line Files
- Electronic Equipment Production Forecast
- OEM Market Share
- Semiconductor Forecast: Product
- Semiconductor Forecast: Equipment
- Semiconductor Forecast: Radiation Hardened
- Semiconductor Supplier Market Share
- Semiconductor Pricing Forecast

Semiconductor Application Markets
- Electronic Equipment Forecast
- Input/Output Analysis
- Semiconductor Consumption by Application Market
- Semiconductor Consumption by End Use
- Semiconductor Purchasing Locations Directory

Semiconductor Equipment and Materials Service
- Capital Spending
- Materials
- Production
- Semiconductor Industry Ratios
- U.S. Fab Data Base
- Wafer Fab Equipment

Semiconductor Industry Service—Products, Markets, and Technology
- Analog
- Application-Specific Integrated Circuits
- Discrete
- Gallium Arsenide
- Memory
- Microcomponents
- Optoelectronics

Semiconductor Industry Service—Analog
- Amplifiers
- Regulators
- Interface ICs
- Comparators
- Data Converters
- Other Analog ICs
- Telecom ICs
- Consumer ICs
- Hybrids

Semiconductor Industry Service—ASIC
- Application-Specific Integrated Circuits
- Cell-Based Integrated Circuits
- Gate Arrays
- Programmable Logic Devices
- Standard Logic

Semiconductor Industry Service—Gallium Arsenide Technology
- Analog/Linear Integrated Circuits
- Digital Integrated Circuits
- Discretes
- Foundries
- Gallium Arsenide Application—Specific Integrated Circuits
- Gallium Arsenide Package Suppliers
- Market Shares
- Optoelectronics
- Shipments and Consumption
- Technology

Semiconductor Industry Service—Memory
- Average Selling Price per Bit/Unit
- Bits/Units Shipped
- DRAM/SRAM/EPROM/ROM/EEPROM/Forecast
- DRAM/SRAM/EPROM/EEPROM Shipments
- DRAM Market Share
- Revenue
- Revenue Trends
- Unit Trends

Semiconductor Industry Service—Microcomponents
- Microcomponent History/Forecast by Regional Consumption
- Microcomponent History/Forecast—Summary
- Microcomponent History/Forecast by Word Length
- Microcontroller Unit Shipment by Manufacturer
- Microcontroller Unit Shipment by Quarter

Semiconductor User Information Service
- Capital Spending by U.S. Semiconductor Companies
- Price Trends—Long Range Forecasts
- Products Trends
- Quarterly Price Trends

Dataquest
a company of The Dun & Bradstreet Corporation
1290 Ridder Park Drive
San Jose, California 95131-2398
Telephone (408) 437-8000
Fax (408) 437-0292

8/88
0001055

The DQ Monday Report

An on-line semiconductor industry information and pricing service

The *DQ Monday Report* offers on-line, comprehensive, worldwide market intelligence *and* pricing data for the semiconductor industry and its products. The report is accessible 24 hours a day via your computer terminal. In addition to current pricing and delivery data for all major classes and types of semiconductor devices, *The DQ Monday Report* tracks all major industry trends. *The DQ Monday Report*'s news bulletins give subscribers up-to-the-minute snapshots of the latest product, corporate, and governmental activities affecting the semiconductor industry.

With *The DQ Monday Report* you can:

- Keep on top of current events affecting the semiconductor industry
- Help your buying or selling decisions by knowing worldwide prices for semiconductor products
- Guide your planning with current prices and histories
- Evaluate the latest in-depth analyses of industry activities

The DQ Monday Report gives you:

- *Up-to-date market intelligence*

The DQ Monday Report brings you the latest news of industry activities—corporate changes, product announcements, even political news affecting the semiconductor industry. "Hot" news items are flagged in the opening log-on display so you can read them first.

- *Worldwide coverage*

You see pricing and industry information for six worldwide regions including:
— United States
— Japan
— Europe
— Taiwan
— Hong Kong
— Korea

Source information comes directly from Dataquest industry analysts located in San Jose, Tokyo, London, Taipei, Hong Kong, and Seoul.

- *Timely information*

The DQ Monday Report updates component pricing and lead times every other Monday. Industry news is updated as it happens. All data are available instantly via Compuserve through your communicating personal computer.

- *Analysis of 25 product groups*

The DQ Monday Report organizes pricing and supporting information into four main product classes—*standard logic, linear, microcontrollers/ microprocessors,* and *memories.*

- *Detailed price breakdowns*

For each semiconductor product or device family, *The DQ Monday Report* lists current minimum, maximum, and mean contract prices for quantities of 1,000 and 10,000, the volume average selling prices, and the range of lead times.

- *Pricing analysis*

By region, *The DQ Monday Report* analyzes price status and movements of the major classes of semiconductor devices, examining user demand, supplier backlogs, trade agreements, and other pricing influences.

- *Instant accessibility*

The DQ Monday Report is available 24 hours a day, every day of the year. All you need is a computer terminal with a 1200/2400-baud modem.

- *Ease of use*

As comprehensive as it is, you don't need a manual to use *The DQ Monday Report*. Simply log on and follow the simple menus to instantly look at industry news, prices, pricing trends, or whatever you need. Scan for the material you need with just a few keystrokes. And if you do need help, one keystroke will help you find out how to get to the information you want.

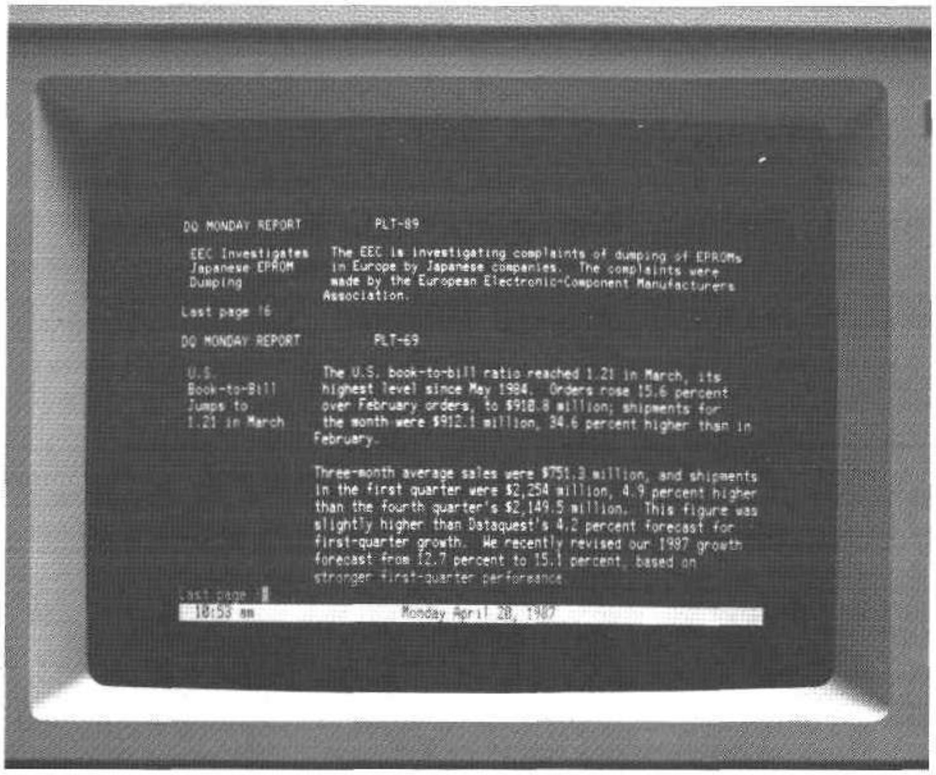
- *Hard copies and files*

You can select any data from *The DQ Monday Report* for hardcopying onto your local printer or for downloading to Lotus files on your personal computer.

Complete information on 25 products

7805-TO92	DRAM 64Kx4-10	SRAM 8Kx8	74HC00
741-TO92 Op Amp	DRAM 256Kx1-10	SRAM 32Kx8	74HC74
339-TO92 COM	DRAM 256Kx4-10	SRAM 128Kx8	74HC138
80386SX	DRAM 1Mbx1-10	74LS00	74HC244
80286, 12 MHz	DRAM 4Mbx1-10	74LS74	
8051	EPROM 256K, 200ns	74LS138	
68000, 12 MHz	EPROM 1Mb, 200ns	74LS244	

Dataquest
a company of The Dun & Bradstreet Corporation
1290 Ridder Park Drive San Jose, CA 95131-2398 (408) 437-8000 Telex 171973 Fax (408) 437-0292



Key market intelligence reports collected from many sources are updated weekly.

Dataquest tracks and serves more than 25 high-technology industries in six major areas, including:

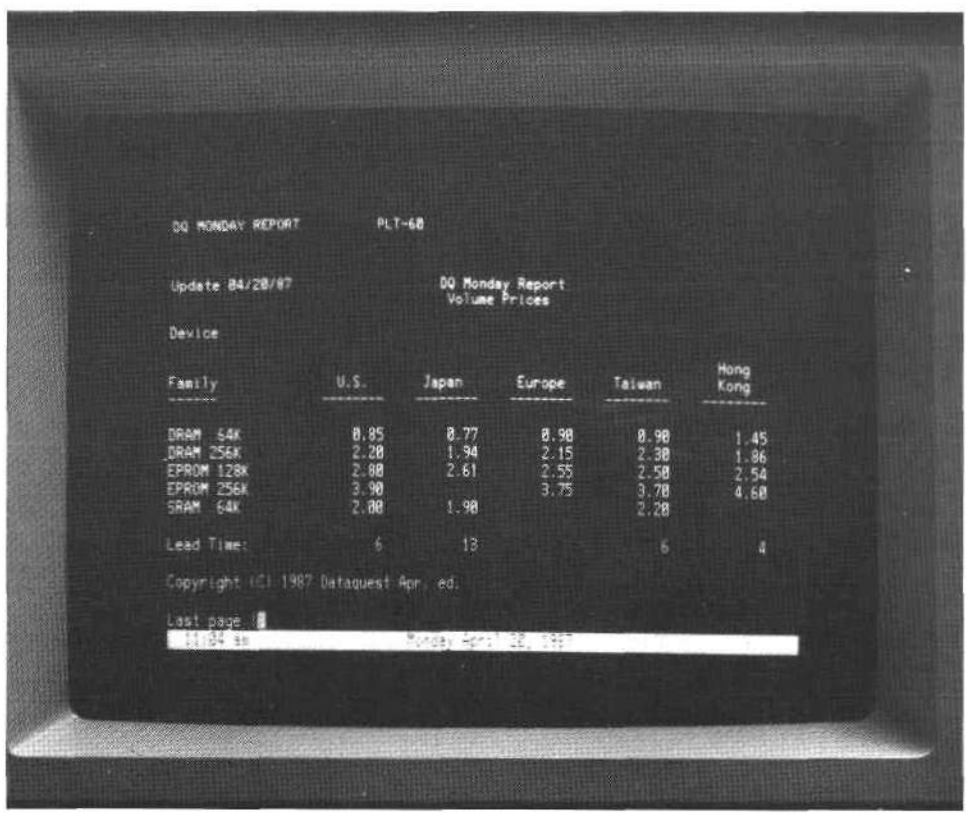
- Semiconductors
- Information systems
- Peripherals
- Office equipment
- Industrial automation
- Telecommunications

Dataquest's client services include:

- Market research and analysis
- Executive and financial programs
- Consulting services
- Publications

For further information about Dataquest or any of its services, please call (408) 437-8000.

Worldwide pricing and lead time information for 25 index products is updated every other Monday.



Easy Ordering

To order any Dataquest publication, or if you have any questions about our publications, please call 1-800-624-3282.

About Dataquest

Dataquest, a Dun & Bradstreet company, is the world leader in high-technology market research, offering clients access to a worldwide network of information, analysis, and publications that provide a critical edge in today's rapidly changing business environments.

© 1989 Dataquest Incorporated

MilAero Technology Service

Dataquest

a company of
The Dun & Bradstreet Corporation

1290 Ridder Park Drive
San Jose, California 95131-2398
(408) 437-8000
Telex: 171973
Fax: (408) 437-0292

Sales/Service Offices:

UNITED KINGDOM
Dataquest UK Limited
13th Floor, Centrepoint
103 New Oxford Street
London WC1A 1DD
England
01-379-6257
Telex: 266195
Fax: 01-240-3653

FRANCE
Dataquest SARL
Tour Gallieni 2
36, avenue Gallieni
93175 Bagnolet Cedex
France
(1)48 97 31 00
Telex: 233 263
Fax: (1)48 97 34 00

EASTERN U.S.
Dataquest Boston
1740 Massachusetts Ave.
Boxborough, MA 01719-2209
(508) 264-4373
Telex: 171973
Fax: (508) 635-0183

GERMANY
Dataquest GmbH
Rosenkavalierplatz 17
D-8000 Munich 81
West Germany
(089)91 10 64
Telex: 5218070
Fax: (089)91 21 89

JAPAN
Dataquest Japan, Ltd.
Taiyo Ginza Building/2nd Floor
7-14-16 Ginza, Chuo-ku
Tokyo 104 Japan
(03)546-3191
Telex: 32768
Fax: (03)546-3198

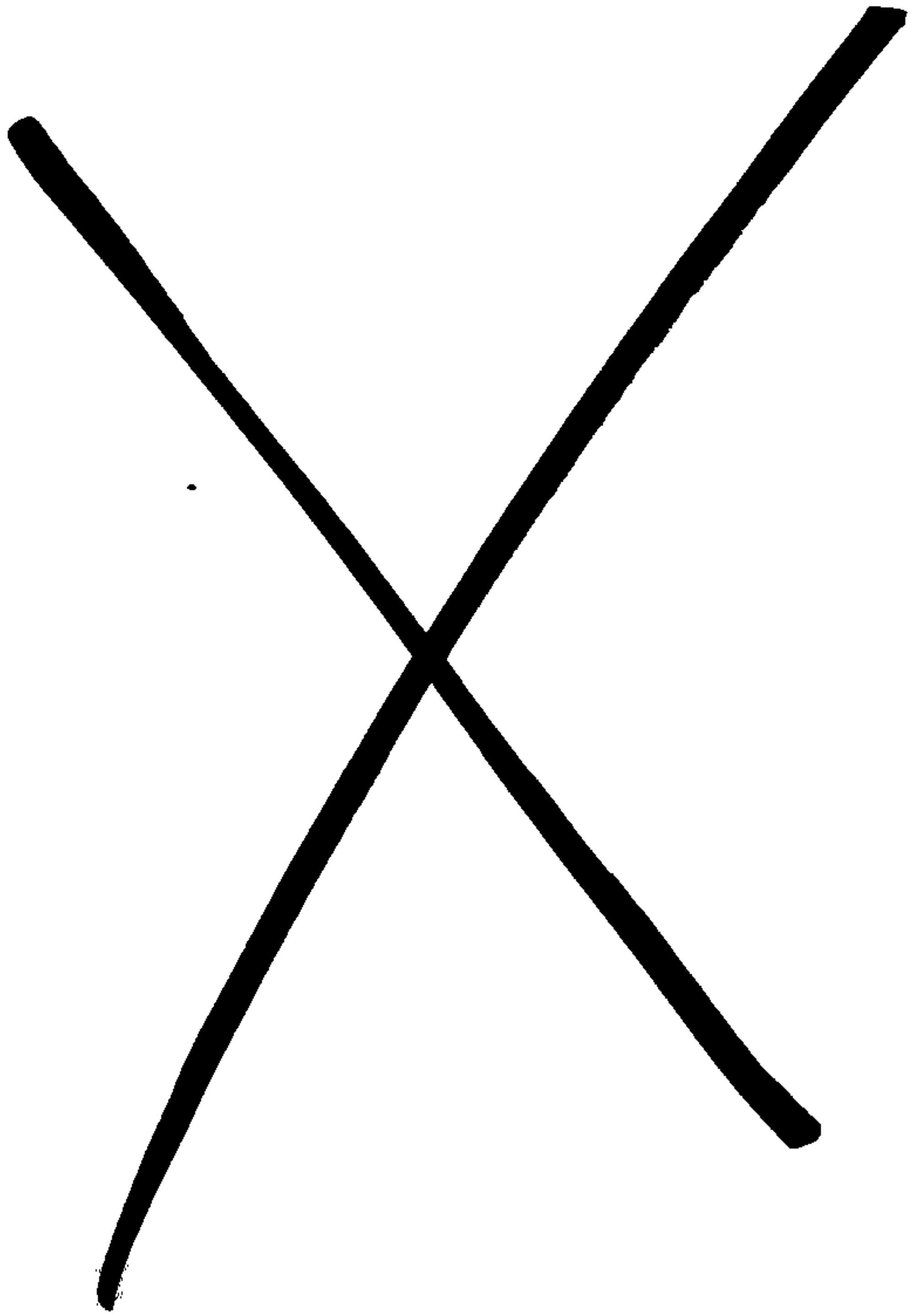
KOREA
Dataquest Korea
63-1 Chungjung-ro, 3Ka
Seodaemun-ku
Seoul, Korea
(02)392-7273-5
Telex: 27926
Fax: (02)745-3199

The content of this report represents our interpretation and analysis of information generally available to the public or released by responsible individuals in the subject companies, but is not guaranteed as to accuracy or completeness. It does not contain material provided to us in confidence by our clients.

This information is not furnished in connection with a sale or offer to sell securities, or in connection with the solicitation of an offer to buy securities. This firm and its parent and/or their officers, stockholders, or members of their families may, from time to time, have a long or short position in the securities mentioned and may sell or buy such securities.

Printed in the United States of America. All rights reserved. No part of this publication may be reproduced, stored in retrieval systems, or transmitted, in any form or by any means—mechanical, electronic, photocopying, duplicating, microfilming, videotape, or otherwise—without the prior written permission of the publisher.

© 1989 Dataquest Incorporated



Introduction

The following is a list of material in this section:

- Table Of Contents
- Introduction To The Service

Table of Contents

MILAERO TECHNOLOGY SERVICE

©1990 Dataquest Incorporated April

MILAERO TECHNOLOGY SERVICE (Continued)

 ©1990 Dataquest Incorporated April

Introduction to the Service

PURPOSE

This section is an overview of the information and services provided by the MilAero Technology Service. It summarizes the service's scope, elements, research methodology and support, and binder contents.

SCOPE OF THE SERVICE

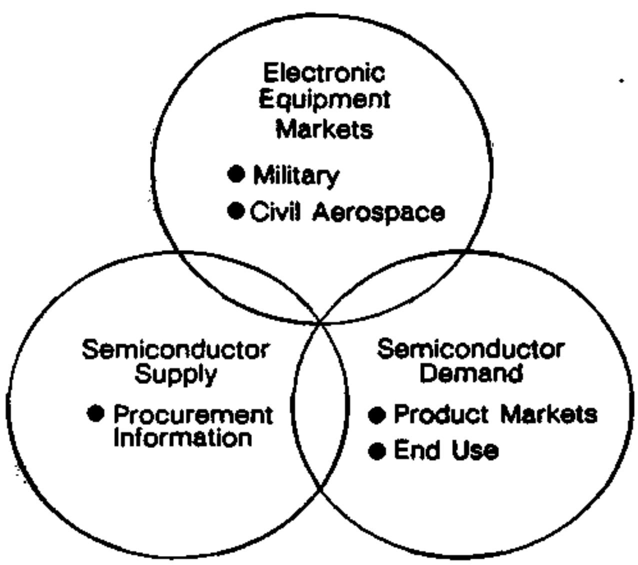
The purpose of the MilAero Technology Service is to provide forward-looking, value-added information about the worldwide military and aerospace electronic equipment markets with emphasis on information concerning semiconductor supply and demand within those markets (see Figure 1).

In the area of electronic equipment, coverage includes assessments of market and technology trends, focused analyses of factors affecting civil aviation and space electronics, and a strategic assessment of defense needs, government budgets, and acquisition programs as they involve electronics.

The semiconductor supply aspect of the service addresses issues and information of importance to organizations concerned about sourcing semiconductors for incorporation into military and aerospace hardware. Technology trends, supply-base profiles, and price forecasts specific to high-reliability technology are included.

Figure 1

MilAero Scope (Worldwide)



0006795-1

Source: Dataquest April 1990

©1990 Dataquest Incorporated April
Reference material—will not be republished

The third leg of the service covers issues of importance to semiconductor suppliers for the military and aerospace industries. Included are product forecasts, end-use analyses, and OEM and program profiles.

ELEMENTS OF THE SERVICE

The service has the following five basic elements:

- A loose-leaf binder contains the essential data that are at the core of the service's scope.
- Newsletters report and analyze electronic equipment system trends, electronic equipment markets, pricing and procurement activity, conferences, and related purchasing issues and trends.
- An inquiry privilege allows the MilAero client and a designated alternate access to the MilAero staff for clarification of or further information on the topics covered in the service.
- Clients may also have access to and use of Dataquest's Corporate Library. The extensive material in the library includes information by both subject and company, the semiconductor portion of which is indexed electronically. The library receives numerous periodicals regularly, including government data, annual reports, and foreign publications.

As a MilAero binder holder, the client and designee also have access to the Client Inquiry Center. The inquiry center provides on-the-spot support and access to available data. If a client's inquiries extend beyond the need for additional data, and the client needs detailed analyses or opinions on topics that are relevant to the service, we suggest contacting the MilAero staff directly, as mentioned above.

Clients are often unaware of what they can seek via the inquiry privilege. The inquiry privilege gives the binder holder access to unpublished information that is available within Dataquest and also to analysts' expertise and opinion. It allows clients to "personalize" the information that they require in order to make decisions that are particular to their (or their company's) needs. We invite clients to make use of the inquiry privilege in order to seek this additional and available information. The inquiry is not typically a means for additional primary research, however.

RESEARCH METHODOLOGY AND SUPPORT

Research for this service is a synthesis of primary and secondary information gathering and value-added analysis. We systematically conduct in-depth interviews of government personnel, OEM personnel, semiconductor suppliers, distributors and value adders, and technological and policy experts in various industries. These interviews are coupled with a wealth of secondary information from academic, industry, trade, and government publications. The amalgamated information is then analyzed and presented in a value-added manner.

©1990 Dataquest Incorporated April
Reference material—will not be republished

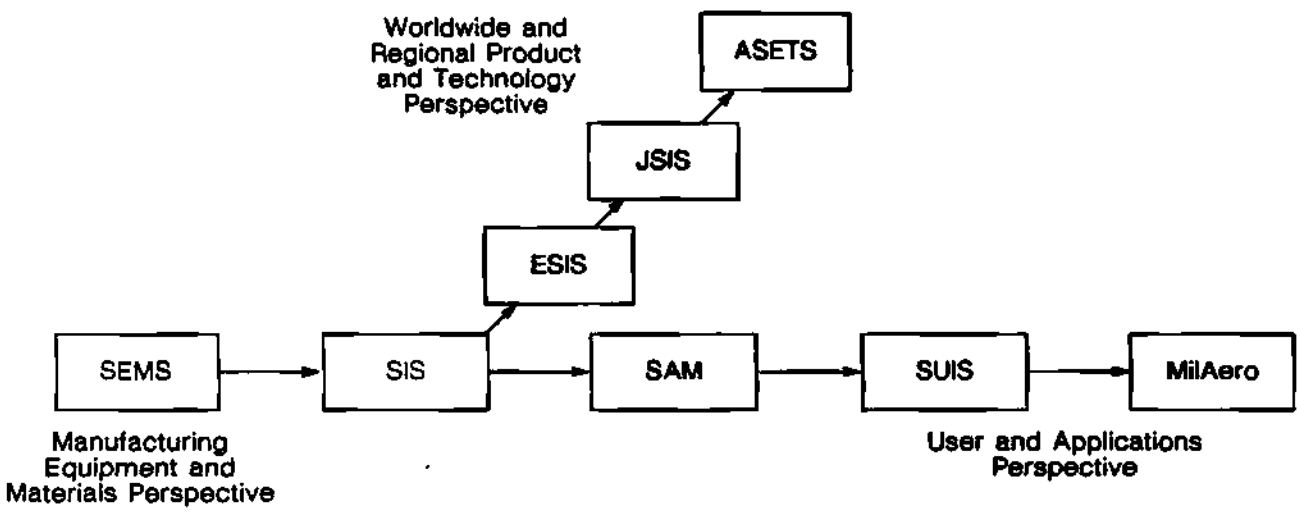
In addition, we utilize our own internal, worldwide staff members who are experts on various products and markets. The seven component division services listed below work in alignment with MilAero:

- Semiconductor Equipment Materials Service (SEMS)
- Semiconductor Industry Service (SIS)
- Japanese Semiconductor Industry Service (JSIS)
- European Semiconductor Industry Service (ESIS)
- Asian Semiconductor and Electronics Technology Service (ASETS)
- Semiconductor User Information Service (SUIS)
- Semiconductor Application Markets (SAM)

Figure 2 depicts the different semiconductor industry perspectives that the service provides.

Figure 2

Dataquest Component Services Perspectives



0006795-2

Source: Dataquest
April 1990

©1990 Dataquest Incorporated April
Reference material—will not be republished

BINDER CONTENTS

There are two binders, one for newsletters and the other for the MilAero database.

The database binder comprises seven primary sections organized by subject. The first section, entitled "Electronic Systems Markets," contains technology and market information concerning military and aerospace electronic equipment. In the military area, worldwide policy, defense budgets, and important RDT&E and production programs are covered. In the civil area, we cover worldwide aircraft and spacecraft production. Both military and civil equipment production data are presented on three areas of the world: North America, Western Europe, Japan, and select other nations. The following equipment categories are covered:

- Military
  - Radar
  - Sonar
  - Missile and weapon
  - Space
  - Navigation
  - Communication
  - Electronic warfare
  - Reconnaissance
  - Aircraft systems
  - Computer systems
  - Simulation and training
  - Miscellaneous equipment
- Civil
  - Space
  - Radar
  - Navigation and communication
  - Aircraft systems
  - Simulation and training

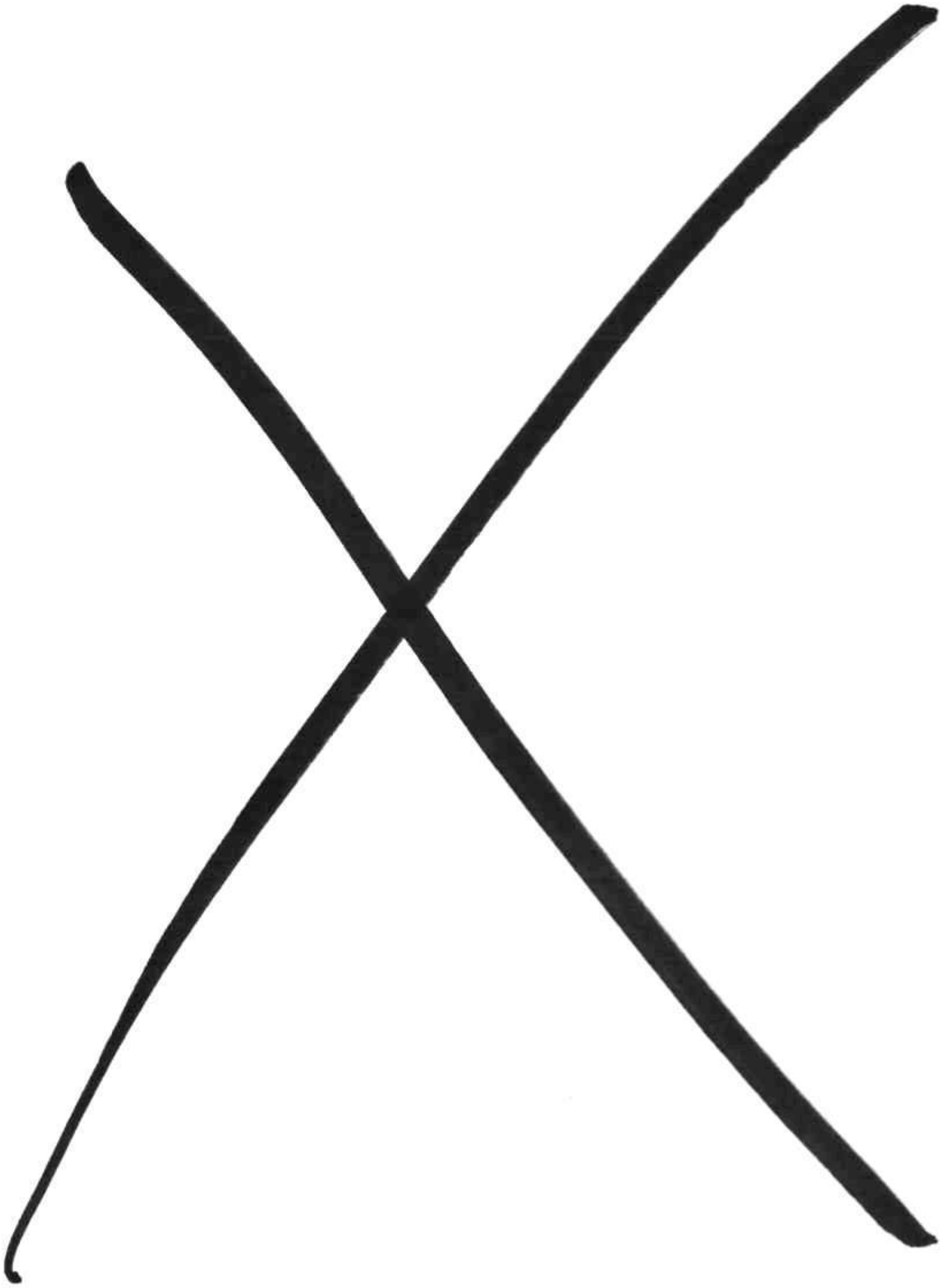
The "Semiconductor Market" section provides detailed coverage of individual product and technological areas including standard logic, ASICs, microcomponents, memory, analog, discrete, optoelectronics, and radiation tolerance. Included is detailed supply-base information.

The next section, entitled "Technology Usage in Systems," analyzes and presents data on semiconductor end-use patterns in military and civil systems.

The "Semiconductor Procurement" section consolidates data concerning the sourcing of semiconductors. It includes a detailed pricing database that estimates future trends for military specification products. This section also presents a complete analysis of sunrise (emerging) and sunset (phasing-out) semiconductor products in the context of a life-cycle analysis. Quality and reliability subjects are also covered in this section.

The "System Manufacturer" and "Semiconductor Supplier" sections provide profiles and competitive analyses.

©1990 Dataquest Incorporated April
Reference material—will not be republished



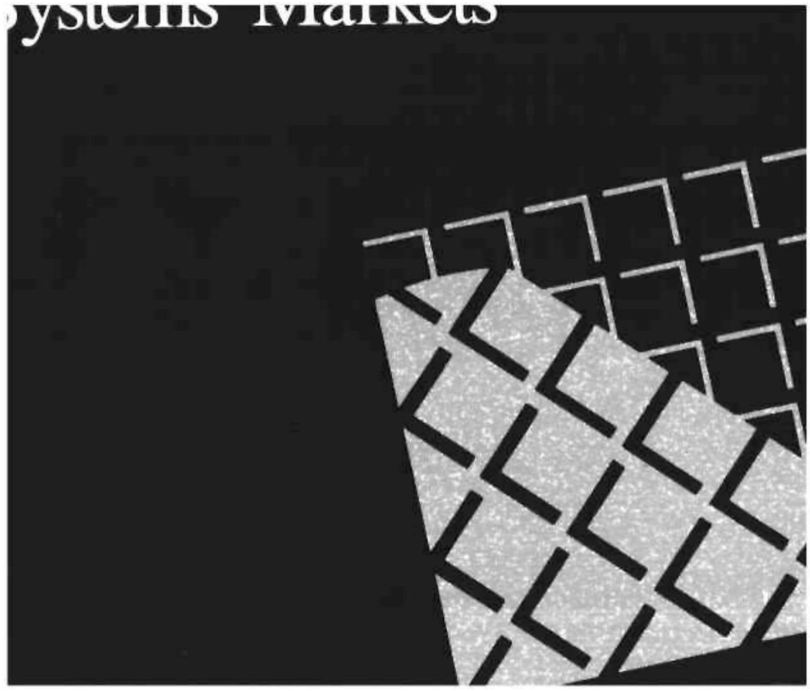
Electronic Systems Markets

The following is a list of the material in this section:

- Military Electric Systems Markets
- Civil Aviation
- Civil Space
- Equipment Production Forecast

NOTE: The arrow symbol indicates the latest document(s) correct location behind this subject tab.

 © 1991 Dataquest Incorporated April



Military Electronic Systems Markets

Dataquest
a company of
The Dun & Bradstreet Corporation

Published by Dataquest Incorporated

The content of this report represents our interpretation and analysis of information generally available to the public or released by knowledgeable individuals in the subject industry, but is not guaranteed as to accuracy or completeness. It does not contain material provided to us in confidence by our clients.

Printed in the United States of America. All rights reserved. No part of this publication may be reproduced, stored in retrieval systems, or transmitted, in any form or by any means—mechanical, electronic, photocopying, duplicating, microfilming, videotape, or otherwise—without the prior written permission of the publisher.

© 1991 Dataquest Incorporated
January 1991

Table of Contents

This booklet is divided into five major sections.

List of Tables

List of Figures

Chapter 1

Worldwide Military Spending Overview

Overview

The trend toward reductions in worldwide defense spending is continuing despite regional hot spots and instability such as the war in the Persian Gulf. However, although overall defense expenditures are dropping, weapon systems with high electronic content are faring relatively better because upgrades to existing systems are increasingly preferred over the procurement of new weapons. Moreover, as force size contracts, growing markets are emerging for force multipliers—weapon systems that give a soldier powerful advantages in the field. These systems, the content of which are well over 50 percent electronic, are focused primarily in smart weapons, command, control, communications, and intelligence systems and also include advanced simulation equipment to reduce training costs.

U.S. Fiscal Crisis

U.S. defense spending has been falling steadily in real terms from its zenith in 1986. These cuts largely preceded the dramatic events in the Soviet Union and throughout Eastern Europe in the late 1980s. In short, it is a deteriorating domestic economic situation, not the collapse of the Soviet empire, that has been the real driver in the move toward lower defense expenditure since the mid-1980s.

This massive fiscal crunch, punctuated by the ever-increasing price tag for the savings and loan bailout and the deficit limitations dictated by the Gramm-Rudman-Hollings legislation, has led to cuts in nearly every federal program, including defense. So far, defense cuts mostly have occurred in the form of prolonged stretch-outs of new programs and reductions in the number of planned purchases of advanced weapon platforms; increasingly, however, reductions in overall force levels may be required.

The programs most affected by the fiscal situation are the most expensive weapon platforms on which development began during Ronald Reagan's defense buildup in the early 1980s. These programs include the Advanced Tactical Fighter (ATF), the Light Helicopter (LH), and the B-2 stealth bomber. Altering these three aircraft programs as a result of an internal Department of Defense (DOD) review in spring 1990 accounted for over $12 billion in projected Pentagon savings through fiscal 1994.

Still, the Pentagon has been slow to adjust defense spending priorities to account for the "new world order," preferring instead to chip at the edges of larger programs. As a result, tremendous pressure is building on Capitol Hill for the DOD to undertake a fundamental reassessment of its roles and resulting procurement needs through the 1990s in light of the fundamentally transformed worldwide threat environment faced by the United States.

While this reassessment takes place, we expect continued commitment in such areas as advanced avionics and electronics in order to give U.S. service personnel an advantage in the field. High-tech programs such as the DOD's Millimeter-Wave and Microwave Monolithic Integrated Circuit (MIMIC) programs, advanced research into high-definition television (HDTV) and displays, and increasing research into optoelectronic systems such as infrared search and track (IRST) radars should increasingly dominate military R&D funding and occupy niche markets that are largely protected from expected massive congressional cutbacks.

Collapse of the "Evil Empire"

During the past year, the western world has witnessed changes in Eastern Europe unimaginable five years ago. The Berlin Wall, for years the fundamental symbol of the divide between western and eastern governments, fell, surprising nearly everyone on both sides. A year later, empty fields stretch out where gun towers stood and guard dogs roamed. In the Soviet Union, communism is waning and politicians struggle to implement

©1991 Dataquest Incorporated January—Reproduction Prohibited

reform efforts that would have been heresy in another era.

These dramatic events are in no small measure the result of 45 years of an active Western alliance. NATO's continued support for deterrence can be given some degree of credit for forcing the Soviet Union to look inward in times of crises rather than projecting its internal difficulties outward in the form of militarily aggressive behavior. After 45 years, NATO is on the brink of achieving what perhaps no other military alliance in the history of the world has: it prevented war.

The cost of this victory, however, has been high, and it will continue to require a substantial investment in military capabilities to guard against possible backsliding and other unforeseen contingencies.

The European Theater

The military threat to Europe historically has come from the East. With the Soviet military machine in disarray, combined with dramatic cuts in Eastern European military spending, substantial arms control agreements, and a steady decline in Soviet military spending, that threat is quickly evaporating.

This reduced threat in Europe was acknowledged in May 1990 by NATO's Defense Planning Committee. Since 1977, NATO had maintained the goal of 3 percent increases (in real terms) for each member nation's military budget. Although few nations have reached such steady growth, the abandonment of the policy demonstrates the easing of the perceived threat among the European allies. Unlike the United States, the strategic interests of which are worldwide, European governments view the collapse of the Soviet threat as an imperative to continue to draw down defense budgets. Military spending among European NATO members exceeded $152 billion in 1989, an increase of only $500 million in real terms, less than one-third of 1 percent from 1988. European defense spending turned downward in 1990 and should continue to decline for at least five years.

Currently, every nation in the European theater is reassessing the military threats it faces and orchestrating a new defense posture based on the "new Europe." With domestic consumption of military hardware sure to decrease, European defense manufacturers are increasingly looking at foreign market opportunities. This occurrence will undoubtedly lead to a tightening of the already highly competitive worldwide arms market, primarily in the Third World, and cut deeper into American manufacturers' potential sales.

In addition, as 1992 draws near, an increasing degree of intra-European cooperation is taking place in the defense sector. The proliferation of business alliances is pervasive throughout Europe and covers nearly every type of weapon system and technology, from the European Fighter Aircraft (EFA) to air-to-air missiles, helicopters, space systems, and HDTV.

The Worldwide Military Environment

According to preliminary indicators, worldwide defense expenditures totaled only $935 billion in 1989, a decline of nearly 2 percent from the 1988 level. The United States and the Soviet Union accounted for more than 60 percent of this total (see Table 1.1). When the world's two major alliances, NATO and the Warsaw Pact, are included in the equation, four-fifths of the total is represented. Besides the two alliances, only a handful of nations are significant consumers of military electronics; these nations include Australia, China, India, Israel, Japan, Pakistan, Saudi Arabia, South Korea, and Taiwan.

The figures shown in Table 1.1 will change significantly during the next several years, as German reunification is completed, the Warsaw Pact is disbanded, and NATO forces relax. In all, 1988 is likely to prove to have been the high point of global expenditures, with the total in 1995 declining to about $800 billion in constant 1988 dollars.

Worldwide Military Exports

Although worldwide attention has justifiably been focused on the changing European situation during the past year, significant events have occurred elsewhere that bear directly on military needs and capabilities. Of particular importance are the continuing conflicts in the Middle East and the increasing internal instability in many southern and southwest Asian nations.

In the Middle East, the Iraqi invasion of Kuwait brought to attention long-ignored contingencies and reminded defense planners of the need to procure systems capable of performing across a wide range of battlefield environments. Eventually, 27 nations committed troops or

©1991 Dataquest Incorporated January—Reproduction Prohibited

Table 1.1

Military Spending by Nation and Alliance
(Billions of Constant 1988 Dollars)

Country	1985	Percent Worldwide Total	1989	Percent Worldwide Total
NATO				
United States	290	31	289	31
West Germany	34	4	34	4
France	34	4	36	4
United Kingdom	37	4	34	4
Other NATO	51	5	56	5
Total NATO	446	48	451	48
Warsaw Pact				
Soviet Union	275	30	290	31
East Germany	6	1	7	1
Other Warsaw Pact	13	1	17	1
Total Warsaw Pact	294	31	314	32
Total Worldwide Expenditure	923	100	935	100

Note: Columns may not add to totals shown because of rounding.
Source: SIPRI 1990 yearbook, IISS 1990-1991 military balance, ACDA World Military Arms Transfers and Expenditures, DFI

equipment to the Gulf conflict, although the United States dispatched by far the largest number of soldiers and hardware.

The events in the Middle East provided a boost to sagging worldwide military sales, particularly within the region. The United States alone concluded new arms sales to Saudi Arabia worth more than $20 billion. Additional sales to Israel to offset the Saudi deals quickly followed. Much of the equipment, however, was simply transferred from the European theater and did not result in new demands on production as the U.S. withdrawal from Europe would otherwise have resulted in equipment destruction or sales elsewhere.

Dataquest anticipates that even after a settlement is reached in the Kuwaiti situation, vast supplies of sophisticated weaponry will continue to pour into this volatile region. Lacking arms control agreements, we expect defense manufacturers to capitalize on the growing desire among nations in the region to arm themselves with the most sophisticated weapon systems. Competition will be stiff.

Besides the Middle East, arms exporters are finding increasingly friendly markets in southern Asia, which, for the first time in 1988, temporarily replaced the Middle East as the world's largest arms importing region.

In eastern Asia, Japanese companies have been supplying a rising percentage of the electronics incorporated in Japan's weapon systems. To date, these companies are prohibited by law from exporting military systems, although exceptions are made often for so-called dual-use technologies. A relaxation of these export restrictions could worsen the international competitive situation significantly.

Moreover, the competition for international arms sales is likely to grow more intense as the Soviet Union surges forward in an attempt to secure much-needed hard earnings. From 1985 through 1989, the Soviet Union exported more than $66 billion worth of military hardware, over $46 billion of which went to developing nations. As the domestic need for equipment recedes both to meet economic needs and to comply with arms control agreements and as political constraints on Soviet markets recede, the USSR will be anxious to increase exports.

Outside the United States and the Soviet Union, the annual worldwide market for defense electronics is currently about $25 billion to $40 billion. France, Japan, the United Kingdom, and the former West Germany account for approximately 33 to 40 percent of this total market.

Most defense electronics purchasers are seeking to reduce defense expenditures for reasons comparable with those faced by the United States. Among industrialized countries, only Japan is continuing to increase defense spending in real terms. In the Third World, India, Pakistan, and Israel are key exceptions to the trend toward significantly reduced defense expenditures. Although somewhat cushioned from trends in overall defense spending because of increasing sophistication of most types of weapons, the international market for defense electronics may still contract during the 1990s as traditional arms importers absorb—often at reduced prices—excess weapons from Europe rather than procure new weapon systems.

Considerable competition already exists for overseas sales of defense electronics. Companies in several European nations, including Britain, France, the Netherlands, and Sweden, as well as Israel and Japan, manufacture products comparable to many U.S. systems. Moreover, European governments tend to protect domestic defense manufacturing companies for economic advantages and reasons of national security. Unlike the United States, European governments usually aid their manufacturers in closing deals with Third-World nations. Additionally, European manufacturers have been cooperating in recent years, and there has been a trend toward various corporate restructurings that cross national boundaries. This trend is creating more efficient competitors in Europe, as well as greater incentives for European governments to protect the consolidated multinational entities. European market integration might raise further barriers to U.S. penetration of European defense markets.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Chapter 2

U.S. *Military Spending Overview*

Overview

The 1980s witnessed an unprecedented peacetime buildup of U.S. military strength. Altogether, the United States spent over $2.3 trillion on defense, nearly $900 billion of which was invested in procurement and R&D accounts.

The defense budget President Bush presented to Congress in February 1989, however, called for "zero growth" in budget authority. This call for reduced growth in defense expenditures was more an acknowledgment of fiscal realities than a fundamental shift in spending policy.

Still, Congress insisted on reducing the budget below the President's request (see Table 2.1). The fiscal 1991 DOD budget, which emerged in October 1990, after one of the most vitriolic sessions in memory, marks the sixth consecutive year of real decline in U.S. defense appropriations. This year's budget includes a cut of over $20 billion from President Bush's original defense request, marking a real decline of over 9 percent. Two-thirds of the cut resulted from reductions in procurement or R&D programs.

Macrotrends in U.S. Defense Spending

To gain some perspective on the defense budget, Figure 2.1 shows the trend in defense spending since the end of the Korean War. The top line indicates DOD expenditures after taking inflation into account. The peak in the late 1960s and early 1970s is the result of buildup for the Vietnam conflict, topping off in 1968 at $300 billion at today's prices, and the subsequent decline bottomed out in 1980 at about $180 billion. The buildup that followed in the 1980s was unprecedented in peacetime, peaking again at about $300 billion.

Going back 35 years, the trend line in defense spending has been slightly up in real terms; annual real growth has averaged about 1.5 percent over the full period.

Since World War II, defense spending in relative terms dipped below 5 percent of the gross national product (GNP) for only two brief periods, 1948-1950 and 1977-1979. More recently, defense spending peaked at 6.3 percent of GNP in 1986 and is now declining steadily. The program proposed by the Bush administration would bring defense outlays to 4.2 percent of GNP

Table 2.1

Fiscal 1991 Defense Authorization
(Billions of Dollars)

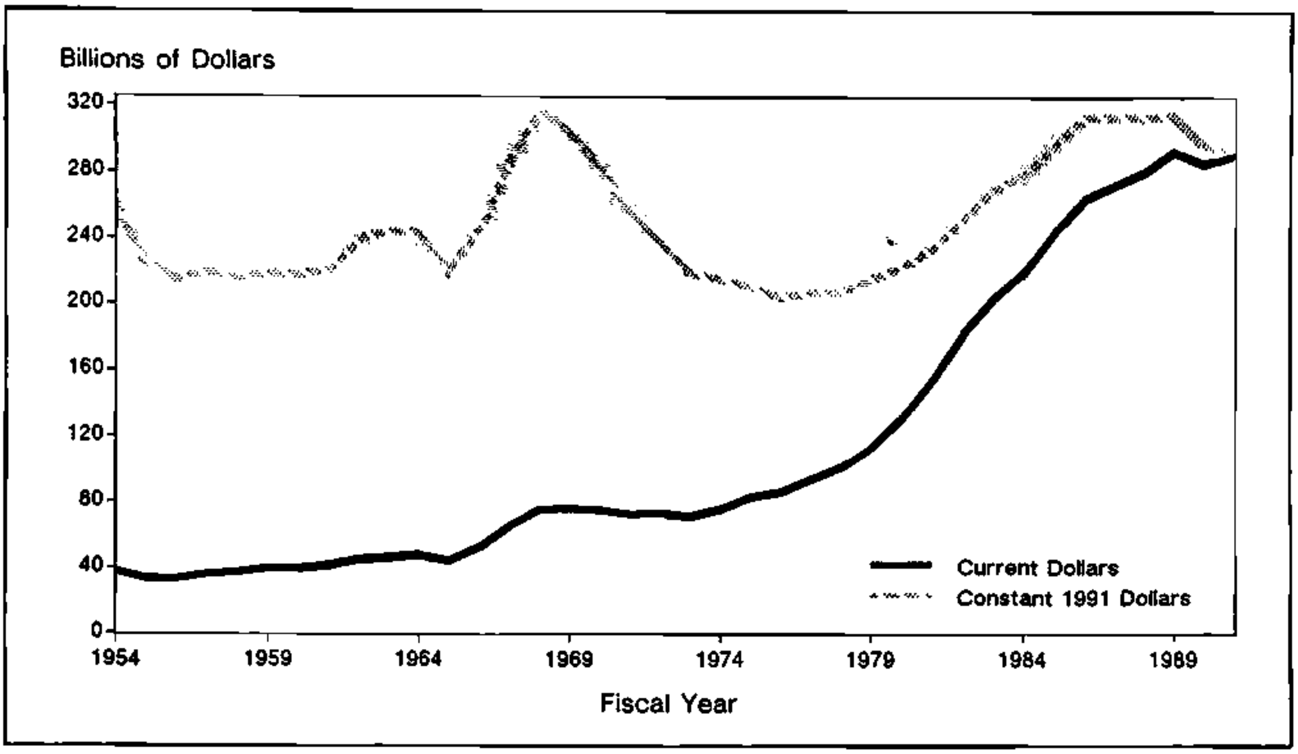
		House	Senate	
	Request	Action	Action	Final
Military Personnel	79.1	78.2	78.2	78.2
Operations and Maintenance	90.1	83.8	85.9	85.5
Procurement	79.0	63.8	67.4	67.2
R&D	38.1	35.7	36.5	36.1
Military Construction	5.7	4.9	5.2	5.3
Others	5.9	5.4	5.2	5.2
Subtotal	297.3	271.8	278.5	276.8
Department of Energy Military	11.0	11.0	11.1	11.0
Total Defense	308.3	282.8	289.5	287.8

Note: Columns may not add to totals shown because of rounding.
Source: Department of Defense

©1991 Dataquest Incorporated January—Reproduction Prohibited

Figure 2.1

Defense Department Outlays
(1954 to 1990)



Source: Defense Forecasts Inc., Dataquest (January 1991)

in 1995, a level not reached since 1947. Dataquest's estimate of future defense budgets shows the DOD expenditures declining to about 3.5 percent of GNP by the end of the century.

Differences between Outlays and Appropriations

Although the DOD's expenditures (also known as outlays) are only now beginning to turn down, defense appropriations actually began to decline in real terms in fiscal 1986. The DOD's spending lags behind decisions on its budget by several years, as shown in Figure 2.2. (The current backlog of appropriated—but unspent—defense funds still exceeds $200 billion.)

Different kinds of appropriations are spent over different periods of time. More than 90 percent of military personnel funds, for example, are spent in the same year that they are appropriated. Nearly 20 percent of funds for ships, however, remain unspent seven years after appropriation. The lag between appropriations for most systems with high electronics content and the actual spending of these funds by the government is typically two, three, or even four years. These delays have cushioned the effects of the downturn in defense budgets for most producers of electronic systems, but they soon will have run their course.

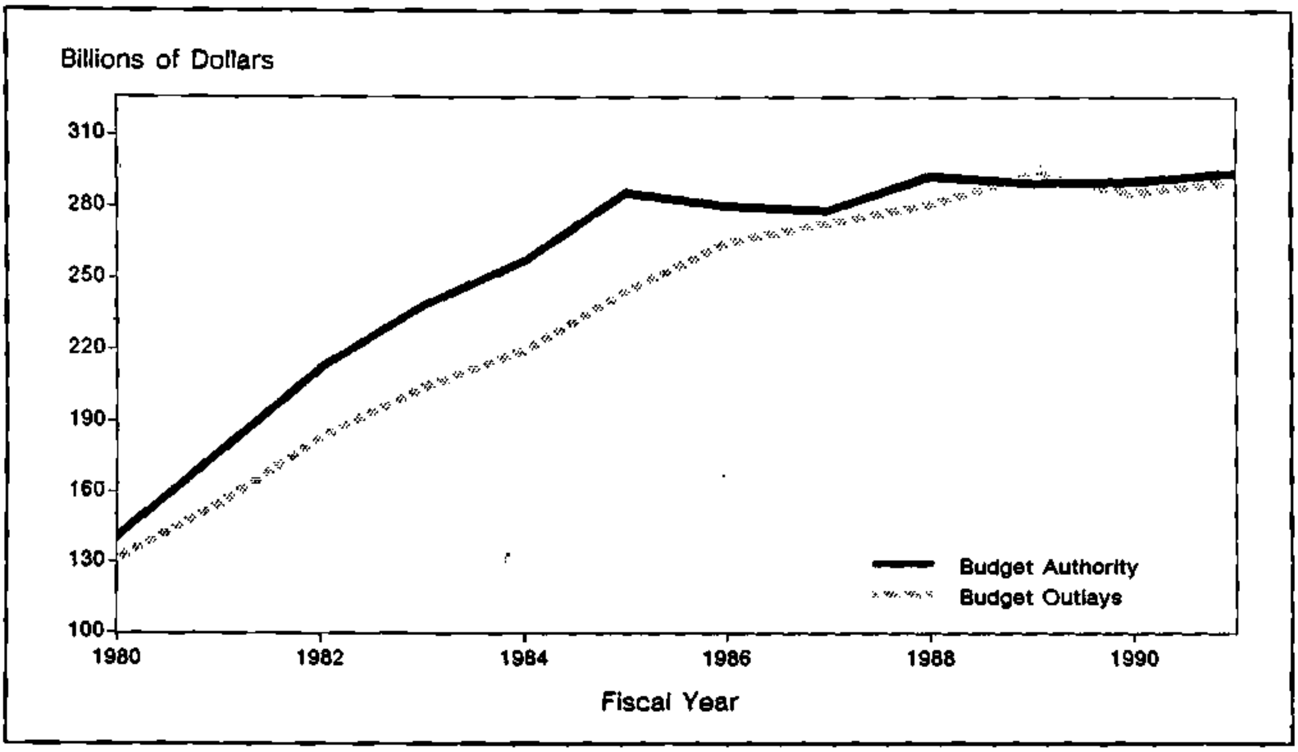
Outlook for the U.S. Defense Budget

Barring extraordinary developments in the USSR or Eastern Europe or protracted war in the Middle East, the U.S. defense budget will decline for the next five years at least and possibly the remainder of the decade. We estimate that cuts will reach approximately 25 percent in real terms by the middle of the decade and possibly 33 percent by the end of the century, returning defense expenditure to pre-Cold War levels. This trend would mean that DOD appropriations would decline from the $289 billion authorized for fiscal year 1991 to about $260 billion in fiscal 1995, then rise at a pace slightly slower than inflation, returning to nearly $300 billion in fiscal year 2000.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Figure 2.2

Appropriations versus Outlays
(Billions of Dollars)



Source: Defense Forecasts Inc., Dataquest (January 1991)

This prospective trend in defense budgets is determined primarily by the nation's fiscal situation, although it is reinforced by the growing understanding that the Soviet Union poses only limited threats to U.S. interests and the risk of war in Europe, already minimal, is shrinking rapidly. Forces justified on the basis of European contingencies account for between 40 and 67 percent of the defense budget. Regardless of the specific percentage, the emergence of a more cooperative and peaceful European security system means that very substantial defense spending cutbacks are possible. New threats in the Middle East will not offset these reductions except in very narrow sectors.

The budget agreement reached in the waning hours of the 101st Congress calls for total spending cuts of $450 billion over five years, with defense cutbacks accounting for no less than $175 billion of that amount. In addition, the agreement places ceilings on defense spending over the next three fiscal years. If the ceilings are broken, then automatic sequestration will force levels back to an amount below the spending limits. Dataquest anticipates, however, that Congress will continue to reduce administration defense proposals as a worsening economy causes the deficit to become even more difficult to bear.

Another changing element in U.S. defense is the more intrusive role of Congress in the decision-making process—not just overall fiscal levels but also specific programmatic details. This micromanagement increased rapidly through the 1980s and will continue as long as administrations produce defense budget requests so large that they become, according to one member of Congress, "dead on arrival."

Distribution of Prospective Reductions

Whatever the final aggregate figure, the "burden" of reductions will not fall equally on all parts of the defense budget. The military services, which have already forwarded their recommendations for the fiscal 1992-through-1997 defense program to Secretary of Defense Richard Cheney, show a clear preference for

©1991 Dataquest Incorporated January—Reproduction Prohibited

protecting modernization programs for conventional weapons at the expense of both the size of their forces and nuclear systems.

The services' proposed cuts are not sufficient to bring the defense budget down to the levels envisioned by Congress. By examining the services' priorities and compressing them to fit into the likely fiscal constraints, we can get a reasonable idea of how the force posture and weapon acquisition programs are likely to be altered.

Overall, the armed forces can be expected to decline from the current 2.1 million men and women on active duty to no more than 1.5 million or 1.6 million. General Colin Powell, the chairman of the Joint Chiefs of Staff, has said that he could live with a 25 percent reduction in forces, more or less setting a goal for the budgeteers. Civilian DOD employees could be cut by at least 200,000 (20 percent), possibly more.

- The army will take the biggest cut in operational forces; its active divisions will be cut from the current 18 to no more than 10 or 12. Army procurement cuts are concentrated on tanks and other armored forces and near-term purchases of air defense systems; the army is attempting to protect its major helicopter improvement programs.
- The air force faces a reduction in the number of tactical air wings from the current 35 to no more than 26 or 28. Aircraft procurement programs are being slashed; aircraft production is being terminated or slowed, while programs to develop new aircraft models are being delayed and curtailed in scope.
- The navy, less dependent on European scenarios in justifications for its forces than are the army or air force, plans to drop from 14 active carrier battle groups and a total of about 560 ships to no more than 12 carriers and about 75 ships overall. The navy also will slow major ship procurement programs such as the SSN-21 *Seawolf* attack submarine, although it has not yet given up on any of them altogether. These plans are the most controversial.
- Both the air force and navy are offering to make big cuts in their major nuclear modernization programs. Likely victims include the B-2 stealth bomber program, both mobile land-based missile programs (which officially will be deferred but almost certainly will never be deployed), and cuts in the advanced cruise missile and Trident submarine programs. Although the Bush administration continues to protect the program internally, the Congress has also imposed radical cuts in the Strategic Defense Initiative (SDI), denying funds that would have made a deployment decision possible in this century.

Impact on Defense Investment

The services' readiness to cut forces will cushion the midterm impact of budget cuts on the defense electronics industry. Table 2.2 breaks down the estimate of future budgets for the DOD by appropriation type. With the projected size of operations reductions, investment accounts should be able to be maintained at their current 44 percent share of the overall budget despite the

Table 2.2

Defense Budget Projection by Appropriation
(Budget Authority in Billions of Dollars)

	Fiscal Year					
	1990	1991	1992	1993	1994	1995
Military Personnel	79	78	76	75	73	71
Operations and Maintenance	87	84	76	75	75	73
Operational Subtotal	166	162	152	150	148	144
Procurement	83	67	77	75	72	72
R&D	37	36	35	35	36	37
Construction	9	5	5	5	6	6
Investment Subtotal	129	108	117	115	114	115
Total*	291	277	270	266	263	260

*Does not reflect sum of components because of rounding and omission of miscellaneous small appropriations.
Source: Defense Forecasts, Inc., Dataquest (January 1991)

significant delays and cutbacks in the major modernization programs just described.

Within the hardware investment accounts (procurement and R&D), resource distribution is likely to change somewhat, as shown in Table 2.3. Aircraft and missile programs appear to be taking the largest punches in preliminary jockeying. Secretary Cheney already has announced major delays and/or reductions in the four key aircraft modernization programs—the B-2 stealth bomber, the C-17 transport, the air force's ATF, and the navy's A-12 attack aircraft. Existing aircraft procurement programs such as the Grumman F-14, General Dynamics F-16, and McDonnell Douglas F-15 are also being curtailed; some will be terminated all together. At the same time, the air force apparently no longer wants to deploy a new strategic missile, while the navy is willing to reduce the planned size of its Trident submarine fleet, meaning eventual cuts in Lockheed's Trident II (D-5) missile program. Among tactical missile programs, delays are being experienced by (among others) the air force's main tactical weapon system, AMRAAM, and by a variety of army air-defense programs. Meanwhile, the navy's Sea Lance missile, built by Boeing, has been killed outright.

Together, predictable delays and cutbacks in aircraft and missile programs should reduce the aerospace portion of hardware accounts from 43 percent in the current fiscal year to 36 percent in fiscal 1995 (see Figure 2.3). Aircraft and missile appropriations will increase toward the end of the decade, however, as many of the programs now being delayed begin to enter full-scale production.

Appropriations for ships, ordnance and weapons, and vehicles also will decline over the next five years, both in absolute terms and as a share of overall investment. Navy shipbuilding will face significant cutbacks in the first half of the decade, while cuts in the latter two categories reflect the impact of European developments on the army's missions. For example, the army now plans essentially to halt tank and related vehicle production for a considerable part of the decade, unless exports can justify the plants' continued operation (an unlikely prospect). A reopening of any U.S. tank production facility would be considered problematic.

On the positive side, spending for both space systems and electronics and communications seems destined to increase relative to overall defense spending over the next five years; our estimates show an increase from 18 percent to 26 percent of total investment. This rise reflects a number of factors, particularly the DOD's efforts to develop force multipliers as the size of operational forces declines and modernization programs slow.

Essentially, force multipliers are sophisticated electronic systems that make it possible to assess events on the battlefield more rapidly, to move forces into range more quickly, identify and track enemy formations with sufficient precision to target them effectively, and maintain effective electronic warfare (EW) capabilities. The types of systems being developed and procured to provide

Table 2.3

Defense Budget for Procurement and R&D by System Type
(Budget Authority in Billions of Dollars)

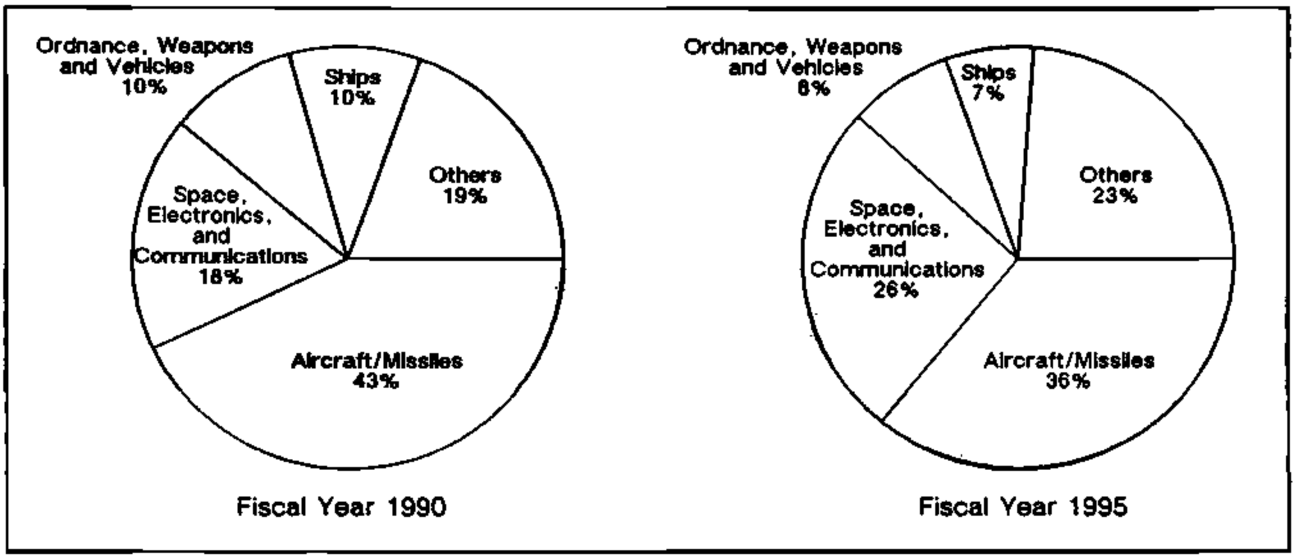
	Fiscal Year					
	1990	1991	1992	1993	1994	1995
Aircraft	37	30	32	30	28	29
Missiles	14	12	13	12	11	10
Space	11	11	13	13	14	14
Electronics and Communications	11	11	12	13	13	14
Ships	12	10	10	10	9	9
Ordnance and Weapons	7	6	6	6	6	5
Vehicles	5	4	3	3	3	3
Other	23	19	23	23	24	25
Total	120	103	112	110	108	109

Source: Defense Forecasts, Inc., Dataquest (January 1991)

©1991 Dataquest Incorporated January—Reproduction Prohibited

Figure 2.3

Distribution of Defense Budget for R&D and Procurement by System Type
(Percentage of Total)



Source: Defense Forecasts Inc., Dataquest (January 1991)

these capabilities include advanced real-time intelligence systems, both space-based and systems deployed on manned and unmanned aircraft; brilliant munitions, which can acquire multiple targets and home in on them using autonomous guidance systems; advanced sensors and related information processing systems; sophisticated command and control systems; and a variety of electronic measures and countermeasures. Additional areas receiving increasing emphasis as operational funds are reduced are advanced computerized simulations and other electronic training devices.

Impact on the U.S. Defense Electronics Market

The overall effect of these changes in R&D and procurement programs is to increase the relative value of the electronics content of defense appropriations. Using factors developed by the Electronics Industries Association (EIA), we can estimate the value of the defense electronics market implied by our projections of defense appropriations through fiscal 1995 (see Table 2.4). Although, the market should remain relatively stable, fluctuating between $43 billion and $49 billion per year. This relative constancy masks an important shift in DOD priorities, however. As noted previously, the electronics content value of aircraft and missiles will decline about $5 billion while appropriations for the electronics on space systems and electronic and communications systems (including intelligence and strategic and tactical intelligence systems) will rise by nearly the same amount.

Contingencies

Given the severity of the U.S. fiscal situation, extraordinary events would be required to reverse the near- to midterm trend toward lower defense budgets. For example, neither the internal conflicts within the USSR and their reminder of the possible fragility of Mikhail Gorbachev's regime nor the slowdown in progress toward U.S.-Soviet nuclear arms control agreements, both of which became evident during the past several months, braked the bipartisan congressional rush toward sharp cuts in defense expenditures. Nor has the war in the Gulf done much to mitigate the overwhelming call for defense spending reductions.

A true upheaval in the USSR, with the possibility or reality of civil conflict, certainly could suspend budget

©1991 Dataquest Incorporated January—Reproduction Prohibited

Table 2.4

U.S. Department of Defense Electronics Market*
(Budget Authority in Billions of Current Dollars)

	Fiscal Year						CAGR (%)
	1990	1991	1992	1993	1994	1995	1990-1995
Aircraft	12.9	10.1	11.2	10.2	9.5	9.6	-5.7
Missiles	6.9	5.9	6.5	6.0	5.6	5.1	-5.9
Space	6.7	6.8	7.9	8.0	8.5	8.7	5.4
Electronics and Communications	9.4	9.6	10.4	11.3	11.5	12.3	5.5
Ships	4.4	3.6	3.5	3.4	3.1	3.0	-7.4
Ordnance and Weapons	1.2	1.0	1.0	0.9	0.9	0.8	-7.8
Vehicles	0.9	0.7	0.5	0.5	0.6	0.6	-7.8
Other	6.2	5.4	6.2	6.3	6.7	7.0	2.5
Total	48.6	43.1	47.2	46.6	46.4	47.1	-0.6

*Includes procurement and R,T,D and E, but excludes direct military sales for export.
Source: Defense Forecasts, Inc., Dataquest (January 1991)

cutting for a time. However, the USSR's economic situation is so desperate and the situation in Europe already has progressed so far that any rational regime in Moscow would almost be compelled to pursue policies similar to those of Gorbachev, enabling U.S. budget cutting to resume.

Unless the Persian Gulf War lasts more than 90 days, it is unlikely to cause an increase in procurement expenditures, because a vast majority of the equipment dedicated to the European theater is being transferred to the Middle East to meet any eventuality. It appears likely that the largest increases in expenditures for the U.S. Gulf operation would be in operation and maintenance.

Over the longer term, a number of contingencies could result in departures toward higher defense budgets. Although a peaceful transition is likely, German unification and the unleashing of national aspirations in Eastern Europe could have unpredictable results over a five- or ten-year period. Such developments could renew U.S. perceptions of a need to prepare for war on the Continent, or at least keep substantial forces there. The situation in eastern Asia also could become unsettled over the long term, what with China's unsettled future course and the remote possibility of a remilitarized and belligerent Japan. Such developments in eastern Asia could have broad effects on defense spending, although not on the same scale as would the European contingencies.

Unsettled conflicts in Third-World nations also could boost defense spending over the long term. The emergence of new wars in Southwest Asia, particularly if American citizens or interests were harmed, could lead to new support for increased defense budgets, for certain kinds of forces. The navy would be the most likely beneficiary, although land-based interventionary forces may need to be strengthened as well. The proliferation of ballistic missiles and chemical and nuclear weapons in some countries in these regions raises additional considerations. Increasingly, arguments for deploying a strategic defense system are founded on the need to protect the United States against threats by Third-World countries. The possibility of use in a war of ballistic missiles equipped with weapons of mass destruction strengthens these arguments, leading perhaps to a serious program to deploy space-based strategic defenses.

Currently, the more likely scenario involves deeper cuts in defense spending than those projected in our best estimate. Perceptions of defense needs tend to run in cycles, and the United States has only recently begun to consider lower budgets. As the armed forces and defense industries begin to decline and Americans get used to a peaceful Europe and the loss of the Soviet enemy, support could grow for even deeper reductions. Failure to deal successfully with the deficit, particularly if accompanied by an economic downturn or shocks in the financial markets, would further boost the case for even lower defense budgets.

How sharp might the downturn be? The outside boundary seems to lie in proposals to halve the budget, in

©1991 Dataquest Incorporated January—Reproduction Prohibited

real terms, within ten years. Several individuals and organizations have supported such plans. Under such a plan, the budget might decline to $270 billion in fiscal 1991 (we estimate $275 billion), reach $250 billion in fiscal 1995 (compared with our $260 billion) but continue dropping to about $200 billion forecast the end of the decade (compared with our projected rise to $300 billion). Such a plan would require some greater reductions in forces than those described previously, but the main effect would be to continue the downturn in procurement in the second half of the decade. Instead of postponing and curtailing major aircraft and missile programs, as is now being contemplated, many programs would have to be canceled. The impact of deeper cuts on defense electronics purchases would not be as severe as the effects on aerospace, shipbuilding, and vehicles, but it would not be trivial.

Key Electronic Programs

Table 2.5 lists the most significant U.S. military programs with high electronics content and the spending levels authorized for fiscal 1990 and 1991, with a projection of expenditures through fiscal 1996. These levels include R&D procurement, advanced procurement, and spare parts funding.

Table 2.5

Key U.S. Defense Programs with High Electronics Contents

	Fiscal Year			
	1989	1990	1991	1992-1996
Aircraft				
A-12	NA	1,600	592	1,600
B-2 Stealth Bomber	5,308	4,302	4,000	18,000
C-17 Cargo Plane	2,014	2,319	1,001	6,200
Advanced Tactical Fighter	675	1,046	964	8,000
F-16 Fighter	3,199	3,220	2,082	7,500
F-15 Fighter	1,555	1,535	1,644	800
F-14 Fighter	1,104	1,635	907	500
F/A-18 Fighter	2,516	2,064	1,635	7,500
AV-8B V/STOL	610	585	471	2,500
E-2C	398	379	406	2,000
EA-6B	555	158	350	1,100
Helicopters				
LH	177	274	291	4,600
AH-64 Apache	1,078	1,602	181	500
UH-60 Black Hawk	492	431	469	2,300
OH-58 AHIP	231	192	305	200
Avionics				
INEWS/ICNIA	37	36	30	800
JSTARS	232	88	270	600
ATARS	60	65	47	730
Strategic Missile Programs				
Trident II (D-5)	2,450	1,662	1,638	7,500
M-X ICBM	1,266	1,724	674	1,800
SRAM II	191	226	167	1,000
Tomahawk Cruise Missile	675	572	698	1,400

(Continued)

Table 2.5 (Continued)

Key U.S. Defense Programs with High Electronics Contents

	Fiscal Year			
	1989	1990	1991	1992-1996
Tactical Missile Programs				
AGM-65 Maverick	345	242	369	100
AMRAAM	848	915	837	4,250
AGM-88 HARM	535	396	369	1,750
AIM-54 Phoenix	394	326	18	0
Harpoon Antiship	201	224	255	1,100
Patriot Air Defense	870	984	811	3,200
Stinger Air Defense	241	115	253	1,100
Avenger	99	122	123	700
TOW 2	168	159	234	1,300
Hellfire	220	128	148	650
MLRS	464	518	461	1,200
ATACMS	144	134	187	850
Advanced Cruise Missile	97	368	473	2,200
Mk 48 ADCAP	507	469	410	2,250
AAWS-M	37	56	38	700
Space Systems				
SDI	3,710	3,582	2,890	11,000
MILSTAR	578	610	603	3,400
DSCS	86	73	120	480
DMSP	209	164	138	550
Boosters	629	550	565	5,000
Ships				
Burke-Class Destroyers	2,837	3,501	3,212	13,000
Seawolf-Class Submarines	1,874	815	187	11,000
Ohio-Class Submarine	1,303	1,281	1,183	400
LHD-1 Assault Ship	763	57	960	2,500
Communication				
Mobile Subscriber Equipment	2,030	979	14	2,300
SINCGARS	249	114	296	1,600
ATCCS	300	280	250	1,650

NA = Not available
Source: Defense Forecasts, Inc., Dataquest (January 1991)

©1991 Dataquest Incorporated January—Reproduction Prohibited

©1991 Dataquest Incorporated January—Reproduction Prohibited

Chapter 3

U.S. Military Electronics

Aircraft and Avionics

Overview

Modern aircraft increasingly rely on electronic and optoelectronic devices to perform almost every in-flight function including navigation, flight control, surveillance, target acquisition, and defensive functions. This dependence is reflected in our estimate that avionics make up between 50 and 60 percent of the cost of next-generation aircraft.

Although the trend toward developing more sophisticated avionics for integration into new weapon platforms continues, a secondary trend toward upgrading existing platforms with advanced avionic systems will garner an increasing share of overall aircraft electronics expenditures from each of the armed services.

Another trend is toward greater system commonality, particularly concerning radar warning and electronic countermeasure (ECM) systems. Historically, the armed services have produced design and performance requirements on an ad hoc basis with little or no coordination of procurement policy. Both Congress and emerging fiscal realities will check much of this independent action throughout the 1990s. The fiscal 1991 Armed Services Committee defense budget report, for instance, directly addressed what congressional members viewed as the Pentagon's misguided desire to develop three separate (but overlapping in function) radar warning receivers.

In the near and midterm, the greatest factor influencing aircraft and avionics procurement will be declining force levels. As recently as 1984, the DOD issued reports calling for a 40-wing tactical air fleet by 1990. Air force tactical air wings currently stand at 35 and will decline substantially over the next few years. As a result of the Major Aircraft Review (conducted in April 1990 by Secretary Cheney) and other internal DOD studies, current plans are to reduce tactical air wings to 28 by 1996, nearly 30 percent fewer aircraft than the Reagan administration's stated goal of just seven years ago. The reduction may not stop there; air force officials acknowledge that a 22 to 24 tactical air wing force by 1996 may be possible. Navy fighter wings also will decline from the current 14 to 12 or less.

This dramatic reversal in planning has major impacts on procurement strategies and annual purchases. In 1989, the U.S. armed forces needed to procure 209 aircraft annually to maintain a level of 36 tactical air wings without the average age of the force slipping. As the number of air wings decreases and older aircraft are retired and replaced with newer craft, the annual number of planes required will decrease to approximately 160.

With this contraction in force size, Pentagon planners are shifting tactical air wing composition, with multirole planes gaining preference at the expense of special-purpose platforms. This trend is due to uncertainties about the threats that will be faced in upcoming years. In the past, most tactical air wings were designed to counter the Soviet threat in Europe. That threat has largely dissipated.

Current plans call for multirole fighters, such as the F/A-16, F-15E, and older F-4s to make up approximately 40 percent of the future force. Air-to-air superiority fighters will compose no more than 25 percent of the force by the mid-1990s, with air-to-ground aircraft such as the F-117A, A-10, A-7, and F-111 accounting for approximately 35 percent. Plans for the late 1990s and early 2000s appear to favor multirole aircraft.

The trend also is downward for naval aircraft. Carrier-based aircraft such as the F-14 Tomcat will have a smaller fleet to service. The Reagan-era goal of a 15 carrier-task force never came closer than the current level of 14 "big decks," with current plans calling to scale back to no more than 12 carriers. This reduction already has had an impact on planned total buy levels of next-generation aircraft such as the A-12 and Naval Advanced Tactical Fighter (NATF).

Next-generation aircraft will use a new avionics systems architecture that will divide avionics into three functional categories: mission management, sensor management, and vehicle management. Technologies for mission management include radars, fire-control systems, and sensors for target surveillance, tracking, and acquisition. Sensor-management technologies are less established than those for mission management, and they continue to be slowed by developmental difficulties and cost overruns. Vehicle management technologies are used for flight-control instruments such as cockpit displays, and fly-by-wire or fly-by-light controls, and navigational aids, such as inertial navigation units and communications gear.

Trends in avionics for mission management lie in multimode and multispectral sensors and embedded transmitters and receivers known as "smart skins." Improved methods of fire control are being explored through head-steerable targeting systems, for which weight and size reduction of components is critical, and through artificial intelligence (AI) aids for pilots such as the Pilot's Associate program. In sensor management, emphasis is on improving systems' ability to process, analyze, and distribute information from many components, particularly with respect to parallel computer processing and improved pattern recognition. In this sector, software development is playing an increasingly important role. In vehicle management, research continues on fiber optics as a complement to and, eventually, substitute for current methods; possible new methods range from fiber-optic gyros to fly-by-light and cockpit displays that project images directly onto the pilot's retina. Future cockpit displays will include the new wide-angle holographic head-up display (HUD), and helmet-mounted displays.

Although the overall electronics content of aircraft will increase in upcoming years, total market size will decrease marginally because of fewer platforms to be serviced. Moreover, markets for upgrades to existing platforms will increase, reflecting services' desire to take small steps rather than big leaps, a new philosophy forced on the military largely by fiscal restraints. In addition, with the Soviet threat retreating, congressional decision makers no longer perceive an urgent need to field advanced systems quickly in order to maintain a qualitative advantage over Warsaw Pact forces. The "fly-before-you-buy" rule will increasingly mark congressional appropriations. Technological drivers for aircraft electronics will continue to be emphasis on stealth, jam-resistant communications, and day/night all-weather capability in a wide variety of hostile environments.

Total appropriations for aircraft electronics procurement decreased in fiscal 1991 to about $10 billion from nearly $13 billion appropriated in fiscal 1990. This decrease largely reflects the stretching of many advanced aircraft programs such as the ATF, LH, A-12 (canceled), and the C-17. Appropriations for upgrades to existing aircraft avionics have not yet started to increase but will do so in 1 to 2 years, offsetting the cut in new aircraft somewhat.

Table 3.1 shows the administration's request and Congress' final appropriation for each type of aircraft for fiscal 1991; electronics account for between 40 and 50 percent of most of these figures.

Continuing Aircraft Procurement

The U.S. air fleet comprises scores of varieties of aircraft, from the nearly four-decade-old B-52 to the recently revealed stealth F-117 fighter/bomber. In this time frame, literally tens of thousands of other types of aircraft were procured, flown, and retired.

Regardless of how world events may change, the U.S. military will continue to develop, procure, and upgrade existing aircraft long after what we now consider the most advanced systems become obsolete.

A wide variety of aircraft currently procured or being upgraded by the U.S. armed forces are described in the following paragraphs. These aircraft represent most of the U.S. air fleet and are indicative of the breadth of the overall ongoing military aviation program.

E-8 Air Force-Army Joint Surveillance Target Attack Radar System (JSTARS)

This program remains in the full-scale development (FSD) phase. Grumman, the prime contractor, received a contract in November 1990 for $523 million to continue its development.

JSTARS is a wide-area ground surveillance radar able to detect, identify, and track moving and fixed targets in all weather conditions. In September 1985, Grumman was awarded the FSD contract, currently valued at close to $7 billion over the life of the program. In 1990, the DOD ruled Grumman to be the only company qualified to compete for future awards. The current plan is to procure 22 aircraft at a total package cost of $6.9 billion for air systems and $1.1 billion in ground systems. (The ground systems of this program, prime contractor of which is Motorola, are detailed in Chapter 3 under "Command, Control, Communications, and Intelligence.")

©1991 Dataquest Incorporated January—Reproduction Prohibited

Table 3.1

Major Aircraft Procurement for Fiscal 1991
(Millions of Dollars)

System	Number of Requested Units	Number of Authorized Units	Remaining Procurement (Number of Units)
E-8 JSTARS	0/232	0/232	23
F-16 Falcon	150/2,357	108/1,857	878*
F/A-18 Hornet	66/2,045	48/1,635	454
AV-8B Harrier	24/457	24/440	45*
F-14D Tomcat	12/780	12/781	0*
F-15E Eagle	36/1,700	36/1,544	130
C-17 Airlifter	6/1,909	2/4,600	118
B-2 Stealth Bomber	2/3,206	0/2,349	55
E-2C Hawkeye	6/389	6/435	42*
S-3 Viking	0/113	0/113	0*
RC-12H/K Guardrail	5/87	5/87	26*
UH-60 Black Hawk	72/469	48/243	528
AH-64 Apache	0/104	0/104	0*
OH-58D Kiowa Warrior	0/25	0/25	0*
ATF	0/764	0/964	750
LH	0/441	0/291	1,292
A-12	8/1,596	0/610	620
V-22	0/0	0/165	0
P-7A	0/21	0/0	0

*Continue to undergo substantial upgrades
Source: Department of Defense

Norden Systems is building the 18001B side-looking phased-array radar antenna. Known as the AN/APY-3, this system is the heart of the program. The sensor uses a Norden VAX 11750 computer and a Litton LR-85A IMS that consists of a navigational processor, sensors, and electronic assembly. Signals from the aircraft are relayed to Control Data Corporation's parallel signal processors, which run at 625 millions of operations per second (mops) and are linked with three separate Raytheon model 860 VAX computers. Reportedly, 154 system processors are aboard each E-8 aircraft, requiring 800,000 lines of Ada-based computer language. (The radar control portion of the system, written in FORTRAN, is reportedly the only exception.) After the data are obtained and processed, they are sent to the surveillance and control data link (SDLC), which was developed by Cubic Corporation, and forwarded to ground receivers.

The F-16 Falcon

The air force's original fiscal 1991 request was 150 aircraft at $2.4 billion and $437 million in advanced procurement. But because the structure and size of tactical air wings will undergo significant changes in upcoming years, Congress, in cooperation with the air force, altered the annual procurement schedule for this frontline fighter. To meet this reduced requirement, $1.9 billion was approved for procurement of 108 aircraft, with $225 million earmarked for advanced procurement. This budget will stretch General Dynamics' April 1990 contract for 600 aircraft.

The air force is currently procuring Block 40 aircraft, which began delivery in December 1988. The three previous block productions—10, 20, and 30—operated with Delco Electronics' M372 computer system with software based on Jovial language. The Block 40 lot shifted flight computers to Teledyne Systems, which will use its TDY-750A general avionics computer. This 16-bit system has 2-mips data throughput capacity. In addition, an award was made in July 1990 to supply Allied-Signal's Bendix Division digital flight-control computer systems for Block 40 aircraft. An award to Westinghouse to provide its AN/APG-68 fire-control radar was made in late 1989 for $110 million. The

©1991 Dataquest Incorporated January—Reproduction Prohibited

Block 40 system also is equipped with Martin-Marietta's Low-Altitude Navigation and Targeting Infrared for Night (LANTIRN).

The F-16 currently is undergoing two separate upgrades. The first, known as the Operation Capability Upgrade (OCU), is intended to increase the avionic and radar fire-control capabilities of 270 F-16A and F-16B aircraft. This upgrade includes expanding computer capacity and adding a radar altimeter. The improvement to the radar will allow for detecting and tracking small targets beyond visual range. The modified aircraft also will be outfitted with AIM-7 and AMRAAM missiles and new high-frequency radios for tactical warning and attack assessment. After the OCU, the aircraft will be qualified for the F-16 air defense fighter role.

The midlife upgrade (MLU) will be performed on 130 additional F-16s. The upgrade, performed mostly for NATO allies, calls for modifications to the aircraft's computer, cockpit, and avionics.

General Dynamics expects major new F-16 sales to Israel, Saudi Arabia, and other Arab nations.

F/A-18 Hornet

The F/A-18 Hornet, the prime contractor of which is McDonnell Douglas, replaces the F-4, RF-4, A-7, and the A-4M in the Marine Corps and navy. The F/A-18 is a twin-engine, carrier-based, multirole high-performance aircraft that provides fighter escort, fleet air defense, interdiction, and close air support for the navy and for marine assault forces.

The fiscal 1991 budget request was for $1.9 billion to procure 66 aircraft and $150 million in advanced procurement. Congress reduced the request to $1.5 billion for 48 aircraft and $110 million in advanced procurement.

In a program that began in October 1989, all F-18s have all-weather and night capability and will incorporate the Hughes AN/AAR-50 forward-looking infrared radar (FLIR) thermal imaging navigation set and a Honeywell color digital moving map. In October 1990, McDonnell Douglas was awarded $221 million to upgrade the APG-56 radar; in November 1990, that contract was increased by $62 million. This contract will run through 1994. Another noteworthy contract is to Litton to provide 200 laser guiding systems with options for an additional 300.

One setback for McDonnell Douglas was the agreement to supply Kuwait with 32 F/A-18C and 8 F/A-18D aircraft in September 1990; this award has been delayed indefinitely.

AV-8B Harrier

The Harrier is a single-engine, single-seat vertical/short takeoff and landing (V/STOL) fighter designed to engage hostile ground and air forces and provide air support to amphibious assaults.

The Marine Corps requested procurement of 24 AV-8B Harrier V/STOL jets in fiscal year 1991 for a total of $457 million. Congress approved $440 million for these aircraft, which are produced by McDonnell Douglas and British Aerospace. The FLIR will be produced by GEC, and the aircraft will be equipped with the Hughes AN/APG-65 radar and Litton AN/ALR-67 airborne warning system.

The Marine Corps currently plans to remanufacture the existing fleet of 258 AV-8As to the B configuration.

F-14D Tomcat

Grumman's Tomcat is a carrier-based, high-performance, long-range fighter interceptor designed for air-to-air combat in order to provide fleet air defense. It is currently the navy's top-of-the-line fighter. The navy had hoped to convert 400 F-14As to the D configuration, but a more realistic figure of 104 conversions has since emerged from the Pentagon.

The latest versions will include a Unisys AN/AYK-14(v) mission computer, a Hughes AN/APG-71 tactical fire-control radar to replace the older AN/AWG-9, and a General Electric AN/AAS-42 IRST system. Martin-Marietta will produce a small number of the IRST systems in an attempt to set up a dual-source competition in future years. Northrop Corp. will produce the TV camera system along with the digital avionics. The D series also is to be equipped with Joint Tactical Information Data System (JTIDS) and High-Speed Anti-Radiation Missile (HARM) missile capability.

The navy requested $780 million to procure 12 F-14D aircraft. Congress approved the full request.

©1991 Dataquest Incorporated January—Reproduction Prohibited

F-15E Eagle

Procurement of the "E" variant of the F-15 continues at 36 per year, down from 42 in fiscal year 1989. McDonnell Douglas, the prime contractor for the aircraft, received nearly $1 billion in related contract awards in fiscal 1990. In addition, an export version of the "E" variant, designated the F-15F, has been approved. It contains the Hughes JAPG-70 radar with alterations made in the software. Substantial sales to the Middle East are anticipated.

Among the improvements to the F-15 are the installation of Martin-Marietta's LANTIRN, Hughes' APG-70 radar (the first to use VHSIC architecture), and new electronic warfare systems and armaments. Major subcontractors include Hughes, Loral Corporation, Martin-Marietta, and Northrop. IBM was recently awarded a contract to develop a VHSIC central computer, designated the AP-1R, for the F-15. The system will use a 32-bit processor capable of 1.1 million instructions per second (mips) with Assembly language software supplied by McDonnell Douglas. The air force plans to continue installation of the AP-1R through June 1992. After that date, a next-generation system using VHSIC technology, also by IBM, should be ready for installation. This system will have a 16-bit processor with a data throughput rate of 3 mips and will offer over ten times the memory of the AP-1R. According to reliable sources, both systems will use Intel chip sets.

F-117A Fighter/Bomber

Also known as the "Wobbly Goblin" for its lack of handling capability, this aircraft has been shrouded in secrecy since its development. The first official descriptions of these aircraft, which were used in operation Just Cause in Panama and are on location for operation Desert Storm in the Middle East, were released in the late summer of 1989.

Although many details remain secret, it is known that procurement stopped with the delivery of the 59 existing aircraft. Harris provides the digital tactical display system and digital moving radar map. IBM provides the mission computer, and Honeywell Inc. supplies the inertial navigation system, air data computer, and multipurpose color displays. Other companies involved in the program include Allied-Signal, F.L. Aerospace, and Teledyne.

The program is already under consideration for a major upgrade known as the Weapon System Improvement Program (WSIP), which is valued at over $1.4 billion over the next 15 years. Most of these funds are likely to be awarded to the prime contractor, Lockheed.

OV-1D Mohawk

The Mohawk, produced by Grumman, is a twin-prop combat aircraft with side-looking radar (AN/APS-94F) and photo (KA-60/76) capability. The primary sensor for this system is the AN/UPD-7 surveillance system. The aircraft is capable of relaying intelligence to JSTARS ground stations. Motorola is currently involved in a $200 million upgrade of the system.

Air Lifter

The C-17, a new transport for inter- and intratheater operations, will replace C-130As and C-141s as they retire from service in the 1990s. The administration originally requested $2.2 billion in fiscal 1991 for the procurement of 6 aircraft. As a result of the Major Aircraft Review, however, that request was lowered to $1.1 billion for 2 aircraft, and total procurement was adjusted down from 210 at a cost of $42.0 billion to 120 aircraft at a total program cost of $30.0 billion. Also as a result of the Major Aircraft Review, the program will be stretched, with 6 aircraft to be purchased in 1992, 12 in 1993, and 18 in 1994. Congress authorized the procurement of the 2 requested aircraft at $460 million for fiscal 1991.

Although the program continues to have strong backing on Capitol Hill, particularly in view of the Persian Gulf situation, the C-17 has experienced considerable delays. The first flight was scheduled to occur in September 1990 but has been postponed until September 1991.

The major contractors are Douglas Aircraft and Pratt & Whitney. Litton was recently awarded $3 million for light-emitting diode (LED) cockpit displays.

B-1B Bomber

The air force fiscal 1991 request for the Rockwell B-1B bomber was only $20 million in new procurement and $134 million in modifications. However, the air force also requested close to $60 million for SRAM II missile integration work, which is covered in Chapter 3 under "Missile Systems."

Congress granted the air force's request for $20 million, as well as $82 million in modifications, which will be

©1991 Dataquest Incorporated January—Reproduction Prohibited

used mostly for continued integration of an EW suite. Recent contract awards include $10 million to Rockwell International to modify the electromultiplex data bus and an award to Westinghouse for engineering services relating to the offensive radar system.

If the B-2 stealth bomber is terminated (see next paragraph), major increases may be expected in the B-1B program. Otherwise, annual appropriations are unlikely to exceed $100 million.

B-2 Stealth Bomber

Details on the cost and specific technologies of Northrop's advanced technology bomber still remain classified, although the B-2 was officially unveiled in November 1988.

The budget request for fiscal 1991 was $2.5 billion for the procurement of five aircraft and $710 million for advanced procurement of ten additional aircraft. As a result of Secretary Cheney's Major Aircraft Review, the air force informed Congress of its intention to nearly halve the proposed fleet from 132 aircraft at $76 billion to 72 aircraft at a total proposed program cost of just over $61 billion.

Even with the reductions, however, the House of Representatives voted to stop the program completely after the 15th bomber. The Senate voted by a narrow margin to preserve funding for two new planes in fiscal 1991, largely the result of intense lobbying by the administration. What emerged from the conference was an agreement to grant the air force enough funds to go ahead with two more aircraft ($2.4 billion), but it was not specifically stated that the funds can be used for this purpose. Although the program survived in the fiscal 1991 budget, it is likely to be in even more serious trouble in fiscal 1992.

The B-2 industrial team is led by Northrop and includes Boeing Advanced Systems Co., GE Engine Group, and LTV Aircraft Products Group as key members. Other major subcontractors include Boeing Military Airplanes, Hughes Radar Systems Group, and Link Flight Simulation Corp. Initial operating capability was expected in early 1993 but has been delayed.

E-3 AWACS

The number of AWACS aircraft is broken down as United States Air Force—33, NATO—18, the United Kingdom—11, Saudi Arabia—5, and France—4. A number of ongoing upgrades to the system could result in total contracts exceeding $1.5 billion over the next several years.

The object of the improvement program currently under way, known as the Block 30/35 program, is to improve target detection systems, sensors, and antijamming communications capabilities. Boeing is the prime contractor to provide 5 development and 34 production model ship sets at a total cost of over $650 million. In addition, Boeing and IBM were selected to upgrade all 18 U.S. aircraft assigned to NATO, a contract worth $700 million.

The upgrades will include a Boeing Have Quick radio communications system worth $230 million, a Westinghouse 5-band radar to detect small aircraft within 250 nautical miles, a Rockwell GPS system, and a computer upgrade using a 4-megaword magnetic bubble memory by IBM with Hitachi 1Mb bubble memory chips. IBM will also provide 4 Pi CC-2E computers, which control all aircraft systems. Control Data is providing the radar data processing system in cooperation with Westinghouse, which is writing nearly 200,000 lines of Ada-based software for the system. Boeing and Westinghouse are cooperating in the aircraft's main radar improvement program, which will build upon Westinghouse's AN/APY-2 system.

E-2C Hawkeye

The E-2C is the U.S. Navy's all-weather carrier-based tactical airborne warning and control system platform. The aircraft is often used to direct F-14 Tomcat fighters through hostile engagements. This aircraft also is used by many law enforcement agencies as a drug-interdiction radar platform.

The navy requested $350 million to procure six new aircraft and $38 million for advanced procurement in fiscal 1991. The Congress, pleased with the performance, provided the full request and additional funds ($47 million) to accelerate Block 2 production, which will include the AN/APS-145 advanced radar and integration with the JTIDS. In August 1990, Unisys received an additional $25 million for integrating the AN/AYK-14(v) mission computers on the aircraft. Loral provides the aircraft antennas.

In September 1990, Grumman negotiated a $46 million contract with Japan to deliver two additional aircraft by 1993, and in November, it was awarded an additional $24 million for advanced procurement of six additional aircraft for the navy.

©1991 Dataquest Incorporated January—Reproduction Prohibited

S-3 Viking Aircraft

The S-3 series comes in a number of variations. The S-3B, built by Lockheed, is the modernized version of the original aircraft. The Viking's mission is to search out and destroy, at extended range, enemy submarines and provide for general fleet reconnaissance. The S-3B upgrade includes Lockheed's data computer systems, Loral's antennas, and Texas Instruments' AN/APS-137 radar. Congress approved the administration's total request for $113 million in modifications.

The ES-3A aircraft, also produced by Lockheed, is an EW version of the S-3. This platform is also undergoing numerous upgrades. Loral is providing mission antennas, Texas Instruments is providing the mission radar, Radstone Technology is providing memory storage units for data collection, and Lockheed Sanders Associates is providing updated miligraphic display systems. Congress also approved the administration's request of $5 million for this program.

RC-12H/K Guardrail

The army Guardrail system is a combined airborne and ground communications intelligence system designed to intercept and locate enemy communication facilities. The Guardrail V system uses the RU-21H aircraft, the Improved Guardrail V (IG V) systems use the RC-12 aircraft, and the planned Guardrail Common Sensor system (GCS), which will combine communications and electronic intelligence sensors, will use the RC-12K airframe.

ESL Inc. is the prime contractor for the program. Beech Aircraft supplies the airframe, Pratt & Whitney provides the engines, IBM provides the communications high-accuracy airborne location system (CHAALS) mission processor, and Concurrent Computer Corporation provides the mainframe computer system. Ramtek makes the displays and Delco Electric provides the navigational equipment.

The army received its full requested amounts for Guardrail V system modifications ($10 million), IG V modifications ($32 million), and GCS procurement (five aircraft at $87 million).

UH-60 Black Hawk Helicopter

The UH-60, produced by United Technologies Sikorsky helicopters, replaces the UH-1 HUEY in the air assault, air calvary, and medevac missions. The Black Hawk is a twin-engine helicopter that can carry more than twice the HUEY's payload and deliver a more lethal amount of weaponry. It is also equipped with double armor to protect it from small-arms fire. The Black Hawk is in the final year of a four-year fixed-price multiyear contract; the current production block is known as the UH-60L. This year's procurement will complete the original planned buy of 1,107 systems. During this multiyear cycle, the army announced an increase of the total requirement to 2,253 aircraft, but the increase was short-lived; a reduced demand of 1,621 was agreed upon in spring 1990.

The army requested $272 million to procure 72 helicopters in fiscal 1991 and $197 million in advance procurement. Congress agreed to 48 helicopters at $117 million and $127 million in advanced procurement.

MH-60 Black Hawk and MH-47E Special Operations Helicopters

These two systems make up the Special Operations Aircraft program. They are designed to provide low-level, night, all-weather, extended range, and highly accurate navigational capability. The program's goal is to outfit special operation units with 23 MH-60K and 51 MH-47E aircraft.

Sikorsky Helicopters is developing the MH-60K under a 38-month, $83 million contract awarded in January 1988. The MH-60K will incorporate air-to-air refueling capability, a Texas Instruments AN/APQ 168 terrain-following/terrain-avoidance radar, and an integrated avionics package that includes a cathode-ray tube (CRT) display and a Hughes AN/AAQ-16 FLIR.

Boeing is producing the MH-47E, which is based on its CH-47 Chinook. The MH-47E will be equipped with an AN/APQ-174A multimode radar, which is a derivative of the LANTIRN system. IBM is supplying the integrated avionics suites. The army will request procurement of 51 of these aircraft.

AH-64 "Apache" Helicopter

The Apache was designed as an airborne antitank weapon to counter the Warsaw Pact force's overwhelming armor advantage. The two-man Apache is equipped with day/night all-weather capability systems, Hellfire antitank missiles, a 30mm chain gun, and an option for several Hydra 70 rockets. The helicopter's heavy armament make its system the army's primary airborne attack system.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Major contractors for this aircraft include Allied-Signal for the auxiliary power unit and displays, General Electric for the digital automatic stabilization equipment, Fluid Components for the advanced fuel-flow sensors, Martin-Marietta for the TADS/PNVS systems, McDonnell Douglas and Westinghouse for the LONGBOW fire-control radar, and McDonnell Douglas for the LONGBOW fire-control radar system and fire-and-forget Hellfire seeker integration.

The Apache was first delivered by McDonnell Douglas in fiscal 1986, with over 600 to date at a cost of over $10 billion. A total buy of 807 aircraft is expected and already funded, with possible foreign sales to Austria, the Netherlands, Japan, South Korea, Pakistan, Spain, Sweden, Switzerland, United Arab Emerites, the United Kingdom, and Egypt. Some units have already been sold to Israel.

The fiscal 1991 administration request was for $245 million, of which $85 million was earmarked for modifications and $160 million for continued development of the LONGBOW upgrade. Congress authorized $77 million for in-service AH-64 modifications, of which no less that $20 million must be used to correct immediate reliability problems.

OH-58D Kiowa Warrior Helicopter

This system is an upgrade of the army's first true scout helicopter. The system operates mainly with air calvary units; the "D" upgrade will soon enter its seventh year of production. Nearly 200 units are in the field; production goal is 243 aircraft to be completed by June 1992.

The most recent deliveries are equipped with air-to-air Stinger missiles and an air-to-ground capability consisting of Hellfire missiles and Hydra 70 rockets. In addition, the 58D series includes Have Quick and SINCGARS radio sets and Honeywell sensors. The prime contractor is Bell Helicopter Textron; subcontractors include McDonnell Douglas, Northrop, Litton, and Allison Gas Turbine.

The army requested close to $70 million for continued modifications and procurement in fiscal 1991, all of which was appropriated by Congress.

Significant Aircraft Components

The air force selected the team of Allied-Signal's Bendix division and Raytheon to produce the Mark XV Identification Friend or Foe (IFF) system, an upgraded version of the Mark XII. The Mark XV IFF is designed to enhance aircraft survivability by its improved ability to enable air defense forces to identify friendly aircraft at great distances in adverse weather or hostile jamming conditions.

The 1989 production award covers five years of full-scale development followed by a 10-year production program and could exceed $4 billion. The Mark XV IFF system also is the U.S. element of the NATO identification program and therefore holds considerable potential for other production contracts.

The LANTIRN system provides the air force with the ability to conduct offensive tactical missions at night. LANTIRN consisted initially of a navigation and a targeting pod.

Martin-Marietta is producing the LANTIRN navigation pods under the terms of a $715 million contract awarded in December 1986 by the air force. The total value of the program could reach $4 billion. Approximately 250 pods were delivered in 1990, and production is expected to reach 20 per month in early 1991. The air force plans to install about 700 LANTIRN systems on F-15E and F-16C/D aircraft. Texas Instruments is a major subcontractor for LANTIRN, producing terrain-following radars for the navigation pods under a $101 million contract.

In addition to U.S. contracts, Martin-Marietta has received orders for the system from Saudi Arabia and Turkey totaling over $100 million.

Developmental Programs

Advanced Tactical Fighter (ATF)

The ATF will replace the F-15 as the air force's top fighter beginning in the late 1990s to the year 2020. A derivative of the aircraft may also replace the navy's F-14s.

After Secretary Cheney's Major Aircraft Review, the air force continues to require a total of 750 ATF aircraft, although it now plans to acquire the aircraft at a slower rate and has delayed initial production by two years. The navy estimates a need for 552 carrier-capable versions of the ATF (designated the NATF), although there is considerable doubt about the viability of the entire program. Through 1990, approximately $1.7 billion has been funded for engine, airframe, and subsystem R&D.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Avionics is a critical element of the ATF. In 1987, the USAF Systems Command estimated that the air force would spend $900 million on avionics during the prototype phase, which is more than will be spent on either the engine or airframe.

The two prime contracting teams, Lockheed-General Dynamics-Boeing (YF-22A) and Northrop-McDonnell Douglas (YF-23A), both unveiled their prototypes in the summer of 1990, and both are conducting extensive test flights.

Previous plans called for procurement to begin in fiscal 1994, but Secretary Cheney pushed that date back two years to complete a slowed demonstration/validation phase. The delay will likely frustrate the competing teams, which have already invested over $1 billion of their own money in this winner-take-all program.

In November 1990, a request for proposal (RFP) was released in the engine competition between General Electric and Pratt & Whitney. Both companies have invested heavily in the program, hoping that a successful bid on the ATF would secure future jet aircraft markets and act as a springboard to even greater foreign sales.

The YF-22A reportedly has weight problems, weighing an estimated 10 percent more than the YF-23A. Although still highly classified, the YF-22. A avionics suite is said to have 30-mips capability based on an Intel i960 chip housed in a 32-bit central computer developed by Hughes. The display computers are being developed by Texas Instruments. The highly advanced electro-optical sensor system, the first of its kind to be integrated with the radar, is being designed by General Electric. Difficulties in the sensor program, which mostly involve insufficient range, have slowed the program.

The YF-23A mission computer, designed by Unisys, is said to be a 16-bit VHSIC version of that company's MIL-STD-1750A airborne computer. The signal processor is being developed by AT&T and includes a Motorola 68020 complex-instruction-set computer (CISC) microprocessor. The electro-optical (EO) sensor system, developed by Martin-Marietta, has encountered performance difficulties. Westinghouse and Texas Instruments have been chosen by both contracting teams to provide the radar system for the aircraft.

The administration requested $764 million in the fiscal 1991 budget to complete demonstration and validation and $234 million to initiate FSD. Congress balked at this request because of what were termed "remaining uncertainties," including what is considered an insufficient effort by the Pentagon to evaluate the potential upgrading or service life extension of the F-15, F-16, and F/A-18 fighters. At one point, the House had zeroed the program altogether, but Congress ultimately approved $964 million to complete the demonstration and validation of the two teams. However, Congress directed the air force to delay entering FSD and conduct studies of alternatives to ATF FSD, such as the F-15 or a derivative.

Assuming that the program continues, an award decision is expected by mid- to late 1991 for an FSD contract worth an estimated $7 billion.

Light Helicopter (LH)

The army's LH is the next-generation rotorcraft expected to replace the AH-1, OH-58 (A, C, D), and OH-6 helicopters and complement the AH-64. The program has had numerous scale-backs from the original concept defined a few years ago.

The army originally hoped to procure 4,168 LHs at a cost of $66.0 billion. After dropping the utility version of the platform in 1988, a figure of 2,098 for $42.0 billion was agreed upon. In late 1990, revised plans were announced that called for building 1,875 LHs at a cost of $35.2 billion.

In November 1988, the army awarded two $158 million contracts to the contractor teams of McDonnell Douglas-Bell Helicopter Textron Helicopter Co., and Boeing Vertol-Sikorsky Aircraft for a 23-month demonstration/validation phase, which ended in September 1990. An FSD and production contract was to be awarded in December 1990, and initial operating capability was scheduled for 1996, but program slippage has delayed an FSD award until at least late 1991.

Approximately 75 percent of the demonstration/validation effort has been directed at developing mission equipment; avionics are expected to make up 60 percent of the aircraft's cost. The Boeing-Sikorsky team unveiled its fan-in-tail design in October 1988, and McDonnell Douglas-Bell revealed its no-tail rotor (NOTAR) design in February 1989. The McDonnell Douglas-Bell team has greater experience in designing attack helicopters, but both tail rotor designs are innovative; furthermore, Boeing-Sikorsky has stated that it intends to use fiber optics, another innovative and relatively untested technology in an operational aircraft, in

©1991 Dataquest Incorporated January—Reproduction Prohibited

some areas. The Boeing-Sikorsky team's major subcontractors and their subsystems are listed:

- Boeing Electronics—Flight-control computer
- Boeing Military Airplanes—Mission equipment package/avionics system integrator
- Collins Avionics—Integrated communication navigation, identification (ICNI), displays
- Hamilton Standard—Flight-control computer, helmet-mounted display
- Harris—Super-high-speed database, digital moving map/terrain database technology, VHSIC
- IBM—VHSIC-based processor
- Martin-Marietta—Target acquisition/designation system, pilot night-vision system
- TRW—VHSIC-based signal and data processors, ICNI, electronic self-defense
- Westinghouse—VHSIC-based computers, millimeter-wave radar, electro-optics

The McDonnell Douglas-Bell Helicopter team has subcontracted with the following companies:

- AT&T—Signal-processing hardware
- Eaton—Electronic warfare suite
- GE and Honeywell—Integrated flight control
- Hughes and Honeywell—Wide-angle helmet-mounted display
- Hughes and Texas Instruments—Mission processor, EOTADs, night vision, pilotage
- Litton—Flat-panel cockpit displays
- McDonnell Douglas Aircraft—Mission equipment package integration
- Northrop—Electronic defense package
- Unisys—Common modules for mission processor

The 7,500-pound weight restriction and $7.5 million per helicopter cost ceiling have created significant technical challenges for the contracting teams and will not likely be met given the reduced procurement numbers. The use of composite materials will reduce the weight, but there also have been reports of abandoning the planned use of the new common avionics suite (ICNI/INEWS), reducing requirements for computer-aided target detection, and making some components optional rather than standard. In an effort to cut costs, Boeing-Sikorsky has contracted Agusta to use an A129 helicopter as a flying test bed for key mission equipment. The army also has made efforts to gauge European interest in LH technology to defray costs, but with little success.

The army requested $411 million in fiscal 1991 to complete demonstration and validation and proceed with FSD. Congress provided $291 million to continue with the demonstration and validation effort but delayed the decision on FSD for at least one year.

A-12 Advanced Medium-Attack Aircraft

This program was canceled in January 1991. The U.S. Navy began development of the A-12 in 1985 to replace carrier-based A-6 attack planes and possibly F-111s. The program remained in the black until summer 1990 after Secretary Cheney's Major Aircraft Review. A total buy of 620 of the General Dynamics/McDonnell Douglas aircraft will begin this year, which is reduced from the originally planned 858. McDonnell Douglas and General Dynamics were chosen as the prime contracting team in 1987 over Northrop/LTV/Grumman. The team was awarded a $4.4 billion development contract.

The peak planned production rate is now 36 per year, beginning in fiscal 1994, as opposed to the original peak of 48 per year beginning in fiscal 1995. Total program costs are expected to be near $52 billion, of which just over $5 billion has already been spent.

Westinghouse will provide the AN/APQ-183 multifunction radar, which will use an electronically scanned phased-array antenna. Westinghouse was awarded the radar contract over Texas Instruments.

Litton will provide the ALD-11 electronic support measures system (ESMS) under a $110 million development contract. Litton's subcontractors will include Ball Aerospace, General Electric, and Ramtron. Litton also will produce the LR-85 inertial measurement unit.

The central computer will be produced by IBM and Intel chip sets. Harris also will provide Night Hawk 1200 and 3800 multiprocessing computers under a $10 million development contract.

The aircraft currently is about 30 percent overweight and has reportedly sustained nearly $2 billion in cost overruns. For fiscal 1991, the administration requested $1.2 billion in procurement, with an additional $395 million in advanced procurement and parts. Disgusted with the program's problems, Congress granted only $38 million in procurement; however, it granted $555 million for advanced procurement.

©1991 Dataquest Incorporated January—Reproduction Prohibited

The first flight of the triangle-shaped stealthy aircraft is now expected in 1992. Additional program cutbacks may be likely.

V-22 Osprey Tilt-Rotor Aircraft

The Pentagon, for the second year in a row, failed to cancel this program. Under the Reagan administration, procurement of V-22 Ospreys was planned to begin in fiscal year 1990, with a request by the U.S. navy and Marine Corps in the original Reagan budget of about $1.3 billion for 12 aircraft.

Designed to meet all four military services' requirements, the tilt-rotor aircraft is capable of many different missions and incorporates significant new technologies such as composite materials (more than 60 percent of the airframe) and full integration of avionics. Total planned cost of R&D and production of the V-22 was $60 billion. The Marine Corps planned to acquire 552 MV-22s at an approximate cost of $22 billion for amphibious troop assault and assault support to replace the CH-46 Sea Knight helicopters currently in service. The air force originally required 80 CV-22s for special-operations tasks, but has since revised that number to 55 aircraft. The army dropped out of the program in 1988 because of budgetary constraints but could fill its previous requirement for 231 MV-22s for medical evacuation and special operations. The navy deferred development of the SV-22A antisubmarine warfare version of the tilt rotor aircraft but has ordered 50 HV-22As for combat search and rescue.

FSD of the V-22 began in May 1986 and will continue until all flight tests are completed in 1992. Ground and flight tests have been successful, but schedule slippage and other problems have driven up the cost of each aircraft to between $23 million and $27 million.

The primary contractor is a Bell Helicopter-Boeing Vertol team. Bell has been responsible for the airframe and transmission and rotor and hub assemblies and integration of the Allison T406 engines. Boeing developed the fuselage and empennage and integrated the digital avionics and fly-by-wire system, cooperating with General Electric's aerospace control electronics system on the latter. Honeywell provided digital control, display units, and the AN/AAR-47 missile warning system, and IBM led the cockpit interface design team. The V-22 also incorporates an AN/AAQ-16 FLIR, by Hughes an AN/APQ-174 terrain-following multifunction radar by Texas Instruments, and two AN/AYK-14 mission computers by Control Data.

Defense Secretary Cheney denied all funds for the V-22 in the Bush administration fiscal 1991 budget request, just as he did in fiscal 1990, stating that the program was too costly and the technology did not offer advances proportional to the cost. Well over $2.5 billion has already been spent on the program.

The Marine Corps keeps fighting for the program on Capitol Hill, going around the Office of Secretary of Defense. To date, this persistence has paid off. The fiscal 1991 budget granted close to $300 million for continued R&D of the program; however, pushing the program into procurement against Secretary Cheney's opposition will be difficult.

P-7A Long-Range Air Antisubmarine Warfare Capable Aircraft (LRAACA)

The P-7A was awarded to Lockheed in January 1989, along with $52 million for full-scale engineering development of two prototype LRAACA aircraft. The P-7A is designed to replace early generation P-3s beginning in 1994.

The navy canceled the program in mid-1990 because of numerous problems involving Lockheed, leading to that company's $200 million charge against earnings. The cancellation also sent shock waves through Lockheed's subcontractors in 30 states and 3 foreign nations. For example, Line Flight Dynamics Incorporated's $48 million contract for head-up displays was canceled.

The navy continues to search for a replacement. Five systems were examined after the Lockheed cancellation—an extension of the service lives of current P-3Cs; a scaled-down version of the P-7; a variant of the C-130; a variant of a Boeing 757; and an upgraded P-3, designated the P-3H. In November 1990, the navy announced its decision to procure the P-3H, modernizing the P-3Cs with new avionics, better engines, and an improved cockpit.

The heart of the P-7A system, the Update IV ASW mission avionics systems, will be preserved. The prime contractor for the Update IV program, Boeing, currently is negotiating with the navy for systems procurement over the next six years. The original plan called for 108 P-3Cs and 125 P-7As to be outfitted with Update IV packages. As of September 1990, the navy plans to purchase 28 Update IV systems by May 1993 for nearly $500 million. The total planned buy is for close to 240 systems at $2.1 billion.

©1991 Dataquest Incorporated January—Reproduction Prohibited

The Update IV mission avionics system includes a distributive processing system based on Motorola's 68000-series microprocessor and installation of the AN/UYS-2 enhanced modular signal processor (EMSP) developed by AT&T. The system will use VHSIC chips developed by Honeywell. The functional elements will be composed of slide-in SEM-E modules, which, although only slightly larger than the SEM-B modules used for ship and submarine systems, will hold three times the microchips and other electronics. The EMSP has been plagued by delays, relating mostly to Boeing's Ada-based software difficulties.

An upgraded P-3 is also expected to contain Rockwell's AN/ARQ-50(v) communications system, which comprises two AN/ARC-207 high-frequency radios and one CMS-80 control-display unit. Texas Instruments is expected to provide the AN/APS-137 radar, and Loral will provide the antennas.

Multi-Role Fighter (MRF)

This highly secret program by the U.S. Air Force is being pursued to eventually replace the F-16 as a single-seat air-to-air and air-to-ground fighter.

The air force has been reluctant to discuss this program for fear of complicating the ATF debate. The DOD has decided to delay concept validation until after five-year development funding for the ATF is secured.

The current schedule calls for concept validation in 1994 or 1995, with FSD beginning in 2000 and procurement in 2002.

Currently, General Dynamics, Grumman, Lockheed, LTV, and McDonnell Douglas reportedly are all spending initial R&D funds to explore possible competition for this fighter, which has potential contracts worth billions.

Unmanned Aerial Vehicles (UAVs)

At Congress' request, the DOD developed the UAV Program, a master plan to determine requirements for remotely piloted vehicles, in 1988. The overall plan called for $1.6 billion to be spent between 1990 to 1994 for UAVs that would not be armed. Industry sources speculate that this market will be one of the few growth areas during the upcoming decade. The EIA believes that the total market for robotics and UAV equipment will rise from $4.8 billion in 1991 to $8.4 billion by the end of the decade. In addition, estimates place corporate internal R&D spending at more than $800 million annually by 2000. The fiscal 1990 defense UAV budget called for $29 million in procurement spending and $117 million in R&D.

There are four categories of UAVs. The first are close-range systems, which are designed to assist ground units by providing aerial reconnaissance within a range of 30 kilometers. Teledyne and Loral have been actively pursuing this program, with Merit Technologies developing software for the system. Other close-range UAV programs are still in the concept-definition stage.

Short-range systems are currently receiving greater attention. Designed for distances of up to 150 kilometers, these systems are currently being designed by both a McDonnell Douglas/Developmental Sciences Corporation team and an Israeli Aircraft Industries/TRW team. Both teams won preproduction contracts in late 1989; only one will survive the competition. The McDonnell Douglas team is pursuing its Sky Owl program, with Hughes developing the internal sensor as part of its preproduction award of $43 million. The Israeli Aircraft Industries entry, which received $18.5 million, is known as JIMPACS.

An FSD contract for the short-range program is expected by October 1991. A total of 308 air vehicles with 38 ground stations will be needed. Other subcontractors involved in the programs include AAI Corporation, Pacer Systems, and Vitro Corporation. Sikorsky's Cypher program also is in the short-range UAV competition. Shaped like a doughnut, this reconnaissance vehicle already has undergone test flights under the Defense Area Research Project Agency's (DARPA's) supervision.

The medium-range UAV program, Joint Service Common Airframe Multiple-Purpose Set (JSCAMPS), is further along in the acquisition process than the short-range UAV. This program will develop a UAV to perform reconnaissance missions as far as 700 kilometers from the edge of the battle. Four companies are competing for the production contract: Northrop's NV-144R, Teledyne with its Model 350, and designs by Martin-Marietta and Beechcraft. Teamed with Computing Devices, Teledyne was awarded a $65 million contract in mid-1989 to pursue FSD. A total of 775 vehicles are expected to be procured.

The final category of UAVs are the endurance or long-range systems; they have a range exceeding 1,000 kilometers. An RFP for the endurance program

©1991 Dataquest Incorporated January—Reproduction Prohibited

is not expected until mid-1991. At the end of 1990, Leading Systems' Amber drone and Boeing's Condor were expected to compete.

The next-generation unmanned aerial vehicle, the Autonomous Air Vehicle (AAV), is being developed by Martin-Marietta for DARPA. AAV will integrate forward-looking infrared sensors and millimeter-wave radars with image and signal processing, artificial intelligence, sensor fusion, and parallel processing techniques. The AAV is based on Martin-Marietta's Geometric Arithmetic Parallel Processor. This program's goal is to develop a UAV that will be able to find and engage targets autonomously in the midst of battlefield confusion and background clutter.

Unmanned Underwater Vehicles UUV

For the most part, these weapons remain highly classified. DARPA spent an estimated $24 million in fiscal 1990 on three separate systems designed to cruise the ocean depths autonomously.

The first program, known as the remote surveillance system (RSS), reportedly is to be deployed with various intelligence-gathering surface ships and *Los Angeles*-class submarines. This program has experienced several technical difficulties and been delayed up to a year. The tactical acoustic system will receive approximately $20 million in fiscal 1991 and is being developed by Martin-Marietta. The third system, developed by Lockheed and believed to be an unmanned, mine-hunting reconnaissance system, will receive approximately $15 million.

Unmanned Ground Vehicles (UGV)

In November 1988, the Pentagon established the marine/army UGV joint program office (JPO) in cooperation with DARPA to study the development and applications of UGVs. The office is charged with overseeing all military UGV programs, guiding UGVs from R&D to capabilities operation. UGVs will be capable of a wide range of battlefield functions including reconnaissance, target acquisition and guidance, detection of nuclear and biological weapons, and mine detonation. Three corporations currently are pursuing various UGV programs—Grumman, LTV, and Martin-Marietta.

Nonplatform-Related Research

Applied research in avionics is currently characterized by two trends: integration and commonality of systems and efforts to reduce complexity for the pilot. The Pave Pillar (also known as Advanced Systems Architecture) and Pave Pace programs attempt to improve integration; the Pilot's Associate program is geared toward improving human performance in conjunction with advanced avionics. Details of specific research programs follow.

Advanced Systems Architecture (Pave Pillar)

The Pave Pillar program is designed to improve the availability, cost, and mission effectiveness of advanced avionics through the integration of electronic subsystems. The application of VHSIC and fiber-optic multiplexing technologies are an integral part of this program. One of the program's goals, establishing a standard architecture, has already been achieved with the introduction of the MIL-STD-1750A computer.

Integrated Communications, Navigation, and Identification Avionics (ICNIA)

ICNIA, like Pave Pillar, is a modular system combining the 16 radios now used on an aircraft into a single system. If part of the system fails, ICNIA bypasses the faulty component and continues to perform the original tasks for which it was programmed, dropping the least critical function if necessary. According to calculations by TRW, ICNIA will increase the time between critical failures up to 67 times that of current discrete avionics systems. The number of different types of circuit boards required will be reduced from more than 1,000 to 28.

Pave Pace

The latest DOD avionics initiative, Pave Pace, aims to create the next generation of avionics technologies, incorporating a 32-bit computer, parallel processing, artificial intelligence, neural networks, and optoelectronics. The system is planned to be fault-tolerant, allowing malfunctioning components to be bypassed without seriously degrading the overall system's performance. Funding of $150 million is planned over the next 7 to 10 years.

This program has three goals: to create new packaging and cooling technologies for highly reliable avionic modules, processors, MIMIC-based antennas, and optoelectronics—fault-tolerance levels of 50,000 hours mean time between failures (MTBF) are sought; to develop a family of small avionics supercomputers with compatible hardware and software; and to prepare

©1991 Dataquest Incorporated January—Reproduction Prohibited

aircraft for the next century, when several parallel-processing computers will be on-board to assist the pilot with infrared (IR) warning and tracking target acquisition, selection and firing of weapon systems, and radar control at computing speeds in excess of 10 billion operations per second (bops).

Pilot's Associate Program

The Pilot's Associate program seeks to balance automation and pilot experience in the cockpit by using expert systems for adaptive aiding and information fusion. Pilot's Associate is being studied by the air force's Wright Aeronautical Laboratories along with Lockheed and McDonnell Douglas for possible use in the ATF. In 1990, the program demonstrated a nonreal-time capability to perform AI techniques that aid the pilot without removing his control. McDonnell Douglas, teamed with Texas Instruments, demonstrated its system to the air force in 1989. Originally planned to be a massively parallel, synchronized system, McDonnell Douglas reduced the level of parallel processing when DARPA decided to emphasize near-term applications. The project will be completed in fiscal 1991 with nearly $23 million in funding. DARPA told the House Armed Services R&D Subcommittee that a real-time demonstration with Ada software and avionics hardware will not occur until 1991.

Advanced Tactical Air Reconnaissance System (ATARS)

This program is designed to replace the current film-based sensor equipment on manned and unmanned aircraft. It includes three components: tactical aircraft reconnaissance system (TARS), unmanned aerial reconnaissance vehicles (UARV), and joint services imagery processing system (JSIPS). When placed in service, it will be the first EO reconnaissance system. The former prime contractor, Control Data, was selected in May 1988 for a 39-month contract potentially worth $120 million. In mid-1990, however, Martin-Marietta purchased the program from Control Data and will act as the prime contractor for the remainder of the program's life.

There are four stages. In the first phase, ATARS was integrated into existing F-4 aircraft for testing purposes. This prototype system completed its design review and first flight test. The air force, however, decided not to produce ATARS for F-4s because of the limited life of F-4s.

The second phase (the first production phase) will be the F-18. This platform has priority because the Marine Corps has an urgent need for additional reconnaissance capability after its decision to cancel the RF-4B program. This phase will begin flight tests in the summer or fall of 1991.

The third phase of the program (the second production phase) involves midrange UAVs. This system will not begin flight tests until late 1991 or 1992. In the fourth and final phase, ATARS will be produced for the F-16.

The program is extremely fluid at this time. Under the air force program, more than 2,000 aircraft originally were to receive EO systems beginning in 1992, but this number is declining rapidly. A short time ago, for example, industry planners were expecting between 250 and 400 F-16 platforms to be equipped with ATARS, but now no more than 110 to 150 F-16s are likely to receive the new system. However, Congress is supportive of the effort, although the level of platforms may be scaled down in the mid- to long term. The air force requested $47 million to continue the program in fiscal 1991 and was authorized the full amount.

Other Basic and Applied Research

Studies currently are being conducted on a variety of technologies that might be incorporated in future generations of aircraft. One such study is the classified Advanced Counter Air Systems conducted by IBM and Grumman for the Army Aviation Systems Command (AvsCom) to determine enabling technologies for a Future Attack Rotorcraft (FAR). By 1996, AvsCom will decide whether to proceed with the FAR or simply upgrade the AH-64s currently in the inventory. DARPA also has funded research on a small, highly agile antihelicopter, fixed-wing aircraft. Another recent solicitation for proposals was issued by the air force's Wright Aeronautical Laboratories for what the RFP described as "evolutionary concepts that would be applicable to electronic support measures or electronic countermeasures." Such concepts would be applied to weapon systems fielded in the next five to ten years in radio frequency, laser, infrared, electro-optical, and programs. An additional area concerns the integration of aircraft electronics and the airplanes themselves. General Electric, for example, received a contract to design a smart-skin integrated processor/transceiver.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Electronic Warfare

Overview

Electronic warfare (EW) systems and components are capturing an increasing percentage of the value of advanced air platforms and are becoming more vital for many types of missions in potentially hostile environments. The ability to detect an enemy at stand-off ranges and then jam hostile radars and missiles has proved decisive in recent U.S. engagements in Libya and Panama. The ability of the United States to win the "electronic war" will be even more essential in the Middle East, as demonstrated by Israel in its decisive victory against Syrian air defenses during the war in Lebanon in 1982.

In the past, most EW equipment such as radar warning receivers and jammers operated at radio frequencies. However, improvements in the technologies of heat-seeking missiles, which operate in the IR range of the electromagnetic spectrum, as well as in other systems operating in the visible range of the spectrum, have spurred the military services to create a broader array of countermeasure programs.

The U.S. inventory currently contains more than 400 signals intelligence and EW systems. The market for EW systems grew at an average rate of 25 percent from fiscal 1982 to 1985 but has since leveled off at approximately $6 billion annually. Procurement of EW equipment may even sustain some small cutbacks in the near term associated with the general downturn in defense spending and acquisition of military aircraft. The acquisition of spares, however, will continue to grow as electronic equipment is used more widely than ever before. The conflict in the Persian Gulf may spark additional purchases of spares. Overall spending on electronic warfare is likely to increase in the early 1990s when the next generation of systems begin to enter production.

Conventional electronic warfare comprises three basic missions: ECM, electronic support measures (ESM), and electronic counter-countermeasures. Electronic countermeasures can be either active or passive. The most common form of active ECM is jamming (either noise or deception). Passive ECM can include maintaining radio/radar silence or using low-observable (stealth) technology. The most common and least expensive passive ECM is the use of chaff, decoys, and/or expendables. Electronic support measures include listening to enemy radars and radios. Radar warning receivers are a type of ESM. Electronic counter-countermeasure systems encompass electronic intelligence (ELINT), signal intelligence (SIGINT), and other measures to ensure friendly access to portions of the electromagnetic spectrum. Antijam capability is built into the equipment; about 15 percent of EW funds are allocated to this technology, although most of it is classified.

Systems Development and Procurement

EW equipment is fielded in a wide variety of systems. The following list of air force EW programs gives an idea of the number of programs involved:

- F/FBE/F-111 Self-Protection
- EF-111A Upgrade Program
- F-4G Wild Weasel Performance Update Program (PUP)
- TEREC/ALQ-125
- Technique 101 Subsystem
- AFEWES Testing-FMS
- AFEWES Upgrading
- ASPJ
- ASPJ/F-16 Integration and Test
- ALQ-131 (V) ECM Pod (R/P)
- Countermeasures Systems (QRC 85-04)
- EW Area Reprogramming Capability (ARC)
- INEWS
- MJU-10/B Infrared Flare
- AN/ALR-56C/M
- Real-Time Electronic Digitally Controlled Analyzer and Processor (REDCAP)
- AN/AAR-47
- RR-180 Dual Chaff
- IRCM/Hare Charcoal
- AN/ALE-47

Aircraft Modifications and Upgrades

Much of the funding for EW equipment falls under aircraft modification programs. Of these, the F-4G, EF-111, and EA-6B programs, as well as the Tactical Protective program to upgrade F-15s and F-16s, are among the most important.

©1991 Dataquest Incorporated January—Reproduction Prohibited

F-4G Wild Weasel Performance Update Program

The F-4G Wild Weasel continues to be the mainstay of air force electronic countermeasures platforms, although funding for the program is almost completed. The F-4G's capabilities are being enhanced with improved receivers and signal processing capabilities. Under a 1986 contract to McDonnell Douglas, about 150 new units, including spares, will be produced for 119 F-4G aircraft. Total new funding for F-4G modifications was $2.7 million in fiscal 1990; there was no new funding in fiscal 1991.

The F-4G currently is fitted with the AN/APR-38 radar attack and warning system. The APR-38 includes an IBM superheterodyne receiver, Texas Instruments' HAWC central processor, Loral's CIS control and display system, and GE's AN/APQ (MOD) pilot's sight. Under the Phase I program just completed, the HAWC processor was replaced by a Unisys signal processor. This Weasel Attack Signal Processor (WASP) has improved reliability, five-times-greater signal processing speed, ten times greater data processing speed, and eight times more memory. The last WASP was delivered in the summer of 1989; a total of 50 units were purchased at $55 million.

Phase II of the F-4G performance upgrade program was to include the development of the directional receiver group (DRG) to improve power in the ALQ-99E jammer, new antenna arrays to increase frequency coverage, and improved software. E-Systems developed the DRG, a steered channelized receiver made of five line-replaceable units, to replace the IBM receiver. The air force declared the E-Systems contract in default in June 1988, however, and the upgrade will be deferred to the Follow-On Wild Weasel program.

The Follow-On Wild Weasel will replace the F-4G in the mid- to late 1990s and is known as the Man Destructive Suppress Enemy Air Defenses (MDS) program. The air force is considering the two-seat McDonnell Douglas F-15E or the one-seat General Dynamics F-16C as candidates for the "Wilder" Weasel's platform. The new aircraft will likely have upgraded mission avionics and use the AN/APR-47 with MIL-STD-1553B computer architecture and a JTIDS data relay system. The earliest flight for the MDS would be in late 1994 or early 1995, followed by a two-and-a-half-year contract for FDs.

EF-111A

In fiscal 1988, the air force began a series of upgrades to the 42 EF-111A Raven electronic combat aircraft. The Raven is designed to provide standoff jamming within its own airspace or accompany bombers while jamming enemy radar; the Raven would also destroy enemy radar sites with radiation-seeking missiles. The purpose of the upgrades is to improve tactical jamming gear in order to increase reliability and maintainability.

Two teams are competing for the $450 million upgrade package. Rockwell, which has handled previous F-111 upgrades, is teamed with Calspan for the mission simulation and threat analysis, Logicon for software development, Teledyne for hardware design and development, and Raytheon for the tactical jamming equipment. The second competing team is led by Grumman, with Eaton's AIL developing the technology to manage radar collection, Comptek for software, IBM for the mission processor, ACA for platform displays, and Smith's Industries for additional software technology.

The first improvements to the Raven will be in computer processing. The 1750A processor, manufactured by Delco under subcontract to Eaton AIL, is two years behind its original schedule; operational test and evaluation was scheduled to begin in January 1989. Although the 16-bit 1750A standard computer is being modified to meet new requirements, it may be dropped as the Pentagon moves to 32-bit instruction set architecture. Other improvements will update the radio receiver and antennas.

EA-6B

Capabilities of the navy's EA-6B Prowler tactical support aircraft were enhanced under the Improved Capability Program (ICAP II) recently completed by Boeing Aerospace. Grumman, however, received an $18 million contract in January 1989 to perform the next upgrades on the EA-6B and, in July 1990, received an additional $114 million for an avionics improvement program to be completed in January 1994.

Additional modifications are ongoing under the Advanced Capability Program (ADVCAP). The ALQ-99 receiver system is the backbone of the ADVCAP. Litton was selected by Grumman to produce the ALQ-99 and flight testing was conducted last year; FSD is expected in 1991. An improved electronic countermeasures set for the EA-6B, the Lockheed Sanders AN/ALQ-149, has been delivered to the navy, increasing the radar and radio frequency jamming coverage of the aircraft. The Lockheed Sanders contract included options for 95 sets. The ALQ-149 consists of eight line-replaceable units, including antennas, receivers, signal processors, computers, and controls.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Sanders Associates has delivered the last of the engineering models of the AN/ALQ-149 for the EA-6B to the navy. The ALQ-149 will detect, identify, evaluate, and jam hostile communication signals and long-range early warning radar systems. The ALQ-149 is expected to be deployed on the ADVCAP version of the EA-6B in the early 1990s. Full-scale production is expected to begin in 1991. Although new aircraft procurement of the EA-6B will cease in fiscal 1991, Grumman will continue to perform upgrades well into the 1990s.

Standalone Jammers and Radar Warning Receivers

Overview

Since 1982, the air force has spent close to $2 billion on electronic jammers, with an additional $2 billion in spending planned by 1995. This money has been spent on a variety of jammers that have been identified as redundant and of questionable effectiveness. These charges led Congress to intervene directly in service planning for electronic warfare in 1990.

Congressional Action

Frustrated by program failures and shortcomings, as well as the services' "go-it-alone" approach to procuring electronic jamming equipment, Congress this year mandated the establishment of a consolidated EW program under the Under Secretary of Defense for Acquisition and allocated $162 million in funding for the program, which it took from a variety of service programs.

The frustration felt by Congress largely grew out of the air force's decision last year to drop out of the air force/navy common Airborne Self-Protection Jammer (ASPJ) program, being developed by ITT and Westinghouse and pursue two separate programs instead: the ALQ-135 and ALQ-184 systems mentioned previously. This move by the air force flew in the face of repeated congressional direction to move toward common systems. In addition, the price tag associated with three separate systems was a whopping $463 million for fiscal 1991 alone.

In addition to noting that $187 million already existed in unobligated funding authority for EW systems, Congress authorized $60 million in new appropriations for the ASPJ and $39 million for the ALQ-184; it denied any funds for the ALQ-135. Congress further directed the under secretary to establish a comprehensive service-wide plan to "eliminate redundancy, maximize commonality, and meet essential operational requirements at the resource levels likely to be available with projected future budgets." After this plan is established, Congress directed the under secretary to terminate all programs that are no longer needed. In short, Congress has mandated competition among the three systems in what may very well evolve into a winner-take-all competition.

ALQ-184

The ALQ-184 is a pod-mounted jammer that is an upgraded version of the older ALQ-119 first deployed in the 1970s. The ALQ-184 is produced by Raytheon. The air force began procuring this system in 1982 and has since acquired nearly 350 jammers at a cost of approximately $500 million. In 1990, the ALQ-184 was put up against the ALQ-131 Block II to determine which system better served the air force's pod-jamming needs. The ALQ-184 won; the air force subsequently planned to procure an additional 766 systems through 1993 at about $636 million before this year's congressional action.

ALQ-135

This system, produced by Northrop, is mounted inside aircraft and is used on the F-15. Procurement has been completed on an upgraded version of the system, known as the quick reaction upgrade, with the purchase of 65 systems at a cost of $256 million. Another upgrade is known as the preplanned product improvement model. This latter upgrade is a two-band system for use on newer models of the F-15. The F-15C will be equipped with the Band 3 version, and the F-15E will use the Band 1.5 version. To date, the air force has procured 121 Band 3.0 and 8 Band 1.5 systems at $362 million. Fiscal 1991 through 1995 plans call for an additional 533 Band 3.0 and 185 Band 1.5 jammers to be acquired at an estimated cost of $1.7 billion.

ALQ-131

This pod-mounted jammer built by Westinghouse has been delivered to the air force in two versions. The most recent version incorporates an advanced receiver/processor to enable the jammer to concentrate its jamming on a specific threat. Procurement of this ALQ-131 Block II was completed by the air force after a buy of 400 at a cost of $792 million and is now being flown in Europe

©1991 Dataquest Incorporated January—Reproduction Prohibited

on F-16 and F-111 aircraft. The system, however, has experienced a number of performance deficiencies.

ALR-56C and ALR-67

Loral's ALR-56 family will become the standard radar warning receiver (RWR) for the air force, while the Litton version, ALR-67, will serve as the standard RWR for the navy and Marine Corps.

The ALR-56A model was placed on F-15A/B aircraft in the early 1980s. The C model, produced by Loral since 1984, integrates radar warning with all on-board EW sensors and avionics and with the ALQ-135 jammer. This integration makes it much more expensive than the F-16 receiver, the ALR-56M. Most of the air force's F-15 fleet has already been outfitted with these receivers. The latest award (in April 1990) was for 57 additional systems to be delivered over the next 16 months.

Versions of the system also are in service on tactical aircraft in Israel, Japan, and Saudi Arabia.

ALR-56M

This system is the air force's latest common RWR for both tactical and wide-body aircraft. The ALR-56M interfaces sensors with countermeasures such as chaff and flares, but not with jammers. There is 80 percent commonality between this system and the ALR-56C. It repackages the ALR-56C technology specifically for the F-16, although studies are ongoing to place the system on the C-130, AC-130U, and C-17. Plans also call for the system to be placed in the B-1B to augment Eaton's ANQ-161 RWR/jammer. The plan calls for about $500 million to be spent for 7 units in 1992, 63 units in 1993, and 54 units in 1994.

The award of the ALR-56M contract to Loral was challenged by Litton and the Government Accounting Office (GAO). In December 1989, Loral reached a settlement with the air force that required Loral to pay $5.8 million in fines, forfeit a $4.6 million target profit from the first two production lots, share 35 percent (originally 25 percent) of lot 3 (258 units) with second sources, delete the fourth production lot (319 units) from the existing contract (of which Loral had been guaranteed at least 65 percent) and reopen competition. In each annual competition, the winning contractor will receive 60 percent of the business. Litton is the second source for three of the five components of the system and is bidding on the other two.

The Pentagon's currently planned buy of ALR-56Ms is shown in Table 3.2.

This plan will be considerably modified, however, as block 50 F-16 production will be lowered from the planned rate of 150 per year.

Airborne Radar Jamming System

The Airborne Radar Jamming System, a high-power standoff jammer, is based on the ALQ-99 but will be mounted on helicopters such as the UH-60 Black Hawk. Developed by Grumman, the system will be used against air defense, surveillance, and target acquisition radars. Its functions will include threat signal detection, emitter location, comparison against a computerized threat library, and jamming signal transmission.

Table 3.2

Pentagon's Planned Buy of ALR-56Ms

	Fiscal Year							
Program	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**Remainder**	**Total**
F-16 Support	15	10						25
F-16 Block 50 (Production)		61	150	150	150	150	390	1,051
F-16 Block 40 (Retrofit)	4	12	78	139	158	36		427
RF-4C Retro	36	72	72	55	46			281
Spares (10%)	1	11	30	36	36	23	39	176
Totals	20	130	330	397	399	255	429	1,960

Source: Department of Defense

©1991 Dataquest Incorporated January—Reproduction Prohibited

TACJAM-A

The army selected a team comprising Sanders Associates and AEL in late 1989 to conduct Phase II engineering development of the TACJAM-A mobile jamming system. The $4 million contract requires Sanders and AEL to design and manufacture four models; full funding of the two-year Phase II could bring as much as $70 million to the contractor. The program was given a congressional boost for fiscal 1991, bringing the new year's funding level to $10 million.

Decoys

The services are developing new active radio-frequency-expendable decoys to counter a number of radar and IR guided missile threats. The navy has historically been the lead service for most of these highly classified programs.

The primary expendable in the U.S. inventory, known as the Primed Oscillator Expendable Transponder (POET), is made by Lockheed. This system has been in the services' inventory for years, with Lockheed producing over 87,000 systems as of December 1990. The follow-on to POET, GEN-X, which is designed to be ejected from navy and marine aircraft, was awarded to Texas Instruments, which anticipates initial program production in 1992. As of December 1990, Texas Instruments had received well over $120 million for this program. Plans are for the system to cost less than $3,000 per unit when in full-scale production.

To avoid radar homing missiles, the navy has begun two additional programs. The first is a decoy to be fired from an aircraft and fly independently, mimicking a fighter's movements. The expendable will include an advanced electronic package and is currently undergoing advanced development under a navy contract with Teledyne. A towed system, designed by Raytheon with Hughes as the primary subcontractor, is also being pursued by the navy. The current plan calls for these systems to enter production in 1993 and be deployed by A-6E aircraft.

Another towed decoy, known as Big Boy, is being developed by Tracor Aerospace and Boeing Missile Systems. This program's goal is to design a lightweight towed electronics package capable of producing a larger radar cross-section than the aircraft it follows, thereby drawing hostile fire away from the aircraft.

A next-generation independently flying decoy, using straight-through repeater antenna performance (STRAP), is also under development. Feasibility awards for this advanced expendable were granted to Lockheed-Sanders, Raytheon, Texas Instruments, and Tracor in 1990, with engineering development planned to begin in 1991. This system would use MIMIC technology to reduce size and increase reliability.

Other programs include the Threat Adaptive Countermeasure Dispenser System (TADS) developed by Tracor for all services and ITT's antiradiation missile decoy being developed under a $12 million development contract. The TADS system is a next-generation replacement for Tracor's current ALE-40 (V) system.

Electronic Support Measures Systems

AN/ALR-67

In production for several years, the AN/ALR-67 is deployed on Navy F-14 A/D Tomcats, F/A-18C/D Hornets, and AV-8B Harriers. The ALR-67 is a countermeasure radar warning system that is designed to eventually be integrated with the ASPJ. Litton is the prime contractor; Dalmo Victor is a second source. The contract includes quadrant receivers, computers, and special receivers.

A follow-on to the ALR-67 is in its early stages. The advanced special receiver program has attracted four competing teams: ESSI, Litton-ATD, and Harris; Dalmo Victor and TRW; Hughes and AEL; and Loral and Texas Instruments.

AN/ALQ-156

Lockheed-Sanders received a contract in October 1988 for FSD of a tactical aircraft version of the ALQ-156 missile detection system and continues to produce the systems. First developed in 1976 under the army, the ALQ-156 works with Tracor's M-130 chaff/flares dispenser.

Small-Platform EW System

This system currently is being developed by Motorola and is intended to eventually service remotely piloted vehicles and UAVs.

Fiber-Optic Laser Warning System

Varo, Inc., is developing this laser-sensitive warning system for air-based, sea-based, and ground platforms.

©1991 Dataquest Incorporated January—Reproduction Prohibited

The fiber-optic system will cover wavelengths between 400 and 100 nanometers (nm), with an angular coverage of 90 degrees. Each sensor will be mounted flat against an outer surface of the platform; each platform will need between four and six sensors.

Infrared Countermeasures

Infrared countermeasure (IRCM) devices jam IR sensors or homing devices. Since 1975, 90 percent of aircraft combat losses worldwide have been due to IR-homing missiles. IR systems were so effective in Afghanistan that the Soviets delayed production of two new attack helicopters until IRCM systems could be designed and fitted onto the aircraft.

The AN/AAR-44 is an IR warning receiver produced by Cincinnati Electronics Corp. for missile detection. Cincinnati Electronics also produces the AAR-34 aircraft self-protection system used on the F-111 and F-15.

The AN/AAR-47, built by the Honeywell division acquired by Loral in 1989, is produced for navy helicopters to provide passive threat protection against surface-to-air and air-to-air missiles. It is a 360-degree missile attack warning system (MAWS) that uses four optical sensors to detect ultraviolet emissions from incoming missile rocket plumes. (This technology has also been demonstrated in the SDI program.) After detecting a missile, the system can automatically release chaff or flares. The system is also deployed on Navy P-3 aircraft and is part of the Marine Corps' survivability augmentation for transport aircraft (SATIN) program to go on C-130s. The navy awarded a $22 million contract in late December 1989 for 210 systems and spares.

To date, passive sensors such as the AAR-47 have been troubled by an unacceptable level of false warnings, limited range, and inability to operate in poor weather. Loral is continuing Honeywell's initial research investment with some success in creating an improved version of the AAR-47.

The AN/ALQ-157 is a 360-degree active modular IR jammer operating on large helicopters and medium transport aircraft for the United States and other NATO nations; it is also produced by Loral. Examples of aircraft using the system include the H-3, H-46, H-47, H-53, C-130, P-3C, and the British Lynx. Current deliveries include the USMC CH-46, filling a 1988 contract for 140 units. Future U.S. Government plans call for placing the system on the replacement for the navy's P-3C and possibly on the A-10.

The AN/ALQ-123 is a podded IR jammer, also produced by Loral, that has been deployed on fighter and attack aircraft including the A-6, A-7, F-4, F-5, F-16, and F-18.

The Matador was developed primarily for large transport and VIP aircraft and features the ability to provide covert, fully synchronized protection against multiple, simultaneous threats. It is reportedly used widely in the private sector and by heads of foreign governments. It is currently on the L-1011, VC-10, Bae-146, Boeing 747, Andover, Boeing 707, and Gulfstream.

The AN/APR-39 system, produced by the Dalmo Victor Division of General Instrument, is designed for use on light- and medium-weight helicopters for both the navy and the army. Possible platforms include the AH-1, AH-64, A-129, HH-65A, UH-1, UH-60, MD-500, Puma, Super Puma, Atlantique, and Super King Air 300 aircraft.

The Challenger by Loral, which was first delivered in late 1989, is the lightest version IRCM device and will compete with the AN/APR-39 for use on light and medium helicopters. The United Kingdom has ordered the system for its Lynx helicopter program. It combines the technologies of the Matador and the ALQ-157 into a smaller package.

Basic Research

Overview

Research in electronics warfare is geared toward multispectral systems. The push for integration will mean that in addition to radio frequencies, systems will have to perform in the visible and IR portions of the spectrum, perhaps using a time-sharing method. Millimeter and microwave technologies are one important area of research. Air Force research currently is focusing on monopulse radar countermeasures. Other areas include communications jamming, high-power radar countermeasures, and expendable radio frequency and IR countermeasures for aircraft.

One area in which research is likely to expand is in space countermeasures. Even in the absence of an SDI space-based component, U.S. military forces are nevertheless increasingly dependent on satellites for communications, and electronic countermeasures to protect these systems could become critical. These satellite-defense ECM systems can be located on-board, on an escort satellite, or on a standoff satellite, in much the

©1991 Dataquest Incorporated January—Reproduction Prohibited

same way that aircraft ECM systems are deployed. ECMs for space are similar to those for aircraft—noise and deception jamming, decoys, chaff, and flares—but require performance specifications for a space environment. Jammers in space will probably rely on advances in packaging and cooling techniques, whereas signal processing will benefit from advances in artificial intelligence and neural networks for signal processing.

In the near future, trends in EW equipment point toward greater integration. Some integrated systems will include a radar warning receiver, a threat processor, expendable decoys, and multimode jammers. INEWS is the largest of the integrated programs.

Integrated Electronic Warfare Systems (INEWS)

The largest EW program in history, INEWS is designed to be standard equipment aboard the next generation of combat aircraft, including the air force ATF and B-2 and the navy A-12. The air force was authorized to spend $30 million in R&D on the program for fiscal 1991.

INEWS will be used to replace the AN/ALQ-165 (ASPJ) or its alternative, on existing aircraft. For combat aircraft of the next century, INEWS will fuse the capabilities of jammers, missile detection/warning, laser-radiation detection/warning, and IR missile jammers using VHSIC technology. Each chip will contain as many as 30,000 logic gates. In a radical departure from past designs, INEWS will share common processors and antennas among the aircraft's electronic systems, allowing savings in weight, space, and cost.

Two industry teams competed for the demonstration and validation of the system: TRW and Westinghouse (with GTE, Honeywell, Northrop, Perkin-Elmer, and Tracor as subcontractors) and Sanders Associates and General Electric (HRB-Singer and Motorola are subcontractors). The Sanders/General Electric team won the development contract worth an estimated $500 million, with production estimates of approximately $7 billion. Full-scale production is planned to commence in late 1993 but will almost certainly slip. The earliest sets, however, were delivered in 1990 to the two competing ATF teams and reportedly are functioning well.

Survivability Augmentation for Transport Aircraft—Now (SATIN)

The need to protect airlifters from missile attack has spurred new programs for electronic countermeasures. The air force is testing the Lockheed SATIN ECM package for the C-130 transport aircraft. Lockheed is also conducting design studies on the C-141 and C-5 transports. The SATIN system is unique because it can be temporarily installed in a single eight-hour shift, allowing kits to be prepositioned in high-threat areas rather than fitted to the entire cargo fleet. Lockheed has delivered a similar prototype defensive electronic countermeasure system for the Marine Corps' fleet of KC-130 Hercules tanker aircraft. The Marine Corps' version is not removable; it includes the APR-39 (V)1 radar warning receiver, the AAR-47 missile detection system, and the ALE-39 chaff and flare dispensing system.

Although the SATIN program received considerable support in the mid-1980s, it has now stalled. The air force and Lockheed both continue to pursue the program, but it is not considered a high-priority item.

Electro-Optic Countermeasures (EOCM)

This defense electronics market is evolving quickly. Because every military measure begets a countermeasure, the increasing use of laser guidance and optical detection is creating a need for EO countermeasures.

The largest current EOCM program is the advanced optical countermeasures (Coronet Prince) program, a pod-mounted system to warn aircraft crews when they have been spotted, or "painted," with a laser. The system would respond with a laser to blind air defense personnel and disrupt optical tracking. After testing aboard an E-4 aircraft, the air force has selected the Westinghouse AN/ALQ-179 EOCM pod for production. The system will be used on high-performance tactical and special-purpose aircraft. Coronet Prince could enter FSD in 1991.

The army has a similar program for helicopters called Cameo Bluejay. Lockheed-Sanders has developed a system for scout and attack helicopters. Other helicopter programs include the Perkin-Elmer AVR-2 laser warning receiver, scheduled for deployment in 1991.

HAVE GLANCE

IR jammers currently are deployed on helicopters, but advances in power and decreased size are necessary before they can be used effectively on aircraft. The classified HAVE GLANCE program aims to develop potential solutions to those problems in IR countermeasures. The HAVE GLANCE system will use

©1991 Dataquest Incorporated January—Reproduction Prohibited

an IR or pulse-Doppler warning system to detect the missile and trigger the laser. In September 1988, Loral was selected over TRW to develop a laser-based IR countermeasures system. The resulting system will be used on strategic platforms until its size can be reduced for tactical aircraft. Demonstration testing is expected in 1991.

Infrared Sensors

Overview

The unique characteristics of sensors incorporating IR focal plane arrays (IRFPAs) are leading to their use in a growing range of military intelligence, reconnaissance, targeting, and guidance systems. Several weapon systems incorporating second generation IRFPAs will enter production during the next three to seven years. Key weapon programs incorporating IRFPAs include the air force's Advanced Air-to-Air Missile (AAAM) and the army's Advanced Antitank Weapon System-Medium (AAWS-M). This midterm market for IRFPA arrays and the materials from which they are constructed can be expected to grow exponentially, reaching a total value of $6 billion per year for military products by the middle of the 1990s.

The inherent advantages of IRFPA-based military sensors over alternative forms of detection, tracking, and guidance systems such as radar will spur additional growth. Operating passively, the IRFPA sensor does not release a signal or signature. Unlike radar, the IRFPA sensor simply collects the natural radiation emissions of objects and therefore cannot itself be detected by the enemy. The focal plane array within the sensor translates the thermal emissions into an electronic pattern that can be shown as a TV-like picture. It also can be stored for later analysis or, in guidance systems, the actual electronic pattern can be compared with a previously stored pattern in order to recognize tanks or other targets.

Another advantage that ensures continued growth of this market is the ability of IRFPAs to operate in any type of environment, including space. Because the sensors are not excited by visible light, they are not dependent on clear weather, daylight, or ground conditions for their operational success. They are also unaffected by smoke, haze, and camouflage, giving users a 24-hour all-weather passive sensor capability that can provide extraordinary advantages to armed forces that operate in hostile and unknown territory.

Three companies have dominated the past IRFPA market: Hughes Aircraft's Santa Barbara Research Center, Texas Instruments, and Loral's Electro-Optics Division, formerly owned by Honeywell. Together, they have produced well over 40,000 modules for use in everything ranging from the navy's F-14 fighter to the army's M-1 tank and TOW antitank weapon.

As promising and successful as the first-generation IRFPA technology appears, it has a number of problems, nearly all of which stem from the materials used to make the focal plane arrays (FPAs). The favored material has been mercury cadmium telluride (HgCdTe), which has proven to be highly sensitive and capable of operating across a wide range of the IR spectrum. In order to be effective, however, HgCdTe must be cooled to at least 77°K or -196°C. In addition, the alloy has proven to be inherently unstable and brittle, making processing expensive. To date, the processing and production difficulties have been the major stumbling block preventing wider proliferation and use of HgCdTe IRFPAs.

Most arrays within both existing IR systems (primarily FLIRs) and the new missiles and reconnaissance systems to be procured in the mid-1990s incorporate HgCdTe as the exciter material in their sensors. The one important exception is the army's new Non-Line of Sight Missile, for which Hughes is developing a sensor using platinum silicide (PtSi). The substrate upon which the IRFPA exciter material has most recently been placed has largely been from the cadmium telluride (CdTe) family, including cadmium zinc telluride (CdZeTe). Although this substrate material will remain the primary focus of ongoing R&D programs, more advanced materials that require less arduous manufacturing processes, such as synthetic sapphire, gallium arsenide (GaAs), and indium phosphide (InP), are also showing promise as substrate materials.

Given the wide utility of IRFPAs, the DOD is spending a considerable amount of money to explore better means of producing HgCdTe-based sensors, in order to reduce their cost, and develop IRFPAs using alternative materials. This massive research effort totals about $600 million in R&D per year.

The Defense Advanced Research and Projects Agency (DARPA) Electronic Sciences Program

This project demonstrates devices, materials, and processing concepts that will provide new technical options for electronic and optical systems used in information transmission, gathering, and processing. The

©1991 Dataquest Incorporated January—Reproduction Prohibited

program also focuses on substantial increases in performance and reductions in costs. Areas of funding include advanced semiconductor processing, new device concepts, reliability and availability of electronics at a reduced cost, innovative optical materials and devices, and thin-film structures.

Work continued under this program in processing technology development for submicrometer electronics and long-wavelength HgCdTe thin films in 1990. The program should demonstrate HgCdTe IRFPAs on GaAs substrates sometime in fiscal year 1991. The work for this program is conducted by Celanese Research Center, Electronic Devices Incorporated, Lincoln Laboratory, Lockheed Missiles and Space Company, Rockwell International Science Center, Stanford University, and Westinghouse Research Center.

DARPA Infrared Focal Plane Array Project

Formerly known as DSTAR, this project is to develop a solid manufacturing base for advanced IRFPAs. Dataquest expects the Pentagon to spend over $200 million during the next five years for this project. Its goal is to produce IRFPAs that meet systems requirements at 1 percent of the current cost of production. The program's focus is centered on HgCdTe in the 8-10 micrometer band and PtSi in the 3-5 band.

Internal government research for this program is being conducted by the U.S. Army Communications-Electronic Command Center for Night Vision and Electro-Optics at Fort Belvoir, Virginia; the Office of Navy Technology; and the Air Force Office of Manufacturing Technology. Outside contractors are Rockwell and Hughes Aircraft's Santa Barbara Research Center for the HgCd Te project and Loral's Fairchild Weston for work with PtSi. Other contractors listed as possible future beneficiaries of this program include Aerojet, Amber Engineering, Ford Aerospace (now part of Loral), General Electric, Honeywell, NERC, and Texas Instruments.

Advanced Long Wave Infrared Circuit and Array Technology (ALICAT)

This program is run by the army's Communications-Electronics Command Center for Night Vision and Electro-Optics. The goal is to produce a dual-band sensor capable of operating in both the medium-wave infrared (MWIR) and the long-wave infrared (LWIR) bands. Hughes' Santa Barbara Research Center is the prime contractor and has demonstrated a 480x4-pixel HgCdTe IRFPA. Current plans also call for use of indium antimony (InSb) for the MWIR band.

U.S. Air Force Pave Pace Program

As noted previously, the DOD Pave Pace initiative is aimed at creating the next generation of avionics technologies, including a 32-bit computer, parallel processing, artificial intelligence, neural networks, and optoelectronics. The sensor portion of the program is being developed by Rockwell, which is concentrating its efforts on the manufacture of simple CdTe detectors. Rockwell is also producing HgCd Te IRFPAs for this program.

U.S. Army Strategic Defense Command Manufacturing and Testing of Hardened Seeker Focal Plane Assemblies (MATHSFA)

The first phase of this program is designed to develop and build samples of LWIR and very long wave infrared (VLWIR) HgCdTe detectors and read out chips in 128x128-pixel and 256x256-pixel configurations. The second phase will have only one or two contractors; its goal is to demonstrate production capability for 1,000 sensor chip assemblies per year.

In June 1990, three contracts, each worth approximately $30 million for 60 months, were awarded to Hughes' Santa Barbara Research Center, Loral, and Rockwell. Companies that also competed for the contract were Aerojet, Amber Engineering, and Texas Instruments.

U.S. Army Night Vision Investigations

The U.S. Army's Communications-Electronics Command Center for Night Vision and Electro-Optics is operating a program entitled Night Vision Investigations, which is developing second- and third-generation night-vision capabilities. The program has been under way for several years. According to army officials, the majority of these programs involve either HgCdTe- or InSb-based detector materials. Current contractors include Advanced Design Corporation, Quest Inc., Omar McCall Inc., Santa Barbara Research Corp., VG Instrumentation Inc., Fermionics Inc., Digital Electronic Corp. (DEC), Honeywell, TLD Inc., Litton, Magnavox Corp., EOIR Corp., and LJF Corp.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Wright Research and Development Center (Wright Patterson Air Base)

The Wright Research and Development Center recently awarded Rockwell International a contract to improve HgCdTe growth on synthetic sapphire. The goal is to reduce costs from between $30,000 and $60,000 per unit to about $1,500 to $3,000 per unit. In addition, the Center has ongoing contracts with Hughes and General Electric. Past contracts have been awarded to Westinghouse and McDonnell Douglas.

Simulation and Training

Overview

Allied military forces spend the vast majority of their time and money not in combat, but in training for combat situations. In the past decade, particularly more recently as fiscal pressures have constrained operations and maintenance budgets, simulation devices have gained an increasingly important role in military training. Simulators are attractive to the services because they can increase training hours and diversity while reducing costs. For instance, the navy estimates that increased use of simulators reduces fuel consumption by 64 percent, manpower by 44 percent, and total cost of navy pilot training by 45 percent.

Although a small number of simulators have been commonplace in both military and civilian aviation for many years, the changing nature of warfare makes naval engagements, armored operations, and even infantry battles sufficiently complex to warrant these devices. The current worldwide market for training devices and simulators is nearly $3 billion and has been projected to increase to $4 billion by 1994. Simulators range from strap-on computers and specialized software to complex electronic combat ranges first developed in the 1970s. Simulators are becoming more realistic as the speed of information processing systems and the clarity of display generators make mimicking real-life, real-time scenarios possible.

Defense training and simulation constitutes a more than $2 billion market in the United States, with moderate growth forecast during the next few years.

Until the 1970s, training was accomplished mainly in classrooms and individual trainer vehicles, which were versions of actual weapon systems dedicated to training. As computer-generated imagery capability expanded, however, these full-mission trainers became less attractive because of their cost and the fact that they often lagged behind the introduction of new operational systems. For example, the B-1B trainer was introduced four years after the B-1B was deployed.

One solution was embedded trainers—an actual weapon system turned into a trainer by connecting software-driven scenarios to the system. Embedded training offers the advantage of greater realism than do mission simulators and ensures that the trainer is as up to date as the operational system. However, the added equipment required for embedded training is costly and complicates logistical support. Some analysts believe that the operational effectiveness of embedded training might have been degraded, as prime contractors might not have placed as much emphasis on the quality of embedded trainers as specialized trainer manufacturers have in the past.

Simulators are also used in part-task training and strap-on training. Part-task training entails simulation at the component level; an example is using computers to train a fire-control system operator. Strap-on training includes on-board training devices and interactive videodisks. One example is the 20B5 pier-side trainer for *Perry*-class frigates.

Simulators are not only useful in training operators but can play a valuable role in gathering data on systems before the systems are deployed. Pilot work loads in various cockpit configurations can be measured and applied to the design of new aircraft, for example. Other human-factor analyses can be applied in simulated combat situations in order to make the most of human reasoning and reaction time. Simulators are also becoming a valuable tool for mission rehearsals; the navy hopes to install the CV Trainer on aircraft carriers for that purpose. Simulators will be used extensively in mission planning and mission support systems.

One of the earliest air combat simulation efforts included the navy's Tactical Aircrew Combat Training Systems (TACTS) and the air force's Air Combat Maneuvering Instrumentation System (ACMI) programs. The former is still generating some new business: Cubic Corporation recently received a $5 million contract to upgrade, install, and test two existing display and debriefing systems for the National Guard as part of the TACTS program.

The 1990 DOD Critical Technologies Plan highlights simulation as potentially affecting "every major DOD weapons development program to reduce design and

©1991 Dataquest Incorporated January—Reproduction Prohibited

production cost, improve performance, improve diagnostics and maintenance, assist in better and faster training of personnel, and improve command and control on the battlefield." But as the market for simulators evolves, so too have the bureaucracies that develop and procure them, leading Congress to intervene in an effort to force the armed services to develop a comprehensive, defense-wide program for developing and procuring simulation technology.

The Senate's fiscal 1991 Defense Authorization bill directs the Pentagon to establish a central office to coordinate simulation policy, establish interoperability standards and protocol, promote simulation within the military departments, and establish guidelines and objectives for coordinating simulation, war-gaming, and training. Congress authorized $15 million to establish this new Pentagon office, which also will have the responsibility of establishing long-term simulation goals and requirements for all Pentagon programs.

Aircraft Simulation and Training Systems

All three services are acquiring major training and simulation systems for aircraft. Some of the largest programs are described in this section.

Specialized Undergraduate Pilot Training (SUPT)

The SUPT program is estimated to cost close to $18 billion over the next 24 years, $7 billion of which would be allocated to three training systems, but budgetary constraints and congressional concerns have placed this long-term program in jeopardy. In 1989, the air force presented to Congress a 20-year, three-plane acquisition program for training, hoping to create two tracks for undergraduate pilot training: bomber/fighter training and tanker/transport training. The air force's plan called for the immediate procurement of 211 jets for the tanker/transport training segment of the program; early in the 1990s, it would begin to procure 538 primary aircraft training system (PATS) aircraft to replace existing T-37 trainers. Finally, the plan called for the purchase of 417 new bomber/fighter training system (BFTS) aircraft to replace T-38 aircraft in the year 2005.

These plans to procure separate training aircraft for the air force were opposed by Congress, however, and the navy has since agreed to buy up to 20 air force tanker/transport aircraft. At the same time, Congress is pressing the air force to buy the navy's T-45 Goshawk for the bomber/fighter trainer role, but the air force claims that the T-45 will be outdated by 2005. While this issue is being resolved, procurement of tanker/transport trainers is going ahead—14 aircraft were authorized in 1990 and 28 were approved for fiscal 1991.

A draft RFP for the tanker-transport system was issued in mid-1989; the proposal stated requirements for an FAA phase-II simulator with an enhanced visual system capable of day, dusk, night, and textured-image generation. Contractor teams submitting proposals included the following:

- Flight Safety International, Learjet
- General Dynamics, Cessna, CAE-Link
- Hughes, LTV
- McDonnell Douglas, Beech
- Rockwell, British Aerospace, Reflectone

Another element of the SUPT program calls for the modernization of simulators used for instrument flight simulations. Night Hawk computers manufactured by Harris will be used under a contract that could be worth more than $3 million. Quintron also is involved in this program.

T-45 Trainer Simulator

The navy's T-45 training system combines both trainer aircraft and simulators. The prime contractor, McDonnell Douglas, will provide a derivative of the British Aerospace Hawk, known as the T-45 Goshawk, as well as ground-based simulators, textbooks, trained instructors, and system maintenance. Students will learn the basics in the classroom and then graduate to the T-45 operational flight simulator produced by Honeywell. Finally, the students will practice flying in the T-45A Goshawk.

Honeywell began manufacturing two operational flight trainers in 1989 and will eventually provide 22 flight trainers. The trainer uses a Gould/SEL 32/8750 computer and a Rediffusion Simulation Incorporated SP-X visual system that gives a wide field of view. The T-45 trainer will provide 11 percent more simulated flight time for navy pilots than did previous versions. The navy also plans to acquire 10 instrument flight trainers. In September 1990, McDonnell Douglas received an additional $33 million to modify the overall simulation system.

©1991 Dataquest Incorporated January—Reproduction Prohibited

F-15E Simulator

In September 1988, the F-15E simulator became the first trainer to be developed concurrently with a new aircraft. The simulator is especially important to F-15 training, because the air force plans to use only 12 percent of the F-15E fleet for training instead of the usual 25 percent.

The F-15E twin-seat simulator gives the pilot and weapon systems officer air-to-air and air-to-ground training in all avionics and sensor systems, including synthetic aperture radar, electro-optics and IR systems, for realistic instruction in navigation, communications, weapons delivery, and electronic warfare. The simulator uses five mainframe computers that process over 600,000 lines of software code concurrently, as well as generate sensor data and imagery for the head-up display and seven other multifunction displays. The system can simulate moving airborne or ground targets, weapons launch, engine noise, and aircraft motion.

Loral, the prime contractor, originally hoped to construct six systems. Three have already been delivered, and a $55 million contract for the fourth was awarded in December 1989. The fifth and sixth F-15E simulators have not been authorized yet, however, and are likely to fall victim to budgetary cutbacks. Subcontractor teams participating in the program include Evans and Southerland Computer Products, Interactive Machines-Gould Computer Systems, International Software Corporation, and Telco-Ingersoll Rand.

C-17 Airlifter Simulator

The C-17 transport aircraft Aircrew Training System is being developed by McDonnell Douglas. One of three companies that participated in the $15 million Phase I part of the program, McDonnell Douglas was given a $421 million contract in late 1988; Singer-Link and United Airlines Services also competed. Phase II will last until the year 2003. McDonnell Douglas let a subcontract worth $90 million to Flight Safety International at the end of 1988 for the flight crew training simulation equipment.

McDonnell Douglas purchased Night Hawk computers from Harris for the C-17 Aircrew Training System in 1989; a minimum of 40 Night Hawk 3000 supermicrocomputers will be provided to be used as weapon system trainers, flight trainers, and cockpit trainers. The award was the largest contract yet for hardware using the Ada language. Evans and Southerland was awarded $4 million in late 1990 to build the image-generating equipment for the simulator, called the ESIG-1000 imaging system.

C-5B Simulator

The air force uses virtual image takeoff and landing (VITAC) for the C-5B simulator system. The prime contractor is McDonnell Douglas Flight Safety Service Corp. In mid-1990, McDonnell Douglas received a $20 million contract for one weapon systems trainer to be delivered in September 1992.

S-3B Viking Antisubmarine Warfare (ASW) Simulator

Hughes Simulator Systems was granted a $10 million contract in late 1989 to integrate an S-3B trainer with their new NOVOVIEW SP-X 500 HT visual system using Evans and Southerland's computer-image generation. A Rediffusion WIDE II display system will also be used in this system.

AV-8B Harrier Simulator (canceled)

McDonnell Douglas was given a contract in mid-1990 to provide an additional training system that will allow for night attack weapon systems training.

E-2C Hawkeye Simulator

Systems and Simulations Incorporated was awarded the prime contract to upgrade the E-2C Hawkeye surveillance simulators in a program that will continue through 1991. Hughes Simulator Systems is a key subcontractor, providing two SP1/T visual systems that make possible a textured day and night visual scene in a variety of weather environments to enhance the realism of the simulation.

A-12 Avenger Simulator

The potential training budget for the life of the A-12 program could run between $80 million and $100 million. In mid-1990, General Electric introduced a Compu-Scene VI system that it hopes to use in this program under a subcontract from McDonnell Douglas. McDonnell Douglas is favored to serve as the prime contractor for the overall simulator system.

©1991 Dataquest Incorporated January—Reproduction Prohibited

General Electric also developed the Compu-Scene V, a visual simulator for avionics training mission rehearsal and research, which uses photographic texture. Texture maps are used to store photographic detail, which is applied to 3-D terrain, moving models, and airfields and buildings. The Compu-Scene V is designed to boost texture map capacity to the point where entire visual databases can be built using terrain elevation and photographic source data.

V-22 Osprey Simulator

Although procurement of this aircraft remains at issue between Congress and the Pentagon, plans are proceeding, albeit slowly to develop a simulation system.

Prior to Secretary Cheney's cancellation of the program in 1989, General Electric was awarded an initial $7 million contract from Honeywell—the prime contractor—to provide an advanced Compu-Scene IV image generator for the operational flight trainer. The system will provide seven image-generator channels for high-resolution out-of-the window displays and an eighth channel for in-cockpit sensor displays. The initial system was to be delivered in the fall of 1991 but has since been stretched; seven others remain optional. Congress restored $165 million to continue program development.

MH-53E Sea Dragon Simulator

Honeywell is also the prime contractor for two operational flight trainers for the MH-53E Sea Dragon minesweeping helicopter. McDonnell Douglas, a subcontractor, delivered the first Vital VII Multiview visual system to the navy in February 1991. The eight-channel trainer will be integrated with the Honeywell flight trainer. The Vital VII Multiview incorporates full raster technology and will simulate runways, taxiways, lightning, hangars, ground support, and traffic hazards.

Special-Operations Aircrew Training System

Three teams competed for this system, which is designed to train aircrews of special operations aircraft such as the MC-130E and Combat Talon II transport helicopters, the AC-130H and AC-130U helicopter gunships, the H-130 tanker, the MH-53J Pave Low helicopter, and the MH-60 Pave Hawk helicopter. The Aircrew Training System will provide ground-based training and real-time mission rehearsal capability.

Loral won the competition in mid-1990 with a proposal worth $72 million, beating teams led by General Electric and Logicon. Loral's subcontractors include Evans and Southerland, General Dynamics, IBM Federal Systems, Lockheed, UNC Support Services, Applied Sciences Associated, FAAC Inc., and Perceptronics.

Synthetic Flight Training Systems

This program represents an attempt to integrate and upgrade existing simulators. The program will cover UH-1, MH/CH-47, AH-1, MH/UH-60, and AH-64 helicopters. The older UH-1 simulator is an instrument flight and emergency-procedures trainer only. The remaining simulators are more complex, with cockpit window visualization for tactical, nap-of-the-earth mission training. The total program calls for 22 UH-1, 1 MH-47, 6 CH-47, 1 MH-60, 16 UH-60, 9 AH-1, and 12 AH-64 combat mission simulators.

CAE-Link, the prime contractor for the overall program, was awarded a contract in 1989 to begin upgrading the UH-60 Black Hawk simulators. The $7 million contract block upgrade for 18 Black Hawks includes out-the-window display improvements and night-vision goggle lighting. The visual system upgrades for the Army Tactical Digital Image Generation includes blowing sand, water, and dust created by rotor wash and capabilities for landing aboard assault carriers and frigates, as well as enabling air targets to "fire upon" simulated Black Hawks.

The AH-64 Apache Simulator

This program has also been awarded to CAE-Link in a 22-month $16 million effort to upgrade seven simulators. About 30 engineering changes and 24 software enhancements will be made. Other Apache upgrades included a $10 million contract for Honeywell and General Electric to develop a visual system for the AH-64.

Finally, Concurrent Computer Company was awarded a $1.1 million contract in October 1990 from Binghampton Simulator Company for six Concurrent 8400 RISC systems to replace the DEC systems in the CH-47 simulators.

Light Helicopter Simulator

The LH program will also make extensive use of simulators. The Army Crew Station R&D Facility for simulation opened in November 1988. This joint effort by Army Aviation Systems Command and NASA Ames Research Center will focus especially on simulation techniques for the LH. It will be a full-mission simulator with a two-position tandem cockpit and will use a fiber-optic helmet-mounted display by CAE-Link.

In May 1989, CAE-Link was selected by the Boeing-Sikorsky LH team to provide operator training systems. As part of the 23-month demonstration/validation contract begun in November 1988, Link will provide flight simulators, part-task trainers, and other equipment to train LHX pilots. Link will also provide risk-reduction efforts for Boeing-Sikorsky that focus on embedded training, visionics, and life-cycle support.

The McDonnell Douglas/Bell LH team chose Grumman, Loral, and McDonnell Aircraft Training Systems to develop aircrew training devices and AAI, ECC, and Hughes to prepare the maintenance and support package.

Avionics and Electronic System Simulators

The armed services are also making extensive use of simulators to train personnel on the use of complex electronic systems.

Emitter Simulator System

This is the navy's largest simulator development program, for which Ford Aerospace was awarded a $215 million contract in 1989. The system will make possible the training of ship and aircraft crews against multiple electronic threats by integrating threat simulators that duplicate radar signals generated by both defensive and offensive weapon systems.

P-3C Update IV Simulator

In mid-1990, CAE-Link's Simulation Division was awarded a $43 million contract for the Update IV simulation program. With cancellation of the P-7A follow-on antisubmarine aircraft, CAE-Link's Update IV simulator is likely to become more important. CAE-Link's initial contract calls for an Integrated Avionics Trainer by 1993 and a Weapon Systems Trainer in 1994.

BSY-2 Processor Simulator

The electronic heart of the SSN-21 submarine, the BSY-2 combat information system, is being produced by General Electric. In March 1990, General Electric also received $114 million to provide the maintenance trainer that will integrate communications, sensors, and sonar subsystems for the system.

ASW Tactical Team Trainer System

Hughes is the prime contractor for this $27 million program, which will include consoles, student mock stations, a tactical command center, carrier ASW modules, and an Aegis combat information system, all housed in a two-story building. The contract contains an option for a second trainer; Hughes will deliver the Device 20A66 after 1993.

CAE-Link also received a $15 million contract in 1989 for two surface ASW team training systems, scheduled for delivery in 1991 and 1992. This system provides tactical and procedural training for ASW teams from up to 16 different classes of ships and their supporting aircraft. The new systems carry the designation Device 14A12 and will use microprocessors distributed on a local area network (LAN). The simulators will replicate generic combat information centers and sonar consoles.

Simulator Networking

New horizons in training are being opened by linking together a number of simulators, allowing trainees to fight with and against other humans. This ability is especially valuable for command and staff level tactical training. The most ambitious program of this kind is SIMNET, sponsored by DARPA since 1982. The prime contractors are Perceptronics, which builds the simulators, and BBN, which develops the communications networks and provides the computer systems. SIMNET reached a milestone in 1989 when developers demonstrated a new technique called semiautomated forces that mixes in tanks and aircraft that are not connected to individual simulators. This new technique enables the program to expand the battle to large-scale size. The network contains simulations of M1 tanks, Bradley fighting vehicles, a platoon of antiaircraft missiles, scout-attack helicopters, close air support helicopters, and related support elements.

The advances demonstrated by SIMNET have spawned a number of other combined arms simulation programs. Two of the more popular programs are the army's Combined Arms Tactical Trainer (CATT) and the Close Combat Tactical Trainer (CCTT). The CCTT program is being accelerated: In 1990, Congress requested that the

©1991 Dataquest Incorporated January—Reproduction Prohibited

army speed both development and fielding of the system.

Other initiatives are under way to connect simulators. The navy is exploring simulator networks for training in antisubmarine warfare using both surface vessels and helicopters. Northrop Corporation has developed a manned flight simulator that allows up to nine pilots to fly simultaneously in a variety of scenarios. The laboratory has three cockpits with projection domes and seven simplified cockpits that resemble video games. The pilots can simulate different types of aircraft and operations such as providing air cover for ground attack aircraft. The laboratory is being used to develop both the A-12 and the B-2 bomber. It is also used to develop cockpit automation technology by the Air Force Human Systems Division.

Despite the increasing number of simulator networks, an industry standard does not yet exist. The absence of standardized protocols currently is a stumbling block; SIMNET's protocols could become the standard but that now appears to be left to the new office on simulation policy previously mentioned. Standardization requires hardware connectivity and shared-symbol sets. In the interim, Singer is developing a black box to connect a number of different simulator types.

Basic Research

U.S. defense agencies spent approximately $65 million in fiscal 1990 on threat simulation development alone. For example, Sanders Associates has delivered its Spartan I software for ASW missions. The program replicates the actions of hostile submarines for ASW training based on interviews with a U.S. expert on Soviet submarine tactics. But research trends in simulation and training generally reflect trends in computer technology (e.g., miniaturization of components, improved software, diminishing complexity for faster results, and use of optoelectronics and AI).

Because software is central to simulation, its development has the potential for improving simulator performance even more than do increases in hardware capacity. Grumman Data Systems is exploring a new approach to compressing images of natural scenery on simulators. Rather than depicting every tree leaf or blade of grass, Grumman is representing objects with simple quadratic shapes such as spheres and cones. This method is 10 times faster than previous simulation techniques and reduces storage capacity by a similar amount.

Considerable advances have been made in more realistic visual imagery and true real-time simulations. For example, Gould Computer Systems' Concept 32/2000, introduced in 1988 and targeted specifically for simulation applications, may provide the fastest real-time processing yet. With a single-board central processing unit (CPU), the 32/2000 provides the computer power of 15 VAX 11/780s.

Future research in defense simulations is likely to focus on how to make simulators more affordable, effective, and interoperable. As computer-based image generators become less expensive, the display portion of the system will become relatively more expensive. Research in HDTV and other advanced displays may contribute to greater cost effectiveness, but efforts will probably focus on reducing the number of picture elements (pixels). Two programs that seek to narrow the area of interest in displays, allowing for rougher (and less costly) images at the periphery, are CAE-Link's Esprit and fiber-optic helmet-mounted display. The Esprit incorporates both a high- and low-resolution projector, applying the high-resolution system only in those areas on which the pilot focuses. The fiber-optic helmet-mounted display, which has been ordered for the army research simulator, uses fiber-optic links to carry imagery from high-resolution off-helmet projectors.

Missile Systems

Overview

Advances in missile technology are taking two distinct directions. The first is a trend toward smart missiles, which allow users to fire and forget. This capability reduces exposed time to hostile fire and, as is the case for fighter pilots, often allows for multiple hostile engagements. The trend toward these smart missiles will continue to bolster the electronics market. Advanced systems will not only contain sophisticated acquisition sensors but often will be equipped with minicomputers or superminicomputers capable of rapidly processing sensor information to guide the missile to its target.

The second trend in missile development is toward standoff systems. These systems are capable of operating autonomously at extended ranges often out of visual sight and include sophisticated cruise missiles and air defense systems. A Standoff Weapons Master Plan was submitted by the defense services in April 1988 to the Office of the Secretary of Defense. This plan included the Modular Standoff Weapon (MSOW); the Advanced

©1991 Dataquest Incorporated January—Reproduction Prohibited

Interdiction Weapons System (AIWS); the Standoff Land Attack Missile (SLAM); and the AGM-130, a rocket-powered glide bomb.

As the capabilities and electronic content of missiles increases, so does their unit cost. It is not unusual for a single missile to cost well in excess of half a million dollars. With such a large expenditure at stake, reliability and accuracy are crucial, forcing an even greater reliance on electronics.

Congress appropriated nearly $6 billion for electronics in fiscal 1991.

System Development and Procurement

Table 3.3 breaks down both the number of and amount authorized for major missile systems in fiscal 1991.

Tactical Missile Programs

Forward Area Air Defense System (FAADS)

The cancellation of the army's DIVAD program in the mid-1980s led the army to reassess its forward air-defense needs. The result of this reevaluation was FAADS. FAADS is designed to integrate complementary missile systems to provide forwardly deployed troops with total air coverage.

The program consists of five mission components: Line-of-Sight Forward (ADATS); Line-of-Sight Rear (Avenger); Non-Line of Sight (FOG-M); FAAD C3; and Combined Arms Initiative (CAI). The final two elements of the FAADS system are covered in this chapter under "Command, Control, Communications, and Intelligence."

Table 3.3

Missile Procurement for Fiscal 1991
(Millions of Dollars)

	Requested		Authorized	
System	Number of Units	Millions of Dollars	Number of Units	Millions of Dollars
AAWS-H	220	236	0	0
AAWS-M	0	16	0	16
ACM	100	366	100	366
ADATS	0	36	0	0
AGM-130	63	38	63	38
AMRAAM	1,800	1,315	900	815
ATACMS	318	169	318	169
Avenger	88	97	88	97
Chapparal	0	0	0	0
D-5	52	1,344	52	1,344
Harm	1,440	369	1,440	369
Harpoon	215	241	215	241
Hawk	0	0	0	0
Hellfire	4,200	165	4,200	148
MLRS	24,000	314	36,000	384
MX	12	674	12	674
Patriot	817	883	817	791
RAM	405	70	405	70
Standard	900	608	900	608
Stinger	6,922	252	6,922	252
Tomahawk	600	809	400	659
Tow	13,284	219	13,284	179

Source: Department of Defense

©1991 Dataquest Incorporated January—Reproduction Prohibited

Air Defense Antitank System (ADATS)

The (ADATS) is the line-of-sight forward component of the FAADS. The system is designed to shoot down assault helicopters that threaten front-line troops. In early 1989, Martin-Marietta delivered the first preproduction ADATS mobile air defense units for live-fire and vulnerability tests in New Mexico. Allied-Signal manufactures the laser encoders. About 562 ADATS units and 10,078 missiles are expected to be procured at a cost of $12 billion.

The program, however, has had repeated setbacks concerning its reliability and inability to complete its mission. This problem has caused a one- to three-year delay in the program, with production not expected until late 1995.

The administration requested $502 million for the program for fiscal 1991, but Congress cut that figure to $378 million. Moreover, the ADATS program schedule has been delayed by about six months because of a 30 percent reduction in the budget from 1990 to 1994.

Avenger

The Avenger system makes up the Line-of-Sight Rear component of FAADS. Produced by Boeing, this pedestal-mounted Stinger system provides a shoot-on-the-move capability. The first Avenger was delivered in fiscal 1989. The army plans a total procurement of 1,207 fire units, but Boeing hopes to produce up to 1,600 fire units to allow for exports. In October 1990, an award of 52 units was granted to Boeing for $14.4 million. The total program cost is expected to reach $1.3 billion.

The most recent Stinger version features a reprogrammable microprocessor with an IR seeker capable of rosette-pattern scanning as well as scanning on both IR and UV channels. It also provides improved countermeasure protection. Other contractors for the Avenger system include CAI for the optical sights, Magnavox for the FLIR, and Texas Instruments for the laser rangefinder.

Fiber-Optic Guided Missile (FOG-M)

The FOG-M is one of three missiles incorporated in the army's Advanced Antitank Weapon System-Heavy (AAWS-H) program and represents the non-line-of-sight portion of the FAADS.

The FOG-M is an antiarmor, antihelicopter missile and guidance system that uses fiber-optic technology to view a battlefield and attack targets from a range of roughly 10 kilometers. The Boeing Company and Hughes Aircraft Company team was selected by the army in late 1988 as codevelopers of the FOG-M.

Contracts awarded to Boeing and Hughes are estimated to surpass $230 million in fiscal year 1991. Boeing will function as the systems integrator; Hughes will produce the TV and imaging IR seekers for the system. Martin-Marietta was awarded a $2 million contract in mid-1989 to provide three imaging IR sensors, which will use a staring platinum silicide-based detector in an IR focal plane array.

The initial contract calls for a 43-month FSD phase, with deliveries of 40 missiles and 8 fire units scheduled for early 1991. Boeing and Hughes will compete for production for a total of 403 fire units; if the army exercises its option to buy 16,000 missiles, the overall program cost could exceed $2 billion.

Stinger

General Dynamics is the prime contractor for the Stinger surface-to-air shoulder-fired missile. Raytheon was named a second source for production in 1987, and a $54 million contract option was awarded to Raytheon in 1989 for 1,500 missiles. Missile production is likely to be divided between the two companies indefinitely.

The Stinger will remain the primary anti-air defense system at the division level until FAADS is deployed. The introduction of the newest version, the RMP Stinger (named for its reprogrammable microprocessor) began in fiscal 1990. For this version, annual buys will consist of head-to-head competitive splits between the prime contractor and the second source.

The army requested $522 million in 1991 procurement funds to acquire 6,922 missiles. Congress approved $252 million.

Standard

The Standard missile, currently in a product improvement program, is a family of supersonic, medium- and extended-range surface-to-air missiles. A two-model weapon that can be used against missiles, aircraft, and ships, it first entered the fleet more than 10 years ago. It replaced the Terrier and Tartar and now is part of the weapons suite of more than 100 U.S. Navy surface ships.

©1991 Dataquest Incorporated January—Reproduction Prohibited

The two principal models are the MR and ER series. The MR series are medium-range defense weapons; the ER missiles are extended-range area defense weapons. Prime contractors for the MR missiles include Aerojet, General Dynamics, Morton-Thiokol, Motorola, and Raytheon. Prime contractors for the ER series include Atlantic Research, General Dynamics, Morton-Thiokol, Motorola, and Raytheon.

The navy requested 900 Standard missiles in fiscal 1991 at a cost of $608 million, which Congress authorized. Raytheon currently is designing the Block IV generation of missiles—the Aegis Extended Range Standard Missile-2. Full-scale production of the Block IV version is planned for the early 1990s. General Dynamics, the prime contractor, will act as codeveloper of the Block-IV guidance and control system. The new missile will be deployed on Aegis cruisers equipped with the Mk 41 vertical launch system and on *Arleigh Burke* destroyers.

Rolling Airframe Missile (RAM)

Fiscal 1990 marked the first full-rate production year for the Rolling Airframe Missile (RAM). The navy requested a total of $70 million in its fiscal 1991 budget; this amount includes funds for procuring 405 missiles.

The RAM is a type of surface-to-air missile for defense against low-flying antiship missiles. General Dynamics is the prime contractor, with Hughes in charge of target acquisition and systems integration. The United States signed a memorandum of understanding with the German government in 1987 to establish a second source in the Federal Republic. The joint company, called RAM Systems GmbH, includes AEG, Bodenseewerk, Diehl, and MBB. RAM Systems GmbH competes with General Dynamics for up to 70 percent of the U.S. and German navies' procurement contracts. The U.S. Navy expects a requirement for as many as 4,900 RAMs, whereas Germany expects to procure about 1,900 RAMs. Denmark and several other countries have expressed interest in the program.

Both General Dynamics and RAM Systems GmbH are working independently on imaging IR seekers to give the RAM dual radio frequency and IR capability.

Patriot

The Patriot missile is the most advanced long-range surface-to-air missile in the current inventory. The system operates with a fast reaction capability, high fire power, and ability to function in severe electronic countermeasure environments. The combat element of the system is the fire unit, which consists of a radar set, an engagement control station, a power plant, antenna, and eight remotely located launchers. The system is highly automated and combines high-speed digital processing with various software routines to effectively control the air space over the theater of operations. The radar uses phased-array technology to provide surveillance, target detection and track, and support missile guidance.

The Patriot system is in its 11th year of production and was initially deployed in Europe in 1985. Raytheon, the Patriot primary contractor, received more than $410 million in June 1990 from the government of Italy. Subcontractors include Hazeltine, which designed the IFF integrator, and Martin-Marietta, which designed the missile airframe and launcher. The army requested funds in fiscal 1991 to procure 817 Patriot missiles at $883 million. Congress approved 817 missiles but reduced spending to $791 million.

The program is likely to undergo a number of upgrades, including the integration of VHSIC sets. In addition to U.S. sales, Japan, Germany, the Netherlands, and Italy have also ordered Patriot systems.

Hawk

The Hawk is a medium-range air defense guided missile system designed to provide air-defense protection against low- and medium-altitude air attacks. The mobile system was first fielded in 1960 and is currently employed by 20 foreign nations. The latest upgrade is the Product Improvement Program Phase III (PIP III) version. Production is scheduled to continue through 1992. Phase II improvements include simultaneous engagements capability, new acquisition radars, and microcomputers. Raytheon is the prime contractor, with Aerojet manufacturing the missile motors. Other major contractors include General Electric, Northrop, and Westinghouse.

The army and the Marine Corps are cooperating in another Hawk improvement program. The Hawk Mobility Survivability and Enhancement Program (HMSE) will reduce the number of trucks in a Hawk platoon from 21 to 10, replace hard cabling with radio up-links, and introduce digital computing into the launcher.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Chaparral

Chaparral is the army's short-range air defense surface-to-air system and is effective against all types of aircraft at low altitudes. The self-propelled system is equipped with a forward-looking infrared subsystem that provides day/night all-weather capability with extended missile range. To enhance missile acquisition and IR countermeasure defense capability, the Rosette Scan Seeker (RSS) guidance section has been developed by Ford Aerospace and Hughes. The two companies bid annually for this award.

The system was initially fielded in 1969, but upgrades will keep the Chaparral in the army's inventory well into the next century.

Advanced Air-to-Air Missile (AAAM)

The AAAM is designed to provide fleet air defense against antiship missile-launching aircraft and jamming aircraft at ranges of nearly 150 miles. The AAAM will replace the Phoenix but is a smaller, Sparrow-sized missile.

Initial demonstration/validation contracts were awarded by the navy in late 1988 to the teams of General Dynamics/Westinghouse and Hughes Aircraft/Raytheon, which formed a company called H&R Co. for this project. Worth more than $42 million, the contracts cover a four-year period. The navy requested $73 million in R&D funds in fiscal year 1990 and $87 million in fiscal 1991. Congress authorized both of these levels.

The Hughes/Raytheon team is developing a rocket ramjet missile with an active radar guidance system and semiactive guidance at midcourse flight. The General Dynamics/Westinghouse team has proposed a tube-fired rocket with semiactive guidance throughout the flight. General Dynamics claims that the lack of an active seeker will save the navy about $100,000 per missile. Full-scale engineering development is planned to begin in October 1991, with FSD scheduled for 1997.

In November 1990, H&R Co. was awarded an additional $23 million to continue demonstration and validation, and the General Dynamics/Westinghouse team received $21 million. Both of these contracts, to be completed by January 1993, call for basic design of a baseline system, free-flight prototype testing vehicles, hardware-in-the-loop testing of guidance subsystems, and comparative guidance testing.

Advanced Antitank Weapon System—Heavy (AAWS-H)

The AAWS-H will be a crew-served TOW replacement weapon to provide both light and heavy forces with the capability to defeat advanced armored enemies.

The family of weapons associated with this program includes the Advanced Missile System-Heavy (AMS-H) and the Line of Sight Antitank Weapon (LOSAT), by LTV, which will use a Kinetic Energy Missile (KEM). In March 1989, the AMS-H began a technical demonstration of an imaging IR seeker produced by Texas Instruments; it is capable of doubling the missile's range while increasing accuracy. The KEM system technology is being infused into the Tow T-SIP program, which is scheduled for development later in 1991.

Advanced Antitank Weapon System—Medium (AAWS-M)

The AAWS-M currently is in FSD. This one-man portable fire-and-forget weapon will be employed by the infantry as the primary platoon-level system to defeat advanced armor. The system is designed to replace the Dragon missile while addressing its deficiencies.

The AAWS-M will feature increased range and lethality, reduced gunner vulnerability, and shorter flight time. In addition, the system will use a long-wave IR focal plane array, giving the system all-weather day/night capability.

After a 27-month technology demonstration phase, the army selected the team of Martin-Marietta and Texas Instruments in February 1989 for FSD. FSD will conclude in 1992 with a field deployment date set for 1994, although Congress has expressed interest in speeding delivery. The fiscal 1991 administration request was for $16 million, which Congress authorized in full.

The army wants over 70,000 systems, with an additional 100,000 for possible overseas sales. If production expectations are achieved, the total program value is estimated to be $5 billion.

Dragon II

The army decided to field the Dragon II, the result of the first phase of the Dragon Product Improvement Program, as its primary shoulder-fired antitank missile until the AAWS-M system is deployed in 1994.

The system has a range of 1,000 meters and provides man-portable, antiarmor capability at the platoon level. Using a wire-guided system, the gunner "walks the missile" into the target by keeping the target in the soldier's gun sights.

The army awarded a $101 million contract to McDonnell Douglas in 1989 for 19,000 missiles. The follow-on Dragon II, developed as part of the second stage of the Product Improvement Program, will feature a new warhead claimed to have 98 percent more penetration than the Dragon I and improved velocity and range. This has become very controversial because the Dragon tested very poorly compared with two foreign missiles, the Bofors Bill and the Milan II. In addition, it is unlikely that additional R&D funds will be spent on this system in light of advancements in the AAWS-M program.

AT-4

The AT-4 is the army's new lightweight multipurpose weapon, better known as a bazooka. The AT-4 is shoulder fired by a single soldier and used against light armor and material targets. The system incorporates a disposable launcher and has an accuracy range of over 300 meters.

Alliant, formerly part of Honeywell, is fielding the system in cooperation with the original producer, FVV of Sweden. First delivery of the system took place in 1989, with continued production expected through at least the mid-1990s.

The army requested $17 million for the continued procurement of the program, which was authorized by Congress.

Hellfire

The Hellfire missile was developed originally as an antitank weapon system for use on helicopters and is currently deployed on the AH-64 Apache attack helicopter. In addition to production of the heliborne version, the army has been testing a ground-based Hellfire that is mounted on a pedestal on a U.S. Army truck in much the same way as the pedestal-mounted Stinger antiaircraft missile. Although the original version of the Hellfire uses laser seekers for guidance, combined IR/RF and imaging IR seekers are being developed.

In March 1990, Rockwell was chosen over Martin-Marietta to receive a sole-source contract to produce Hellfire. Martin-Marietta, however, did garner $42 million for FSD of an improved laser-guidance system to develop a more powerful warhead and develop a new IR seeker. This program is known as the Optimized Hellfire and will eventually be fielded with a seeker resistant to electro-jamming. The production run for the Optimized Hellfire may be as high as 22,390 missiles.

The navy requested a total of $42 million in Hellfire spending for fiscal 1991 for 1,198 missiles, which Congress approved. The army requested authorization of 3,002 Laser Hellfires for $123 million. Congress authorized the full navy request and granted the army $106 million for 3,002 missiles.

TOW Missile

The tube-launched, optically tracked, wire-guided (TOW)-2 missile is the most powerful antitank weapon used by the infantry. It is found at the battalion level in ground units and also is mounted on the Bradley fighting vehicle, the Improved TOW vehicle, the High-Mobility Multipurpose Wheeled Vehicle (HMMWV), and the AH-1S Cobra helicopter.

When the missile is fired, a sensor in the launcher tracks a beacon in the tail of the missile, which allows the gunner to walk the missile into the target by maintaining the objective in the launcher's cross hairs.

The basic TOW has been with the U.S. Army since 1970. The TOW-2 configuration became operational in 1983, followed by the TOW 2A program, developed to overcome advanced Soviet reactive armor and fielded in 1987. No less than three improvement programs are currently under way, including the TOW Sight Improvement Program (TSIP) that will significantly enhance TOW capabilities and effectiveness through the 1990s.

Hughes Aircraft is the prime contractor. Texas Instruments is the major contractor for TOW-2 retrofit kits, which include a digital missile guidance set and the AN/TAS-4A night sight. Emerson Electric is the prime supplier of the missile guidance set, the launcher, and the optical sight.

Procurement of 13,284 missiles at $219 million was requested in fiscal 1991 by the army and Marine Corps. Although a replacement for the TOW-2 is being explored as part of the AAWS-H program, the army will continue to upgrade the TOW-2. One example is the test-firing of an experimental TOW-2 with mm-wave RF data link by Hughes under a $3 million contract awarded in 1986. The army currently is attempting to improve speed and range with the RF data link.

AGM-130

The AGM-130 Low-Cost Advanced Technology Missile (LOCATM) is under development to replace the Maverick air-to-ground missile. Projected to weigh 300 pounds, the missile is expected to have a range exceeding 25 miles. The system basically is a rocket version of the GBU-15 glide bomb.

In September 1990, Rockwell received a $2.6 million award to certify the system aboard F-15E aircraft. Previous awards have resulted in certification on the F-111 and F-4.

The air force has expressed an interest in acquiring 960 TV-guided systems and 3,088 IR-guided missiles. The administration requested $38 million to procure 63 systems, and Congress authorized that level.

SRAM-T

The Short-Range Attack Missile—Tactical (SRAM-T) is an advanced next-generation nonnuclear cousin of the SRAM II strategic missile.

In 1990, Boeing was awarded $10 million to begin FSD and McDonnell Douglas received a $27 million contract to begin integration studies for the F-15E fighter.

The current air force plan is to procure 565 SRAM-Ts to place on F-15s, F-16s, and F-111 aircraft. The program is expected to have a 20-year life. Significant subcontractors include Hercules, Hamilton Standard, and Litton.

The air force requested $119 million in fiscal 1991 funding for the program. Congress authorized $35 million.

Maverick

The Maverick is an air-to-surface missile program used by both the air force and the navy. Its primary mission is as a day/night all-weather sea and land interdiction missile against small ships and fixed land targets.

The prime contractor is Hughes, with Raytheon serving as the second source. Buys of this missile have been large; in 1989, approximately 3,300 missiles were procured for $340 million. In 1990, the buy was 2,900 missiles for $240 million. The services requested nearly 2,020 missiles for fiscal 1991, but Secretary Cheney canceled the program two years ahead of schedule. The complete final buy of 3,132 missiles (2,730 for the United States and the rest divided among New Zealand, Germany, Denmark, and Spain) was awarded to Hughes in March 1990. The fiscal 1991 appropriation stands at $14 million to close out the lines.

The first version of the Maverick, introduced in 1972, had an optical guidance system and was followed by the D version, which began delivery in 1983. This version contains the IR guidance. Honeywell Electro-Optics is the contractor for the imaging IR seeker.

Other significant subcontractors include Aerojet and Morton Thiokol for the rocket engine, Allied-Bendix and Raymond Engineering for the missile fuse, and Chamberlain Manufacturing for the warhead. Additional foreign sales may keep production going for some time.

High-Speed Anti-Radiation Missile (HARM)

The AGM-88 HARM is designed to defend aircraft against surface-to-air missiles while they are performing strike missions. The system travels at a speed of +Mach 2 and explodes close to the target, projecting 2,500 fragments.

Texas Instruments is the prime contractor for the HARM and recently produced its 10,000th missile. The team of Ford Aerospace and Communications Corporation was expected to qualify as a second source in 1989, but with the reduced buys, Congress prefers that the missile continue to be single-sourced.

Subcontractors for the missile include Morton Thiokol for the smokeless motors and Ford, which recently received a contract to develop 100 low-cost seekers for the current Block 4 missiles.

The U.S. military requested the purchase of 1,430 HARMs in fiscal 1991 for $369 million. Congress authorized that amount. In addition, Spain requested procurement of an unspecified quantity in 1990 and Germany requested 400 HARMs for the Tornado.

Texas Instruments was awarded the C-1 guidance head using the Loral/Ford C-2 seeker. Production of these seekers is expected to continue through 1997.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Advanced Medium-Range Air-to-Air Missile (AMRAAM)

The AMRAAM (designated the AIM-120) will replace the AIM-7 Sparrow as the principal medium-range radar-guided air-to-air missile in the U.S. inventory and has been selected as a standard NATO weapon. In the U.S. inventory, the missile will begin service on F-14, F-15, and F-16 aircraft.

Unlike the Sparrow, AMRAAM has launch-and-leave capability by virtue of its built-in radar, as well as greater speed (Mach 4) and increased reliability.

Because of reliability difficulties, the program was halted by the air force in February 1990. The air force is now convinced that the reliability problems have been adequately addressed by prime contractors General Motors and Hughes and second-source Raytheon, and the program has resumed.

The air force originally planned to purchase 24,000 missiles with a peak monthly production rate of 3,000. With the scaling back of aircraft purchases, however, the air force revised its requirement and now seeks to procure 15,500 AMRAAMs with a peak production rate of 1,800 per month. Lot 5 production is expected to be awarded in April 1991 for 900 missiles, which are scheduled for delivery between April 1993 and April 1994.

General Motors-Hughes Aircraft subcontractors include Chamberlain Manufacturing Co. for the warhead, Hercules for the rocket motor, M/A-COM for the microwave components, Watkins-Johnson for radio frequency processors and data link receivers, Northrop for the inertial navigation unit, and United Telecontrol Electronics for the rail launchers.

The navy requested procurement of 550 missiles at a cost of $422 million in fiscal 1991. The air force and Marine Corps requested the remaining 1,250 missiles for a total of $893 million. Congress authorized a total of $814 million for 900 missiles.

Although production just began, an improvement program for the AMRAAM has already been announced. Both Hughes and Raytheon are working on the AMRAAM Producibility Enhancement Program, which includes 26 engineering upgrades to components in the missile. Hughes will design 10 of the upgrades, including a better transmitter, a frequency reference unit, a fuse antenna, an inertial reference unit, and an RF processor. Raytheon is working on 11 others, including upgrades to the fuse, the remote terminal, the RF processor, the data link processor, the inertial reference unit, and the gyro. Hughes and Raytheon will collaborate on the remaining five upgrades, which are improvements to the mission computer, the computer input/output (I/O) device, the range correlator, the filter processor, and the intermediate frequency receiver.

AMRAAM is likely to be the single-largest tactical missile production program in the 1990s. Eventual purchases by European allies (e.g., Denmark and Norway, both of which have expressed interest) and other friendly nations will add significantly to production runs. With modifications, the program is likely to continue well into the next century; its predecessor, Sparrow, has been in production for more than 30 years.

Phoenix

The Phoenix (AIM-54) was introduced to the navy F-14 fighter in 1974. The missile is a supersonic, all-weather air-to-air missile with semiactive midcourse and active terminal guidance, which provides the F-14 with the capability to intercept hostile aircraft at great distances. It has been produced by Hughes and Raytheon since 1974.

The navy had been buying these missiles in lots of 400 or more for the past several years, spending between $300 and $400 million per annum. The 1990 buy was for 420 and was to be the last with the navy canceling the program.

Congress, however, demonstrated concern that halting production would leave too large a gap between this system and its designated follow-on, the AAAM. Congress authorized $64 million to slow production of the 420 missiles approved in 1990 so that 180 improved AIM-54C Phoenix missiles can be procured in 1991. Future buys are unlikely, although upgrades to the program clearly receive support from Capitol Hill.

Sidewinder

The AIM-9 Sidewinder air-to-air missile is a short-range dogfight missile used by dozens of modern air and naval forces. The Sidewinder program is one of the oldest, least expensive, and most successful in the U.S. inventory. The latest version is the AIM-9M, which was introduced in 1982. The 9M version incorporates

©1991 Dataquest Incorporated January—Reproduction Prohibited

enhanced infrared countermeasure capabilities. Raytheon, the prime contractor, received a contract in September 1990 to provide 710 missiles at a cost of $18 million.

The air force has fulfilled its requirement of AIM-9Ms and will take delivery of those already on contract through 1992. Congress authorized funds for the air force to begin investigating the use of an upgraded version of the Sidewinder, the AIM-9R, in lieu of the European Advanced Short-Range Antiaircraft Missile (ASRAAM).

Army's Tactical Missile System (ATACMS)

The ATACMS is an anti-armor weapon with deep-strike capability. The ATACMS will be used against enemy second-echelon forces, air defense, command and control sites, and tactical ballistic missiles.

LTV Corporation was awarded several contracts in 1990, totaling almost of $500 million, to proceed with FSD.

ATACMS will be launched from the Multiple Launch Rocket System (MLRS). A terminally guided warhead that will use mm-wave seekers is currently in development for the MLRS, and this technology could be applied to the ATACMS. An international joint venture consisting of Martin-Marietta, Diehl GmbH (Germany), Thomson-CSF (France), and Thorn-EMI (United Kingdom) completed field tests of components for the terminally guided warhead in late 1988.

The army requested $87 million in fiscal 1991 to procure 318 systems. Congress authorized the full amount.

MLRS

The MLRS is a free-flight area-fire artillery rocket system. Its missions are counterfire and suppression of enemy air defense. The system can fire 12 conventionally armed rockets without reloading. Initial operating capability was achieved in 1983. Beginning in fiscal 1989, the MLRS has been coproduced by the United States, the United Kingdom, Germany, France, and Italy. The second multiyear procurement contract runs through 1993.

LTV is the primary contractor. Major subcontractors for the MLRS include Atlantic Research for the rocket propulsion system, Unisys for the stabilized reference/positioning package, Norden for the fire control and payload interface modules, and Sperry-Vickers for the launcher-drive system.

The army requested $372 million in fiscal 1991 funding to procure 24,000 missiles. Congress increased authorization to 36,000 missiles at $443 million.

Harpoon

The Harpoon is a short-range antiship cruise missile that can be launched from ships, aircraft, and submarines. It was introduced into the U.S. fleet in 1977 and on the P-3 series aircraft in 1979. The Harpoon is battle-proven after successful engagements against Libya in the Gulf of Sidra in 1986.

The navy is in the process of developing a new IR Harpoon variant, the SLAM. The navy requested $241 million to procure 215 missiles in 1991 and was authorized that amount.

The prime contractor for the system is McDonnell Douglas. Other significant subcontractors include Honeywell for the radio altimeter; IBM for the missile mission computer; Lear Seigler for the strap-down, three-gyro navigation system; Texas Instruments for the active radar seeker; and Westinghouse for the on-board computer.

Harpoon has been sold to dozens of foreign nations. Additional foreign sales were announced in 1990, with McDonnell Douglas awarded close to $50 million for system delivery to Turkey, South Korea, Indonesia, and Australia.

Sea-Launched Cruise Missile

The sea-launched cruise missile, or Tomahawk, is a long-range cruise missile capable of carrying both nuclear and conventional payloads and can be deployed both on surface ships and submarines.

Both nuclear and conventional Tomahawks are fitted with the TERCOM terrain guidance system. Missiles fitted with conventional warheads and designated for land targets are also fitted with DSMAC guidance, which uses an optical lens system to zero in on targets.

The total Tomahawk buy was set at 4,030 for a number of years, but in 1990 the navy announced that it would end the program after the procurement of 3,630 systems. No more than 880 of these missiles will be nuclear-capable. Of the 2,800 conventional systems, only a few hundred are designed for antiship capability.

©1991 Dataquest Incorporated January—Reproduction Prohibited

The Tomahawk is dual sourced between General Dynamics and McDonnell Douglas. Each company is guaranteed an annual split of at least 30 percent.

The navy requested 600 missiles in fiscal 1991 at a cost of $809 million. Of the 600 requested, 75 would be nuclear-capable. Congress, in accordance with the lower overall requirement stated after the budget submission, authorized a total of 400 missiles for $659 million. Congress also stated its intention to continue to authorize 400 missiles annually until the final buy is complete at the end of fiscal 1992.

Long-Range Conventional Cruise Missile (LRCCM)

The LRCCM is the navy's next-generation ground-attack sea-launched system. The navy requested concept definition studies of the LRCCM after the Defense Acquisition Board designated it as the lead service in December 1988.

The concept-exploration phase is planned to last two years. The services will choose from Boeing, General Dynamics, Lockheed, Martin-Marietta, McDonnell Douglas, Northrop, Rockwell, and TRW. The DARPA will continue to work on propulsion, guidance, and manufacturing techniques for the LRCCM in a parallel effort to attempt to insert technologies prior to FSD.

Sense and Destroy Armor (SADARM)

SADARM is a low-cost sensing submunition that can detect and destroy lightly armored vehicles. The system will be fired from self-propelled artillery and is the first of the arm's new fire-and-forget smart weapons. Total program costs over the next 15 years were planned to exceed $6 billion for over 123,000 rounds, but this figure will probably slip.

The projectile, which entered FSD in mid-1988, can be launched from either a 155mm howitzer or the MLRS. After launch, the submunition is dispensed from its carrier over a designated area and detects appropriate targets using two types of sensors. One sensor operates in IR and the other in mm-wave. Upon detection of a target, SADARM fires a series of explosives that travel at extremely high velocity in order to assist target penetration.

In September 1986, a division of Honeywell that is now an independent company called Alliant Techsystems and Aerojet both were selected to pursue SADARM development. Although the program, has reached early testing milstones set by Congress, slippage has occurred and a production decision now is not expected until mid-1994. The army received nearly $300 million over the last two years and requested $105 million to continue development in fiscal 1991. The full amount was authorized by Congress.

Strategic Missile Programs

Advanced Cruise Missile (AIM-129) (ACM)

The ACM, a second-generation long-range air-to-ground missile, first entered advanced procurement in fiscal 1986. Although details are still classified, some sources estimate that the program's budget has reached about $7 billion. The ACM, the first cruise missile to employ stealth technology, is scheduled to be deployed on both B-52Gs and B-1Bs. The air force had requested a total of 1,461 missiles, but that number was lowered to 1,000.

General Dynamics is the prime contractor, but McDonnell Douglas was chosen as a second-source producer after considerable quality control problems were discovered at General Dynamics in late 1987. In 1990, because of the lower number of the missiles to be purchased, Congress expressed the desire that the program return to a single source.

Reliable sources indicate that the missiles have a range of about 3,000 miles and that launch platforms will include a mix of ACMs and existing air-launched cruise missiles (B versions).

The air force requested $473 million for the program in fiscal 1991 for the procurement of 100 missiles. Congress approved that entire funding level.

D-5

The Trident II D-5 is a three-stage solid-propellant inertially guided ballistic missile with a range of more than 4,000 nautical miles. The new *Ohio*-class submarines each can carry 24 Trident II missiles that can be launched while either on the surface or submerged.

The navy requested $1.5 billion for development and procurement of 52 D-5 missiles in fiscal 1991; Congress authorized the full request. Lockheed, the prime contractor for the D-5, continues to receive large awards, (e.g.,

©1991 Dataquest Incorporated January—Reproduction Prohibited

$345 million in October 1990) for long-lead items. Subcontractors for the system include Raytheon and General Electric, both of which produce guidance systems, and Rockwell, which produces and supports the inertial navigation subsystems. Westinghouse is involved in launcher-system hardware, and Atlantic Research continues developmental work on the post-boost control system. Production of the Trident is likely to continue into the mid-1990s.

Mobile MX

The initial fiscal year 1990 budget reflected the Reagan administration's effort to deploy 100 Peacekeeper missiles both in silos and on rail garrisons. New production was planned at 12 units per year.

The Bush administration subsequently proposed a plan to deploy 50 existing MXs on rails while developing a smaller, mobile intercontinental ballistic missile (ICBM) called Midgetman; the MX rail garrison cost has been estimated at about $5.6 billion, not including missiles.

Boeing and Martin-Marietta are major contractors for the rail-garrison MX. Other contractors include General Electric for Mark 21 reentry vehicles; Litton for guidance receivers; Rocketdyne for test missiles; Rockwell for inertial measurement units; and Honeywell, which makes the ring laser navigational gyroscopes.

The administration requested $1.8 billion to begin obtaining 12 MX missiles and train procurement for the rail-garrison mode of deployment.

Although procurement of 12 missiles at a cost of $574 million was approved, Congress balked at granting any funds for the rail-garrison deployment, noting that nearly 75 percent of the planned systems would be completed under current air force plans before completion of operational tests. It is unlikely, given the international situation and Congress' mood, that a rail-garrison deployment will be made in this decade.

Midgetman

Little life is left in the small ICBM (SICBM) program, which never was able to garner the political support necessary to survive. Secretary Cheney actually canceled the program in 1989 but was overruled by President Bush.

This year's Defense Authorization bill denied the $202 million requested by the Pentagon and instead authorized minimum funding for the program under an overall ICBM modernization program.

Congress emphatically stated that both the rail MX and Midgetman were unlikely to proceed any further than the basic R&D already approved because of the enormous costs involved and the ongoing START negotiations with the Soviet Union, which may prohibit the deployment of at least one of the systems.

Contractors for the Midgetman include Aerojet for the second-stage rocket, Rockwell for FSD of guidance and control systems, General Electric for adaptations of the Mk 21 reentry vehicle, Boeing, Hercules, Martin-Marietta, and Thiokol. A force of 300 Midgetmen is estimated to cost $17 billion.

Short-Range Attack Missile II (SRAM II)

The SRAM II is a supersonic low-radar cross-section nuclear-armed missile, which will upgrade existing armaments on long-range bombers deployed from the 1990s on. Boeing, the prime contractor, emphasizes the use of state-of-the-art technology such as VHSIC, composite materials, and ring-laser gyros to increase the missile's range and accuracy and reduce its radar observability. By the end of fiscal 1990, Boeing had received over $200 million in developmental contracts.

The program, however, has been plagued with technical difficulties, beginning with the Department of Energy providing a warhead that was too large for the missile. The air force stated in mid-1990 that it was giving Boeing until the end of 1990 to develop plans to correct two of the more serious program problems—cracking fuel propellent in the motor during cold weather and software delays for the guidance system.

Boeing has received additional contracts to integrate the system in to the B-1B bomber. Boeing's subcontractors include the following:

- Boeing Military Airplanes—B-1B integration
- Delco Electronics—Missile computer
- Hamilton Standard—Flight actuators
- Hercules-Bacchus—Rocket motor
- Litton—Guidance system
- Moog Missile Systems—Flight actuators
- Rockwell—Prelaunch computers
- Teledyne Ryan—Altitude sensors

©1991 Dataquest Incorporated January—Reproduction Prohibited

The air force plans to procure 1,633 SRAM II missiles at a cost of $2.3 billion if the technological difficulties can be solved.

The air force requested $191 million in development funds for fiscal year 1991 and was granted $177 million by Congress. Flight testing could be completed in fiscal year 1992, with a possible initial operating capability in 1994.

Military Space

Overview

U.S. government spending on space-related R&D and procurement is expected to reach $19 billion in fiscal 1991, rising to $21 billion in 1992 and $23 billion in 1993. Approximately one-fourth will be dedicated to military space systems and one-fourth to space-related military R&D. Of these amounts, most will be spent on communications and reconnaissance systems. This spending is largely a realization of the fact that close to 80 percent of all military communications will soon travel through space. Moreover, this emphasis represents a shift in priorities from the mid-1980s when the SDI was expected to garner the largest share of military space spending through the 1990s and beyond.

The need to launch spacecraft reliably will also play a more vital role than it does currently and require increased spending in upcoming years. The DOD intends to launch 145 unclassified satellites between 1991 and 2004. The NAVSTAR global positioning system is scheduled to account for 61 of the 145 launches; an additional 45 will be R&D satellites.

System Development and Procurement

Table 3.4 shows the fiscal 1991 quantity and funding for major military space satellites and launchers.

Major Military Space Systems

Fleet Satellite Communications System (FLTSATCOM)

These satellites are designed to provide multichannel UHF communications for the U.S. Navy. The navy currently uses a constellation of five FLTSATCOM satellites and three leased satellite spacecraft for worldwide ultrahigh-frequency communications. In the summer of 1988, the Defense Acquisition Board approved the construction by Hughes of one HS 601 advanced satellite for $120 million. The contract included an option to build an additional nine satellites, and in August 1989, the board decided to procure nine more satellites as part of a program to upgrade this UHF constellation. The total program will cost about $1.5 billion and will be completed in fiscal 1993. Each satellite is designed to function for five years, and the navy currently plans to procure an additional ten replacement satellites.

Table 3.4

Major Military Space Systems
(Millions of Dollars)

	FY90		FY91	
System	Quantity	Funding	Quantity	Funding
Fleet Satellite Communications	3	322	3	250
Defense Support Program Satellites	1	347	1	326
Defense Meteorological Satellite Program	1	107	1	138
MILSTAR	-	610	-	500
Defense Satellite Communications System	-	48	-	64
Medium Launch Vehicle	3	165	5	270
Space Boosters	3	220	2	209
Strategic Defense Initiative		3,800		2,900

Source: Department of Defense

Defense Support Program (DSP)

Third-generation satellites currently are being procured for the DSP, which provides early warning of missile launches from foreign nations and from ships or submarines at sea. The first DSP spacecraft were launched in 1971; the first of the current Block 14 upgraded spacecraft were launched in March 1989. These newer DSP satellites have greater survivability, sensitivity, higher power, and a longer lifetime than do their predecessors. Built by TRW, nine of these $180 million satellites are expected to be put in orbit in the next few years. Aerojet ElectroSystems developed and built the DSP's IR telescopes and sensor subsystems. Aerojet also was granted a $39.2 million contract in October 1990 for sensor integration and data analyses. IBM developed the software for the DSP, and Logicon recently won a subcontract from IBM for additional types of software.

Total cost of the program is estimated to be more than $2 billion. Congress awarded the full request of $70 million for DSP satellites in fiscal 1991 while awarding just $20 million of the $47 million requested for new ground link-up systems; the stations that were cut would have been placed in Germany.

An RFP was issued in October 1990 for a follow-on system to DSP to be known as the Advanced Warning System. This program is likely to replace the previously planned Boost Surveillance and Tracking System (BSTS).

Defense Meteorological Satellite Program (DMSP)

This system is designed to provide U.S. forces with necessary weather data. Funded at almost $200 million annually, the DMSP continually maintains two satellites in polar orbit to record visual and IR imagery for strategic and tactical missions. General Electric is the prime subcontractor for this program; it recently awarded Westinghouse a $6.8 million subcontract for support of prime sensors known as the Operational Linescan System (OLS).

Second-phase studies are currently being conducted for the program's Block VI satellites, which are scheduled for launch beginning in 1991 and to continue launching through 1993 or 1994. Potential upgrades include active sensing techniques, increased survivability and autonomy, satellite internetting for relaying data, and integration into the Air Force Satellite Control Network.

NAVSTAR Global Positioning Satellite (GPS)

This system is a defense-wide program, with the air force as the lead in the program. The NAVSTAR GPS program will provide aircraft, artillery, ships, tanks, and other weapon systems with accurate information on their position, velocity, and time. The prime contractors are General Dynamics and Rockwell. Although Block II NAVSTAR satellites, first launched in February 1989, were four years behind schedule, the outlook for the GPS program is good because the technology is established and is used on many types of military systems.

In mid-1990, General Dynamics received a $23 million contract for launch and logistics support on the Atlas vehicles used to place the satellites in polar orbit. A total of 13 satellites are now in orbit. A total of 21 satellites and 3 spares are planned for the program. Block II satellites differ from their predecessors in that they have greater size and weight and longer mission life; they are expected to orbit for about seven years.

In 1990, Harris received a $7.5 million contract for operation and maintenance of ground systems, and Rockwell received $26.0 million to integrate GPS with Delta rockets.

SCI Systems beat Rockwell Collins to become the main supplier of GPS receivers for aircraft and navy vessels in late 1990. The award calls for SCI to produce 6,046 receivers for $175 million, beginning with an award of $18 million for 599 systems to be delivered in 1991. In addition, Litton is leading a team made up of Rockwell and Boeing to produce miniature GPS receivers for the navy.

Additional principal electronics subcontractors for the NAVSTAR program include ARINC Research, Canchan Marconi Stanford Telecommunications, Datum, Frequency Electronics, General Dynamics Electronics, Hughes Aircraft, Interstate Electronics, ITT, Logicon, Magnavox, Texas Instruments, Trimble Navigation Limited, and Unisys.

Military Strategic/Tactical and Relay Satellite System (MILSTAR)

The fiscal 1991 defense budget will require the Pentagon to limit its expansive plans for MILSTAR, the DOD's plan for secure satellite communications into the 21st century. Nearly $6 billion has already been sunk into MILSTAR's development, but the plan to launch at

©1991 Dataquest Incorporated January—Reproduction Prohibited

least eight jam-resistant survivable satellites and numerous ground communications terminals is in serious jeopardy.

During congressional review of the budget in 1990, the Senate zeroed the program because of its excessive costs, while the House scaled the program back substantially. The conference bill emerged with MILSTAR still alive, but with only one-half of the administration's $1.2 billion request. In addition, Congress directed the DOD to consider adopting a less costly alternative and ordered that six, not eight, satellites be in orbit at any one time. Furthermore, Congress directed that all costs associated with the system be made public by 1992. Lockheed, which is constructing the first satellite, to be delivered in mid-1992, along with ground terminal contractors Magnavox, Raytheon, and Rockwell, stands to suffer the most.

As originally planned, the MILSTAR constellation of satellites would have provided extremely reliable, high-frequency communications for U.S. nuclear and other military forces under the most difficult circumstances. Most details of the program remain classified, but the air force had hoped to begin deployment using Titan IV/Centaur boosters in the mid-1990s. Total cost of the MILSTAR program, without alteration, would have reached between $35 billion and $40 billion.

MILSTAR would be the first defense communications satellite to use frequency hopping on the up-link to deter enemy listening and jamming, as well the first to use phased-array antennas. The satellites are designed to resist attacks against communications signals by radio jamming, lasers, antisatellite interceptors equipped with explosive charges, and electromagnetic pulses. TRW has responsibility for the communications payload under Lockheed, the prime contractor. Hughes Aircraft provides the superhigh-frequency down-link subsystem, TRW provides the extremely high-frequency up-link, and E-Systems is developing the UHF communications subsystem. Other subcontractors include ARINC, Booz-Allen, Hamilton, Computer Sciences Corp., Electromagnetic Sciences, Electrospace, Ford Aerospace, General Electric, GTE, Linkabit Inc., M/A-COM, Martin-Marietta, Motorola, Raytheon, Tracor, Ultrasystems, and Yardney.

Defense Satellite Communications System (DSCS)

The current DSCS consists of seven satellites, including two dormant spare satellites, orbiting at an altitude of 37,000 kilometers. The primary function of the DSCS is to relay information by and for the White House Communications Agency, State Department, and the DOD's worldwide military command control system. Although the DOD is moving toward using superhigh and extremely high-frequency radios in other satellite programs such as MILSTAR; DSCS replacement satellites would use ultrahigh frequency.

The follow-on program for the DSCS is known as DSCS III. The prime contractor for DSCS II satellites was TRW, and the series III satellites were awarded to General Electric. By 1998, the new satellites will be placed aloft by Atlas II rockets. Current planning calls for a total of two launches each year from 1991 through 1993, followed by one launch each year from 1994 through 1997. This schedule allows for five functioning satellites and two spares to be maintained in orbit.

Funding for fiscal 1991 was approved in full by Congress. The total requirement is for 10 DSCS-3 satellites through fiscal 1997 at a cost of $200 million.

Intelligence Systems

The DOD spends approximately $5 billion annually for a network of satellites and computers to collect information about economic and military developments in foreign nations and monitor world events. In addition, the Tactical Exploitation of National Capabilities Program (TENCAP) uses intelligence satellites such as White Cloud, Magnum, Vortex, and Chalet satellites to provide battlefield commanders with information on troop movements and potential targets. During the 1990s, the DOD plans to launch at least four Lacrosse radar imaging and four KH-12 photographic satellites that could be used for TENCAP. Contractors include Geodynamics, Lockheed, and TRW, among others.

Air Force Control Network

This network of radars is the U.S. government's official tracking system for space objects, as well as the military office charged with the coordination of satellite communications. In 1990, Ford Aerospace was given an additional $55 million to operate and maintain the network. The contract includes four yearly options worth a potential $260 million. The award is known as the Network Support Program (NSP) and demands the monitoring of more than 111,000 satellite contacts annually.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Pegasus

Developed by Hercules Aerospace Corporation and Orbital Sciences Corporation, Pegasus is a low-cost, flexible method of boosting satellites by using a three-stage solid-fuel rocket launched from the wing of an aircraft traveling at 40,000 feet.

The maiden launch of the rocket in April 1990 was a success and in November 1990 DARPA exercised its option to procure a fifth system. With more emphasis now placed on lightweight survivable and less costly satellites, the system seems destined to grow substantially.

Medium Launch Vehicles

Procurement of the Delta II and Atlas II space boosters is funded under the medium launch vehicle (MLV) program. McDonnell Douglas is the prime contractor for the Delta II, which is used for NAVSTAR GPS, SDI experiments, and commercial launches. General Dynamics is the prime contractor for the Atlas II, which is used primarily for satellite communications systems. First flown in December 1988, each Delta II rocket can carry an 8,400-pound payload into low-earth orbit (or 2,500 pounds to a 22,300-mile height) and costs about $50 million. The first seven launch vehicles are being produced under a $316 million contract. Production and launch support of all 20 MLVs has an estimated value of $750 million. DOD's long-range plans calls for 64 unclassified launches aboard Delta IIs between 1991 and 2004.

The air force selected General Dynamics to provide high-performance medium launch vehicles (MLV-II) to launch ten General Electric DSCS-3s and one P87-B NAVSTAR technology development satellite. The air force is not buying the launchers but rather the launch services of General Dynamics, resulting in a cost savings of at least $100 million per flight compared with the space shuttle. The launch schedule calls for four satellite launches in 1991, followed by one per year through 1997.

Heavy Launch Vehicles

Martin-Marietta produces the Titan IV and Titan II Space Launch Vehicles that are funded by the air force. The Titan IV, which flew for the first time in 1989, can carry payloads as heavy as 65,000 pounds (comparable to the space shuttle payload) at a cost of about $3,000 per pound.

In September 1990, Martin-Marietta was granted a $324 million contract to proceed with the Titan IV program. The contract calls for 41 rockets to be procured at a cost of $12.2 billion. Loral Instrumentation was awarded a $2 million contract in 1989 to provide telemetry data processors for the Titan IV. The Centaur upper stages are scheduled to be delivered in September 1995.

Space-Related Research

Overview

Research in military space has been dominated by the SDI since the mid-1980s. This program has covered a wide range of research topics from artificial intelligence to propulsion systems. In addition, DARPA and the individual military services are funding their own research into inexpensive satellites, new launch systems, antisatellite weapons, and the National Aerospace Plane, as well as other basic technologies.

Lightsats

Lightsats may possibly comprise a $100 million annual market by the end of the decade; they were given a special line item of $50 million in the fiscal 1991 budget. Currently, over 36 corporations are working to capture a portion of the market, which SDIO estimated in 1990 would reach hundreds of satellites annually. Among the larger competitors are Ball Aerospace, Boeing, Martin-Marietta, Raytheon, Rockwell, and TRW. Other competitors include FIAR of Italy, General Electric, Israeli Aircraft Industries, and MATRA. In late 1990, a contract was awarded to TRW for $5.5 million to build a satellite that weighs less than 1,000 pounds. The contract has options for 12 additional systems known as the Space Test Experiment Platform (STEP).

Space-Based Wide-Area Surveillance System (SWASS)

The SWASS was one of the highest long-term priorities in military space research just two years ago, but technical difficulties, interservice fighting, and congressional skepticism all but killed the program in the fiscal 1991 budget.

Originally designed as a system capable of tracking tanks and other battlefield weapons, the Defense Acquisition Board in October 1990 recommended that any decision to proceed with SWASS be delayed until at

©1991 Dataquest Incorporated January—Reproduction Prohibited

least 1995. It is hoped that by that time the air force's and navy's differences can be worked out. The air force wants the system to operate through radar scanning while the navy prefers an IR system. Congress zeroed the Pentagon's $60 million request for SWASS in fiscal 1991.

Advanced Launch System (ALS)

The ALS is a new family of space vehicles designed to provide relatively low-cost launches at high launch rates across a wide range of payload sizes. The goal of the ALS program, in place since 1986, is to reduce the cost of space launches from the current approximately $3,000 per pound to $300 per pound by using simpler booster and engine designs, composite materials, and advanced production processes.

One factor in keeping prospective costs low would be a high rate of production. The total cost of an ALS fleet could be as high as $80 billion through 2010 depending on U.S. launch requirements, especially those for the SDI, which now appear unlikely to support mass production.

In December 1988, three Phase II ALS contracts were awarded for studies and technology demonstrations as part of the Space Transportation Main Engine and Space Transportation Booster Engine programs; Boeing, General Dynamics, and Martin-Marietta were awarded a total of $264 million by the air force. Boeing is working on expendable structures, including cryogenic tanks, composites, and low-cost heat shields, as well as automated operations. General Dynamics is demonstrating multipath redundant avionics, adaptive guidance, navigation and control, expert systems, and electromechanical actuators. Martin-Marietta is studying cryogenic tanks, composite materials, automated launch vehicle integration, ground operations flow management, and mission analysis simplification. The studies are scheduled for completion in 1991.

Other ALS contracting activity includes five awards totaling $83 million to Aerojet TechSystems in March 1989 for engine components. Aerojet is developing a liquid hydrogen turbopump, an engine propellant control effector system, an engine controller, a methane/oxygen gas generator, and a methane/oxygen thrust change assembly. Pratt-Whitney and Rocketdyne were also awarded contracts for engine development: Pratt-Whitney received a 40-month $23 million contract to develop a liquid oxygen turbopump; Rocketdyne also received $23 million to develop a liquid-methane turbopump. NASA spent $81 million in fiscal 1989 on guidance system development but contributed only $5 million to the ALS effort in fiscal 1990.

The ALS is scheduled for initial operating capability in the year 2000, with FSD expected to begin in fiscal year 1993. However, delays in program funding may push this date back as far as 1995.

Antisatellite Weapon System (ASAT)

The DOD's ASAT program has been problematic at best. Congress has repeatedly passed legislation prohibiting the testing of ASATs in space, and the DOD terminated LTV's aircraft-launched ASAT program when it ran into repeated technical problems and huge cost increases.

The Defense Acquisition Board approved Milestone 0 development of a new ASAT in mid-1989, recommending that the army take the lead in development based on research conducted for the Exoatmospheric Reentry Interception System (ERIS) interceptor program. An award by the Army Strategic Defense Command for demonstration and validation of a system was made to Rockwell in December 1990. The award allows Rockwell to proceed with development.

Under the proposed ASAT program, the first system to be developed would be a land-based kinetic kill missile. Later systems would incorporate directed-energy weapons such as the free-electron and chemical lasers. The army is working on the free-electron laser through 1991, and the air force is conducting parallel research that will lead to a decision on ASAT directed-energy systems this year. In December 1988, The Air Force Space Division awarded eight study contracts totaling $7 million. These studies will report on current and future kinetic energy technologies for the ASAT mission, including those applied to sensors, boosters, command and control, and surveillance. Contractors include Advanced Technology, Boeing, General Dynamics, Lockheed, Logicon, LTV, Rockwell, and Science Applications International Corp. The air force is also continuing research into technology, cost, and alternative concepts for directed-energy weapons.

National Aerospace Plane (NASP)

The National Aerospace Plane is a hypersonic (+Mach 5) plane designed to take off horizontally from conventional airfields and achieve an orbital speed in excess of 18,000 miles per hour. NASP is intended to deliver both

©1991 Dataquest Incorporated January—Reproduction Prohibited

military and civilian payloads into space. Some defense applications might include strategic reconnaissance, high-velocity strategic bombardment, and rapid surgical strike missions. NASP is envisioned as an air-breathing, hydrogen-fueled, single-stage-to-orbit vehicle.

The NASP was planned to fly in 1995 after an investment of over $4 billion. Close to $2 billion has already been spent, but by mid-1989, the NASP program was one year behind schedule and $700 million over budget.

However, the plane accomplished some milestones in 1990. The supersonic combustion ramjet (scramjet) engine was successfully tested to speeds of Mach 17, and wind tunnel tests of one design were completed at speeds approaching Mach 14. In addition, first production occurred of titanium sheet fractions of an inch thick. This manufacturing technology is vital to provide the NASP with needed thermal protection.

In October 1990, a design featuring a twin-tailed, wedge-shaped plane with engines incorporated inside the body was determined to be the best suited to meet the NASP requirements. In November 1990, the determination was made to outfit the plane with three air-breathing scramjet engines. By 1993, a decision will be made on whether or not to proceed with the production of two experimental vehicles to test the NASP's design features.

Although the U.S. program has moved slowly, international competition for a space plane is intensifying. A European effort was begun in 1988. A separate French effort with Aerospatiale, Dassault, SDP, and Snecma is also garnering increased levels of government spending, and Japan plans to spend nearly $5 million on hypersonics in 1991.

NASP contractors are led by General Dynamics, McDonnell Douglas, and Rockwell for the airframe and Pratt-Whitney and Rocketdyne for the engine. In May 1989, the air force chose to continue development of both Pratt-Whitney and Rocketdyne propulsion concepts; each company received close to $65 million. A consortium on research materials technology was formed in March 1988 and includes General Dynamics, McDonnell Douglas, Pratt-Whitney, Rocketdyne, and Rockwell. Total funding for the consortium is $150 million through 1990.

A second consortium will develop vehicle subsystems for the aircraft, including accelerated development of rocket propulsion systems, crew escape systems, turbopumps, slush hydrogen production, instrumentation, air data systems, and high-temperature antennas. The NASP will use scramjet (supersonic combustion ramjet) technology; officials predict technology spinoffs including propulsion and composite materials and computational and fluid dynamics. NASP will be aided by related research efforts in space technology. One example is the Light Detection and Ranging System (LIDAR), developed by the air force and Georgia Institute of Technology, which will collect information on atmospheric density as high as 50 miles.

Strategic Defense Initiative (SDI)

The fiscal 1991 Defense Authorization left President Reagan's original SDI plan in tatters. Besides a reduction of nearly $1.8 billion from the administration's request of $4.7 billion, legislation mandates a redirection of many ongoing SDI projects.

The fiscal 1991 Defense Authorization Bill eliminates the five program elements that have dominated SDI since its inception in 1984 and creates five new funding categories: Phase I Defenses, granted $817 million; Limited Protection Systems, given $389 million; Theater and Antitactical Ballistic Missile (ATBM) Defenses, given $180 million; Follow-On Systems, given $754 million; and research and support activities, given $749 million. This restructuring is Congress' attempt to push the administration away from the grandiose three-phase program that guided past budget requests and to set DOD planning toward more realistic possibilities, such as a limited protection system.

Phase I Defenses Programs. In late 1986, the Reagan administration decided to deploy a strategic defense system in the near term. This decision led to the description of, and focusing of financial resources and technical expertise on, the so-called Phase I programs, with a deployment target set for the mid-1990s. It is now unlikely that any element of the original Phase I program could be deployed before the turn of the century.

The Phase I system included five main components: Boost Surveillance and Tracking System (BSTS), Space Surveillance and Tracking System (SSTS), Ground-Based Surveillance and Tracking System (GSTS), Battle Management (BM/C3), and Space-Based Interceptor (SBI). Together, these systems were to make up a defensive shield with limited capabilities which, once deployed, could be updated and expanded to incorporate more advanced technologies.

The following list the major components and competing contractors envisioned in 1987 by the Defense Acquisition Board:

- Major contractors for Phase I SDI development
  - BSTS
    - Lockheed with GM/Hughes, IBM, SAIC, and TRW
    - Grumman with GE/RCA, GTE, Honeywell, Litton/Itek, McDonnell Douglas, Rockwell, Raytheon, and Sparta
  - SSTS
    - TRW with Honeywell and Sparta
    - Lockheed with Aerojet, GM/Hughes, and Raytheon
  - GSTS
    - SAIC with Honeywell and TRW
    - McDonnell Douglas with Aerojet, GM/Hughes, and Lockheed
  - BM/C3
    - TRW with Ford Aerospace, GRC, and McDonnell Douglas
  - SBI
    - Martin-Marietta with Acurex, Ford Aerospace, GE, Litton, LTV, McDonnell Douglas, Phonton Research, Rockwell, and Xaman Science
    - Rockwell with Aerodyne, Aerojet, Calspan, Honeywell, Mission Research, Teledyne Brown, and Space Vector

Surveillance and Tracking Systems. Fundamental research on technologies for both the BSTS and SSTS programs will continue because they are useful for providing warning of any missile attack, providing tracking data to any weapons that might eventually be deployed, and serving as possible verification tools for future arms control agreements. However, neither system is likely to survive much longer than a year or two. Instead, significant technologies will be incorporated into other, less ambitious, programs.

Both BSTS and SSTS were intended to replace the current space early-warning systems and approximately 30 ground tracking stations. In the event of a hostile launch, the new space-based sensors would identify and track enemy missiles, relaying necessary telemetry to interceptors and ground control personnel. The BSTS system was to be made up of six satellites and three spares, each with 23 sensors, and have a total program cost approaching $8 billion. Satellite production was expected to begin in 1995. Although the original concept for the BSTS included battle management and command, control, and communications capabilities, the versions now in development do not include BM/C^{3}I capability. At the midcourse phase of the enemy missiles' flight, BSTS would hand off target data to the SSTS, which would have the additional burden of delineating between the real warheads and decoys.

As currently designed, the SSTS system would accomplish delineation by using passive IR sensors that could fine-tune the data collected from incoming objects. Plans called for 18 SSTS satellites to be placed about 1,250 miles above earth. Lockheed and TRW are the prime contractors for the SSTS; Lockheed was awarded $139 million additional funding in January 1989, and TRW was awarded $102 million in additional funds. The demonstration/validation phase is expected to last through 1991; a ground demonstration of the technology is scheduled for 1992, after which a single contractor will be selected. FSD is scheduled for 1992 through 1997, with production slated for 1995 to 2000. This schedule will be altered radically even if the program is not terminated altogether.

A study conducted by MIT's Lincoln Laboratories recommended the addition of a GSTS to complement space-based sensors. McDonnell Douglas was recently awarded a $340 million contract to validate GSTS technology, but the system may fall victim to budget cuts following completion of the current phase.

Currently, additional plans are to select either Rockwell or Hughes to demonstrate a long-wave IR sensor for a pop-up version of GSTS. The winner of that competition will join McDonnell Douglas, Honeywell, TRW, and Sparta, which already are evaluating the program.

Brilliant Pebbles. The newcomer on the strategic defense scene, with a 300 percent increase in funding for fiscal 1990, was Brilliant Pebbles, the brainchild of scientists at Lawrence Livermore National Laboratory in California. The Pebbles are small, lightweight, space-based, kinetic energy weapons that could be produced in

©1991 Dataquest Incorporated January—Reproduction Prohibited

mass quantities at acceptable costs. Each pebble contains the electronics necessary to receive firing and guidance information from the surveillance and BM/C3 system and lock onto hostile warheads. To enhance its survivability, thousands of these weapons would be stationed in orbit, blanketing the potential trajectories of enemy missiles. The scientists at Livermore sought to create an autonomous system with enough on-board computing strength to manage all functions from tracking to kill independent of ground-based support.

In a secret study conducted in 1990, JASON, a group of approximately 50 of the country's top scientific thinkers, found that the off-the-shelf commercial hardware originally expected to be used in Brilliant Pebbles would not be adequately hardened to operate in the nuclear-anticipated environment. Emphasis must therefore be placed on low-cost hardening methods, which could be a boon for companies that offer hardened semiconductors such as those engaged in the DOD's GaAs program and those that offer alternative technologies.

The Defense Science Board, which looked at many of the technical problems faced by Brilliant Pebbles, noted that the nation would have to greatly increase its space launch capabilities to orbit the large number of interceptors the concept requires. At current costs of $3,000 per pound for orbital launches, Brilliant Pebbles, with at least 10,000 interceptors, would be completely unaffordable. As previously noted, some progress has been made toward the development of advanced launches; still, the target of $300 per pound of payload, which could make Brilliant Pebbles marginally affordable, is far out of reach.

In mid-1990, the Pentagon selected six companies to compete for development of Brilliant Pebbles: Ball Space Systems, Boeing Aerospace, Martin-Marietta, Raytheon, Rockwell, and TRW. Two of these companies will be selected in 1991 for further development contracts each worth $200 million.

Command, Control, and Communications. The weakest link in the SDI concept has always been the battle management/command, control, and communications program (BM/C3). The BM/C3 component must coordinate all the other elements of any system and transmit information on the trajectories of the targets, lock-on data, and firing commands within minutes of any hostile launch. A potential Achilles heel of any SDI, the BM/C3 component must also be able to resist jamming and other forms of electronic warfare.

Even before the current budget cuts, the Defense Science Board's *Strategic Defense Milestone Report* stated that "the design of BM/C3 components is in a very early stage, reflecting the sketchiness of the system design as a whole."

Already in trouble, BM/C3 is likely to be rethought drastically as the SDI program adopts more modest goals. This outlook does not bode well for prime contractor TRW and its key subcontractors Ford Aerospace, McDonnell Douglas, and GRC.

Space-Based Interceptors. Prior to emergence of Brilliant Pebbles, a relatively small number of weapon satellites were to be placed in orbit, each satellite containing large numbers of interceptor rockets that could engage hostile missiles in their boost phase before multiple warheads and decoys could be deployed. Each such battle station would have the electronics necessary to ascertain the status of individual interceptors and receive firing commands, guidance information, etc. Although considerable technical advancements in rocket engines and miniaturization apparently have been made, reducing the prospective price of each interceptor, the overall cost of the system and questions about its vulnerability raised doubts about the concept. Existing contracts awarded to Martin-Marietta, Rockwell, and 17 major subcontractors are not likely to be followed by major new awards.

SDI National Test Bed. Reductions in SDI's prospective funding profile combined with strict limitations on physical testing will add importance to devices and procedures necessary for test and evaluation. Funding in this area is expected to continue, albeit at a slower rate. The SDI National Test Bed, currently in construction at Falcon Air Force Base in Colorado Springs, Colorado, is the most important component. The facility will serve as the nerve center for all future testing of strategic defense systems by integrating command and control systems and other SDI test and simulation facilities. Martin-Marietta Information and Communications Systems was awarded a five-year $569 million contract in 1988 to design, install, and operate the National Test Bed facility. Funding was cut in fiscal 1991 by 23 percent, forcing Martin-Marietta to lay off approximately 230 workers in late 1990.

Subcontractors include CAE-Link, Carnegie-Mellon, Computer Tech Associates, Ferranti (United Kingdom), Geodynamics, Hughes, IBM, Logicon, Nichols Research, and Ralph M. Parson Co. Logicon won an award in 1989 to assist Martin-Marietta in integrating

©1991 Dataquest Incorporated January—Reproduction Prohibited

the National Test Bed program by providing threat scenarios, object data, and engagement simulations through 1993.

The test bed will allow testing and evaluation of strategic defense concepts, architectures, and hardware through simulations. In short, the facility will allow system-wide testing before construction—a potential cost saver. Cray supercomputers will generate the simulations.

Accidental Launch Protection. Senator Sam Nunn sparked interest in this program in late 1989. The system would be designed to protect against the accidental firing of small numbers of missiles and provide some protection against small missile forces that may be proliferating around the world in the next century.

The current plan calls for the use of 100 nonnuclear ERIS missiles produced by Lockheed to be placed in Grand Forks, North Dakota. Such a step would be consistent with the 1972 Antiballistic Missile (ABM) Treaty. Subcontractors include TRW, Hercules, Singer-Kerfot, Texas Instruments, GM/Hughes, and Honeywell. These missiles theoretically could cover most of the continental United States against a small number of missiles on trajectories that would enter the United States from the north.

To provide terminal defenses, the ERIS system could be deployed in coordination with a High-Endoatmospheric Defense Interceptor (HEDI) system produced by McDonnell Douglas. Subcontractors for this program include Aerojet TechSystems and Hughes Missile Systems. The two-stage rocket, with over $450 million in development funding, can travel up to 10,000 feet per second. The 75-pound nonnuclear HEDI warhead would be detonated in the path of the incoming warhead, releasing small pellets to destroy the incoming warhead on impact. However, serious technical difficulties must be overcome if the HEDI system is to be made operational. The largest problem is in the missile's sensor window, contracted to Aerojet TechSystems, which must withstand blistering heat and high speeds. The Army Strategic Defense Command last year awarded Automated Sciences Corp. a $25 million contract for HEDI and ERIS target development, integration, and test planning.

Enabling technologies for SDI include high-power microwaves, precision pointing and tracking systems, noncooperative target recognition, and brilliant guidance. Research also has been conducted into ways of controlling large space structures and methods to improve the survivability of up and down communications, and control links between the earth and satellites. In rocket propulsion, research has focused on the application of composite materials, very large scale integrated circuits, software development, advanced sensors, optical information processing, and artificial intelligence.

Shipboard Electronics Systems

Overview

Budgetary pressures have forced the navy to abandon its long-standing objective of a 600-ship fleet. Still, as demonstrated by the Persian Gulf War, the navy continues to play vital roles in defense of U.S. interests overseas. The prospective decline in the number of ships will no doubt cut into the shipboard electronics market, now over $10 billion annually, but the electronics content of new ships and their subsystems is increasing substantially.

To meet emerging challenges with smaller fleets, the navy is concentrating on gaining technological advantages. A series of studies (many of which are still highly classified) over the past two years have stressed the need for advanced electronics as the best means of offsetting force reductions. Quo Vadis, a study carried out by the navy's Director of Research and Development Requirements, Test and Evaluation, reportedly stressed the need to integrate technological advancements, threat perceptions, and the latest intelligence into a coherent plan for the future navy. Navy-21, a classified study conducted by the Naval Studies Board of the National Academy of Sciences, concluded that investment in R&D, particularly of survivable computer and information subprocessors, reconstitutable space systems, and smart weapon systems, should receive high priority.

As in avionics, greater commonality and integration will be the focus of future naval electronics procurement. In the near term, emphasis will continue to be placed on two areas: ASW sensors and air defenses.

Major Ship Programs

Fiscal 1991 defense authorization for new shipbuilding includes funding for 13 ships. Table 3.5 shows the number and authorization for major platform construction.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Table 3.5

Principal U.S. Navy Shipbuilding Programs

	FY90		FY91	
Ship	Quantity	Millions of Dollars	Quantity	Millions of Dollars
DDG-51 *Arleigh Burke* Destroyer	4	2,792	4	3,221
SSN-688 *Los Angeles*-Class Submarine	1	732	0	0
SSN-21 Seawolf Submarine	1	1,688	1	1,140
LHD-1 Amphibious Ship	0	34	1	960

Source: Department of Defense

SSN-21 Seawolf

When the first Seawolf, now being built by General Dynamics' Electric Boat Division, goes to sea in May 1995, it will be the first new U.S. attack submarine design in nearly 20 years. Future ships were to be dual-sourced between Electric Boat and Newport News Shipbuilding and Dry Dock, but with reductions in the number of submarines to be purchased, the question of dual-sourcing has become controversial. The navy now plans to acquire only nine Seawolfs by the year 2000, and additional delays may be likely.

The SSN-21 will be equipped with Harpoon and Tomahawk missiles and Mk 48 torpedoes. Other systems include surface-search radar, a BSY-2 combat system with bow-mounted transducers, wide-aperture array sonar, and the TB 16 and TB 23 towed-array sonars.

The electronic heart of the submarine will be the BSY-2 advanced combat system. The prime contractor for this system is General Electric, which is taking over for IBM (IBM built the BSY-1 system used on *Los Angeles*-class attack submarines). Delivery of the first BSY-2 is planned for late 1993 or early 1994. When completed, the BSY-2 system will allow for multiple targeting and tasking and reduce the time between detection and launch of systems. Navy officials expect the BSY-2 to give the SSN-21 three times the effectiveness of the improved *Los Angeles*-class submarines now in the fleet.

Using distributive processing architecture and fiber optics in lieu of more bulky and less dependable wires, the BSY-2 will incorporate six Enhanced Modular Signal Processor (EMSP) systems from AT&T. In addition, 200 Motorola 68030 32-bit microprocessors will divide tasks between acoustics, command and decision, weapons, and display. In March 1990, AT&T was given $22 million to produce 14 standard electronic module B (SEM-B) kits for the BSY-2. In May 1990, Logicon received an $18 million contract to evaluate the safety of all combat control software.

Martin-Marietta received a $14 million contract in 1989 from General Electric for full-scale engineering development of the wide aperture array listening device, a key element of the AN/BSY-2 combat system. The device consists of hydrophones mounted on the outside of the submarine's hull and will collect, process, and display acoustic sensor data. The contract could be worth between $300 million and $500 million over the next 10 years.

IBM has an initial contract of $75 million for the towed-array sonars. SPD Technologies also was awarded a contract in 1989 for electric plant control panels for the SSN-21, to be delivered by June 1991. The submarine will also use a WLQ-4(v)1 EW system incorporating the BLD-1 direction finder produced by Litton.

SSN-688 Los Angeles-Class Submarine

Procurement of *Los Angeles*-class submarines, which entered service in 1976, has been terminated. The navy zeroed its request in 1991, effectively canceling the program as part of President Bush's cuts in defense spending. Congress authorized this recommendation, although the Senate recommended the procurement of two submarines for a total of $1.8 billion.

The *Los Angeles*-class submarine uses the BSY-1 combat system built by IBM. The SSN-688 uses Mk 48 torpedoes manufactured by Gould, Emerson Electric Mk2 decoys, as well as the Unisys UYK-7 computer. Other components include the BPS-15A Sperry radar for surface search, navigation, and fire control; IBM's BQQ-5 I BM passive/active search and attack sonar; and

©1991 Dataquest Incorporated January—Reproduction Prohibited

the OK-276 thin-line array sonar. Through 1990, 61 SSN-688s had been authorized and 44 were delivered; the remainder will be delivered by 1995.

DDG-51 Arleigh Burke Destroyer

The *Arleigh Burke*-class guided missile destroyer will serve as the primary U.S. multitask ship well into the next century. Congress approved the administration's fiscal 1990 request of $3.6 billion for the procurement of five ships and granted $3.2 billion in fiscal 1991 for four ships. Navy plans call for a total of 38 ships at a total cost of $31 billion. Contracts for the initial ships have already been awarded to Bath Iron Works and Ingalls Shipbuilding.

The DDG-51 uses the following subsystems: Mk 41 Mod 0 vertical launchers for standard missiles, ASROC, and Tomahawk missiles; SPS-64, SPS-67, SPY-1D phased array, and SPG-62 radars; and SQS-53C and SQR-19 towed-array sonars. Principal subsystem suppliers include the following:

- Gas turbines—General Electric
- AEGIS—RCA (more than 600 submarines)
- UYK-43 and 44—Unisys (CSC software)
- SM-2 missile—Raytheon/General Dynamics
- SPY-1D—RCA/Raytheon
- Mk 99—Raytheon
- SQQ-89—Westinghouse
- SQS-53C—General Electric
- SQR-19—Gould Inc./General Electric
- UPX-24—Litton
- Mk 41 launcher—Martin-Marietta/FMC Corp.

Future DDG-51 class ships will contain sprinkler systems in accommodation compartments and steel ladders in place of aluminum ladders as a result of the May 1987 Blue Ribbon Panel report on the Iraqi attack on the USS *Stark*. Although a nine-month delay from the original procurement schedule and rising costs are indications of problems with the DDG-51 program, the destroyer's future looks bright. The first ship is undergoing sea trials and is expected to be commissioned in 1991.

LHD-1 Wasp-Class Amphibious Assault Ship

The LHD-1 will be used to deploy Marine Expeditionary Forces and Brigades. The navy did not request procurement funds for an LHD-1 in fiscal 1990 when the overall goal of 83 amphibious ships, including the LHD-1, LSD-41, and others, was pushed back from 1994 to 1999. The stretching of the program was designed to save costs.

However, the navy has stated a current requirement for five LHD-1 ships by the mid-1990s and five more by 1999. The LHD-1 uses Sea Sparrow missiles, the SYS 2(V)3 weapon control system, Mk 91 fire control system, and three radars—the Hughes air-search SPS-52, the ITT SPS-48, and the Raytheon SPS-49. Ingalls Shipbuilding, the prime contractor, delivered the fourth LHD-1 in April 1989; three more have been authorized by Congress. Fiscal 1991 authorization was $960 million for one ship. Total cost for the ten-ship LHD-1 program will be more than $10 billion.

Major Electronic Subsystems

With lifetimes of 25 years and more, individual ships receive repeated modernization of their key electronic subsystems. Major navy modernization programs are described in the following paragraphs.

AEGIS Air Defense System

With the end of the CG-47 *Ticonderoga* procurement program in fiscal 1988, the AEGIS advanced air defense missile system continues to be procured for DDG-51 Arleigh Burke destroyers. The AEGIS system reached initial operating capability in 1983. Although it has been criticized by Congress and the GAO as expensive and not completely reliable, the final report on the USS *Vincennes* incident, which indicated human error, has diverted attention away from any technical shortcomings of the hardware.

AEGIS uses SM-2 medium-range missiles, three clusters of four Unisys UYK-7 computers, and Mk 41 launchers manufactured by Martin-Marietta. The navy plans to buy more than 50 AEGIS systems, 29 of which are to be installed on the DDG-51s. RCA is the prime contractor for the AEGIS system, which is projected to cost about $1 billion per ship. Subcontractors to RCA include the following:

- Aerojet General—Mk 32 torpedoes
- Computer Sciences—CMS-2 software
- FMC—Mk 26 launchers
- GD, Raytheon—SM-2 missile

©1991 Dataquest Incorporated January—Reproduction Prohibited

- General Dynamics—Mk 15 CIWS Phalanx gun; RIM-66/67 surface-to-air missile
- Raytheon—continuous wave illuminator (CWI)
- General Electric—SQS-53 bow-mounted sonar
- Gould—SQR-19 tactical towed array sonar
- IBM—LAMPS Mk III helicopter ASW, AAW
- Hughes Aircraft—AN/UYA-4, -21 weapon control displays
- Martin-Marietta, FMC—Mk 41 vertical launching system
- McDonnell Douglas—Tomahawk cruise missiles, Harpoon missiles
- Raytheon—Mk 99 fire control; AN/SPS-49 air search radar; SLQ-32(V) elecronic warfare suite
- RCA—Mk 131 command and control
- RCA, Raytheon—AN/SPY-1 phased array radar
- Lockheed—AN/SPQ-9 weapons radar
- Unisys—AN/UYK-7 computers

The Mk 26 launcher uses a digital interface with the Mk 1 weapons control system, one of the AEGIS' three computerized subsystems. The Mk 1 accepts weapon assignment commands and threat criteria from the Mk 1 command and control system, as well as data from the radar. The Mk 1 also generates commands for the Mk 26 launcher and Mk 99 fire control system, using the UYK-7 computer and the UYA-4 display. Future AEGIS systems will replace the AN/SPY-1A multifunction phased-array radar with the AN/SPY-1D radar and the AN/UYK-7 computer with the AN/UYK-43 computer.

Antisubmarine Rocket (ASROC)

The ASROC, an all-weather antisubmarine missile system, is manufactured by Alliant. The ASROC incorporates Mk 46 acoustic homing torpedoes; Mk 112 launchers; and a computer linked to SQS-23, SQS-26, or SQS-53 sonar for fire control. Ships that use ASROC are equipped with Mk 114 fire-control systems. Alliant remains the prime contractor for the conventionally launched ASROC; Loral was chosen as the prime contractor for the vertically launched ASROC, with Martin-Marietta as a second-source supplier. The navy authorized $86 million in fiscal 1991 for further development of the system. In September 1990, Alliant was granted an additional $65 million for foreign military sales of the system, which is expected to be completed in December 1992.

SQQ-89 Integrated Combat System

The SQQ-89 is one of three integrated navy weapon systems programs incorporating computer-controlled surveillance and detection equipment as well as advanced communications facilities and weaponry. Currently in production, the SQQ-89 is a sonar system for surface ships that integrates detection, location, tracking, and fire-control functions. It is installed on CG-47 *Ticonderoga*-class cruisers and DDG-51 *Arleigh Burke*-class destroyers. Components include the AN/SQS-53B (a hull-mounted low-frequency sonar), the SQR-19 tactical sonar towed array, the SQQ-28 LAMPS Mk III acoustic processing system, the Mk 116 Mod 5-7 ASW control system, and the Sonar In-Situ Mode Assessment System. The navy plans to install one of four variants of the SQQ-89 on up to 130 ships by 1995. Contractors include General Electric for the AN/SQS-53C, a new version of the hull-mounted sonar now in production. In September 1990, Westinghouse was chosen over General Electric for a three-year production contract for seven SQQ-89 systems. Until then, Westinghouse had been the second source to General Electric. Current plans call for a total of 110 basic systems at $4.3 billion and $1.4 billion for R&D through the life of the program. Congress authorized $280 million for this program in fiscal 1991.

Countermeasures Antisurface Ship Missile Defense (ASMD)

These programs make up the navy's main systems for protecting surface ships electronically. The AN/SLQ-17, produced by Hughes, is deployed on aircraft carriers. This deceptive jammer, known as "ghost," is often combined with GTR's AN/WGR-8 tactical EW receiver to form the AN/SLQ-29 suite.

The navy is now in the process of replacing the AN/SLQ-17 with the SLQ-32(v)1 system. This new system represents the navy's largest electronic warfare investment. It was recently awarded to Raytheon over Hughes, which will serve as the system's second source. Major subcontractors include ROLM, Teledyne, Scientific Atlanta, Varian, and Watkins-Johnson.

The SLQ-32 will be produced in four versions. The basic SLQ-32 will identify enemy approaches, notify the crew, and release chaff. The SLQ-32(v)2 also will be equipped with an expanded frequency coverage. The SLQ-32(v)3 will add active electronic countermeasures. The SLQ-32(v)4, the most advanced version, will be designed specifically for aircraft carriers. Congress authorized $93 million for this program in 1991.

©1991 Dataquest Incorporated January—Reproduction Prohibited

The navy announced in October 1990 that it planned three additional advanced programs to coordinate electronic warfare jamming with antimissile systems. The three programs are Electronic Warfare Coordination Module (EWCM), the Rapid Antiship Missile Integrated Defense System (RAIDS), and the Advance Integrated Electronic Warfare System (AIEWS).

Information Processing and Display

Improved information processing systems and displays are critical to the highly integrated systems that the navy will procure in the next century. Some of the key programs are described in the following paragraphs.

Naval Tactical Data System (NTDS)

The NTDS, deployed on all major naval combatants, combines digital computers with displays and data links for the automated organization and display of information for command and control, threat assessments, and weapons allocation. Although early systems employed the AN/UYK 20 or AN/UYK-7 computers, these are scheduled to be upgraded to the AN/UYK-43 and AN/UYK-44 computers. Hughes is the prime contractor for the NTDS and has already delivered 2,500 UYA-4 and UYQ-21 displays. The navy will spend more than $60 million in fiscal 1991 on this system.

Advanced Combat Direction System

The Advanced Combat Direction System is the next-generation follow-on to the NTDS, which, beginning in 1992, will be installed on all aircraft carriers. One advanced feature the Advanced Combat Direction System has over the NTDS is an automated electronic surveillance/emitter identification, association, triangulation, and tracking capability. The Advanced Combat Direction System will facilitate integration of antijam data links with new tracking algorithms; the navy hopes that this feature will lead to higher track data accuracy, more identification detail, and greater track-processing capacity. The Advanced Combat Direction System will be installed in two blocks: Block 0 will consist of new hardware and Block I will add new software and hardware. The system eventually will be deployed on all surface ships except those equipped with the AEGIS air defense system.

AN/SPA-25G Radar Display

ISC Cardion Electronics manufactures AN/SPA-25G radar displays. The AN/SPA-25G uses a digital scan converter to overlay sensor data with graphic symbols on ships' tactical displays. Production currently is under way; the development contract was valued at about $13 million. Key features of the AN/SPA-25G include VME-based digital architecture and use of 68000 processors.

Shipboard Computers

The navy currently uses two standard shipboard computers: the UYK-43 and the UYK-44. The UYK-43 is a large-scale computer installed on surface ships and submarines for radar processing, weapons fire control, carrier air traffic control, communications, and navigation. The UYK-44 is a medium-size computer used for much the same purposes. The latest AEGIS cruisers are equipped with 6 UYK-43s and 23 UYK-44s; SSN 688s are equipped with 2 UYK-43s and 5 or 6 UYK-44s. Unisys produces UYK-43s, and Control Data was chosen in 1988 as a second source. In 1991, Unisys and Control Data will compete for production awards. General Electric, Microlithics, and Raytheon currently are being qualified as additional UYK-44 suppliers.

While the navy is researching its next-generation computing requirements, upgrades are planned for the UYK-43 and -44. The navy approved the upgrade program in December 1988. The navy expects to spend about $29 million for UYK-43 improvements from fiscal year 1989 to fiscal year 1994 and about $19 million for improvements to the UYK-44 in the same time frame. Both the UYK-43 and -44 will benefit from additional memory and enhanced central processing units (CPUs) that will be four to six times faster than existing units. In addition, the UYK-43 will receive a coprocessor. The navy expects to install its next-generation computer, outlined in the navy's Next-Generation Computer Resources study, in 1996. The advanced computers are expected to incorporate modular design and use international computer standards.

In 1990, Unisys announced a joint venture with Cable and Computer Technologies (CCT) Inc. CCT will attempt to make a commercial version of the Unisys AN/UYK-43 system.

Signal Processors

The navy will receive a new signal processor in the mid-1990s. Developed by AT&T, the EMSP, or UYS-2, will replace IBM's UYS-1 as a key element in all platforms used for antisubmarine warfare. Using VHSIC chips developed by Honeywell, the EMSP will be able

©1991 Dataquest Incorporated January—Reproduction Prohibited

to process data from acoustic detection systems, synthetic aperture radars, adaptive beam forming, and electronic warfare systems. The navy projects software development costs to total about $60 million for the EMSP compared with $150 million for its predecessor, the UYS-1, although it now appears that this figure is optimistic. IBM was given an additional contract in March 1990 to deliver 80 processor upgrades to the UYS-1.

In addition to expected lower development costs, the EMSP's open architecture, designed for flexibility and adaptability, may offer further advantages. The EMSP will be installed on the LAMPS III helicopter and on platforms using the SQQ-89 integrated combat system. The navy also expects to install the EMSP in the SSN-21's BSY-2 system, Surveillance Towed Array Sensor System (SURTASS), and the Advanced Low-Frequency Sonar System.

Antisubmarine Warfare Systems

In addition to ASW systems designed for specific platforms, the navy procures many systems that are interoperable among platforms. Among these systems are sonobuoys, sensor nets, and towed-array sonars. The navy canceled procurement funds for the Low-Cost Sonobuoy Program in 1990 because of technical deficiencies but has provided research funds to improve the system's accuracy. Contractors involved in research include Hermes Electronics, Magnavox, Sippican, and Spartan. Production for 1994 for the enhanced system is planned. Procurement of other sonobuoys continues. Magnavox was awarded $7 million for 42,552 AN/SSQ-57B sonobuoys and 42,552 LAU-126/A launcher containers in early 1989. In addition, the SQQ-62 Directional Comm and Activated Sonobuoy System (DICASS) is undergoing an upgrade program to improve its detection range. The navy bought 15,026 DICASS systems in 1989 for a total cost of $23 million.

Sound Surveillance System (SOSUS). SOSUS, which has been deployed since the 1950s, is a fixed network of sensors on the ocean floor. The navy spent $30 million in fiscal 1989 and $20 million in fiscal 1990 to improve the system. In fiscal 1991, $31 million was approved for the same purpose. The upgrade program, the Fixed Distribution System, could cost as much as $7 billion. It will use the latest signal processing techniques and fiber-optic technology. Four teams continue to compete for this program: AT&T, General Electric, Hughes, and IBM. One team will eventually be chosen to pursue full-scale engineering development.

Submarine Operational Automation System (SOAS).

In March 1990, General Electric was given a $45 million DARPA contract to pursue SOAS for 5 years. This 20-year R&D program will introduce AI-based computer systems to assist submarine commanders in managing vast data flows. SOAS will be integrated onto submarines some time in the next century, probably on the SSN-21 or its follow-on.

Sonar and Radar Equipment

The navy purchases a wide variety of sonar and radar equipment, including multifunction systems such as the SPY-1 and mission-specific systems such as fire-control radars and mine-warfare sonars. Key programs are described in the following paragraphs.

SPY-1 Multifunction Radar. Used in the AEGIS air defense system, the SPY-1 is an electronically scanned fixed-array radar that operates in the E-F band and is controlled by the UYK-7 computer. The SPY-1B version is deployed on AEGIS cruisers beginning with the CG-59 *Princeton*; the SPY-1 D will be deployed on DDG-51 *Arleigh Burke*-class destroyers. RCA manufactures the antenna, Raytheon manufactures the transmitter, and Computer Sciences Corporation provides the software. General Electric integrates antennas, transmitter groups, and the Mk 99 fire control systems into the SPY-1D; in mid-1990 it was given a contract to produce five SPY-1Ds for DDG-51 vessels.

Mine Warfare Sonars. Two sonar systems currently are being procured for navy mine warfare ships: the SQQ-30 and SQQ-32. The SQQ-30, comprising a search sonar and a classification sonar, is produced by General Electric and will be fitted to MSM-1 *Avenger*-class and MCM-1 *Osprey*-class mine countermeasure ships. The SQQ-32 began initial production in 1989 when Raytheon won a $47 million contract. Raytheon will produce the detection sonar, and Thomson Sintra of France will produce the classification sonar. The SQQ-32 is designed to provide simultaneous search and classification data as well as independent display.

Towed-Array Sonar. Towed-array sonar systems include the SURTASS and the Tactical Towed-Array Sonar (TACTAS). SURTASS was first deployed in 1984 as a successor to the AN/BQR-15 Towed-Array Surveillance System; it is towed by slow, small surface ships. For fiscal years 1990 and 1991, the navy received about $140 million to procure the specialized T-AGOS ships

©1991 Dataquest Incorporated January—Reproduction Prohibited

that tow SURTASS. TACTAS is also for surface-ship use; it is used for passive detection and classification of submarines. The SQR-19 is currently in full-scale production and has been installed on *Spruance* destroyers since 1987. The SQR-19 is slated for deployment on all major ships built since 1970.

Air and Surface Search Radars. The navy procures at least 10 different air and surface search and surveillance radars. Among these, the Hughes SPS-5 2C 3-D radar, which provides target position in range, bearing, and elevation, currently is operational on LHA-1 ships and some guided-missile destroyers. The SPS-52C is also scheduled to be deployed on the LHD-1 amphibious assault ship. The SPS-55 radar is currently in production and is installed on DD-963, CGN-41, and CGN-47 ships. Manufactured by ISC Cardion, the SPS-55 will replace the older SPS-10 on destroyers and larger ships. The SPS-67, which operates in the C-band, will complement the SPS-55, which operates in the X-band. The SPS-67 is manufactured by Norden and United Technologies. The navy would like a total of 220 systems, approximately one-half of which have already been delivered. In fiscal 1991, the navy received $33 million for SPS-67 radars. Another new system is the SPS-65 (V), which is a pulse-Doppler air search and target acquisition radar operating in the D-band. The SPS-65 (V), manufactured by Westinghouse, is intended for use on ships that are not fitted with the NTDS; the SPS-65 (V) includes an advanced radar/weapons interface system.

Fire-Control Radars. The navy procures a number of fire-control radars, which differ from search and surveillance radars in range, bandwidth use, and sophistication. Westinghouse produces the W-120 and W-160 fire-control radars: the W-120 operates in the I/J band and is used for small-ship gunfire control, and the W-160 is a multimode, pulse-Doppler, X-band radar for ranges between 45 and 90 kilometers. The W-160 includes the antenna, the microwave assembly (transmitting and receiving units), and electronic equipment that includes a computer and digital signal processor.

Hughes produces the FLEXAR weapon control. FLEXAR is a next-generation shore and ship weapons control system for short- and medium-range missiles or guns for use against ships, aircraft, or other missiles. The FLEXAR currently is in the test and evaluation stage, although technology developed for the FLEXAR is now being used in the multifunction radar for the Hawk air-defense system. The R-76, manufactured by RCA, currently is in production. The R-76 is the principal sensor in the H-930 series of fire-control systems. Operating in the I-band, the R-76 includes a director, transmitter, receiver/signal processor, computer, and servocontroller.

Target Acquisition Radars. The navy currently is upgrading the Mk 23 target acquisition radar to improve response time, expand radar coverage, and increase flexibility. The Mk 23 is produced by Hughes and used with Sea Sparrow missiles against a variety of targets. Upgrades include a new computer and a phased array antenna with phase shifters. The Litton AN/UPX-24 (V) Shipborne IFF system, also is in production. The UPX-2 4 (V) accepts commands from, and provides target reports to, the AEGIS computer. Over 20 systems have been installed on CG-47 *Ticonderoga*-class cruisers, DDG-51 *Arleigh Burke*-class destroyers, and the LHD-1. Approximately 10 more systems are currently under contract, with additional systems proposed. For fiscal 1991, four Mk 23 systems were authorized at a cost of $38 million.

Trends in R&D

Like the other armed services, the navy is continuing to develop and procure advanced computers capable of integrating a wide variety of weapon and sensor systems, particularly for air defense and ASW applications. Navy officials cite that the most important advances in the navy's R&D program continue to include software for communications architecture and information processing systems, low-loss fiber-optic cables, improved materials for superconductors, composite materials for structures, and advanced materials for integrated circuits.

The navy puts special emphasis on antisubmarine warfare, spending approximately 25 percent of its R&D budget, or slightly over $2 billion annually on basic ASW research. Some of the navy's ASW requirements include self-noise monitoring, synthetic aperture arrays, over-the-horizon targeting, advanced capability torpedo optimization, analysis of oceanographic data, and fire control. Research on underwater surveillance concentrates on developing integrated acoustic display and wideband acoustic recall software packages.

Some of the more advanced programs for submarine detection include research into nonacoustic techniques, including magnetic anomaly detectors, wake-detection analysis, use of fiber optics, and use of blue-green lasers to probe ocean depths. ASW conducted by surface ships is depending increasingly on small ships (defined as

©1991 Dataquest Incorporated January—Reproduction Prohibited

weighing less than 1,500 tons). This trend may imply that research funds could be diverted toward ASW methods better suited for smaller ships closer to shore than for larger ships. In that event, one might expect more research into depressed tow arrays and possibly variable depth sonars.

DARPA's advanced submarine research includes six separate categories: fiber-optic telescopes that do not penetrate the hull in the traditional manner, composites for internal and external components, superconductive high-level magnetic field to reduce or eliminate sonar signals, smart skins, electronic drives to reduce weight, and magnetohydrodynamic propulsion to eliminate propeller noise.

Vehicles and Weapons

Overview

Systems included in this category are powered and motorized vehicles, torpedoes, artillery, and crew-served weapons. These types of equipment tend to have relatively small electronic content. However, the armed services are increasing their attempts to integrate different weapons to make a combined arms approach on the tactical battlefield feasible. A key element of successful combined arms is the coordination and integration of fire control, which requires that diverse types of weapons be made compatible. One example of this trend in current procurement is the army's effort to coordinate several gun and missile development programs as part of the FAADS, which is discussed earlier in this chapter. Another trend in vehicle and weapon procurement is toward greater commonality, which is apparent in the army's plan to procure a common chassis for families of vehicles.

Table 3.6 shows total program acquisition costs, including R&D spending and procurement, for key vehicles and weapons described in this section.

M1 Abrams Main Battle Tank

The Abrams is the army's primary ground combat system for closing in on and destroying enemy forces on the ground. The tank is in its 10th year of production; over 6,000 are in the field. The Abrams, which replaces the M60 series of tanks, is manufactured by General Dynamics; extensive foreign sales are possible.

The M1A2, of which only 62 will be manufactured for the army, will feature an improved 120mm cannon, a nuclear-biological-chemical overpressure system, a Texas Instruments Commander's Independent Thermal Viewer, an improved carbon dioxide laser rangefinder, and an internal data bus to connect electronic sensors and control systems. Upgrades have been subject to a $300,000-per-tank cost limit, but this goal is unlikely to be met.

The heart of the M1 is made up of vetronics systems, which provide high-speed, MIL-STD-1553 digital databus capability. The CPU is made by Texas Instruments. The computer is based on Motorola's 68000 processor, most of which will be made up of 68020 systems. The primary navigational systems are made by Smith's Industries. Other subcontractors include Allison Transmissions, Hughes, Textron Lycoming, Garrett AiResearch, Cadillac Gade, Honeywell, Koll Morgen, Singer-Kearfott, and Computing Devices of Canada.

Table 3.6

Major Vehicle and Weapon Acquisition and Funding
(Millions of Dollars)

System	FY90 Quantity	FY90 Millions of Dollars	FY91 Quantity	FY91 Millions of Dollars
M1 Abrams Tank	481	1,227	225	489
M2 Bradley	600	608	300	449
HMMWV	7,246	218	8,262	252
Mk 50	200	271	265	328
Mk 48 ADCAP	260	438	240	350
Mk 15 Phalanx	18	60	17	62

Source: Department of Defense

©1991 Dataquest Incorporated January—Reproduction Prohibited

M2 Bradley Fighting Vehicle

Bradley fighting vehicles are 60,000-pound, fully tracked, lightly armored vehicles used to accomplish reconnaissance and security missions. The Bradley uses a 25.00mm automatic gun as its primary armament and a 7.62mm machine gun and a TOW missile as its secondary armament. FMC Corporation is the prime contractor. The army's request for fiscal 1991 was 600, each with a total cost of about $680 million. Congress authorized $480 million for 300 M2s. U.S. requirements for Bradleys have been lowered from a total of 8,811 to 6,700, but foreign sales are likely.

High-Mobility Multipurpose Wheeled Vehicle (HMMWV)

This contemporary version of the army's jeep can be used as a TOW and Stinger weapons carrier, a command and control vehicle, a forward observer, a forward air controller, or to protect rear areas. A new five-year contract was awarded in mid-1989 for approximately 33,000 vehicles. The army is authorized to procure 8,262 HMMWVs in fiscal 1991 for a total of $252 million. LTV is the prime contractor.

The HMMWV can be equipped with the lightweight LTACFIRE fire control system provided by Litton and Mobile Subscriber Equipment built by GTE. In mid-1990, Loral was awarded $11 million to upgrade the AN/MRC-142 radios on-board the vehicles.

Mk 50 Barracuda Advanced Lightweight Torpedo

Initial operational tests were completed in 1990, but, because of design problems, the Mk 50 was not slated for operational use until this year. A successor to the Mk 46 Mod 5 lightweight torpedo, the Mk 50, is designed to be launched from either ships or aircraft and is used against submarines. The prime contractor is Alliant; Westinghouse won an $8 million contract in 1987 for second-source production. The Westinghouse team includes Martin-Marietta and Argo Tech Corporation (formerly TRW). The navy was authorized to procure 265 torpedoes at $328 million in fiscal 1991. U.S. procurement of the Mk 50 can be expected to continue well into the next century. Sales overseas also are likely to be extensive.

The DOD was authorized $5 million in 1991 to study the cost, performance, and schedule of a program to develop a variant of the VL ASROC to carry an Mk 50 torpedo.

Mk 48 Mod 5 Advanced Capability (ADCAP) Torpedo

The Mk 48 torpedo, produced by Hughes and Westinghouse, is carried by all navy attack and ballistic missile submarines for use against other submarines and surface ships. The Mk 48 ADCAP is an improved version of the original Mk 48, which has been in service since the late 1960s and is carried on SSN-688 and SSN-637 class attack subs and *Ohio*-class ballistic missile subs. The torpedo is 19 feet long, can travel up to five miles, and contains 650 pounds of high explosives.

The older system carries the Electronics Assembly Warhead (EAW) package. The current system uses technology that is approximately 20 years old. The navy plans to replace the current EAW system through open bidding in fiscal 1991.

The ADCAP version completed operation validation in fiscal 1988 and was introduced into the fleet in August 1988. Full production began in January 1989 with 100 torpedoes. The program has been dual-sourced between Hughes and Westinghouse. However, early in 1990, OSD gave guidance to the NAVSEA Systems Command to single-source the program beginning in fiscal 1991.

In fiscal 1990, Westinghouse was awarded 55 percent of the contract largely because it reduced costs by moving its guidance and control systems production to Puerto Rico. Congress authorized the navy to procure 240 Mk 48 ADCAP torpedoes at $350 million in fiscal 1991.

Mk 15 Phalanx

The navy's Mk 15 Phalanx Close-in Weapon System is a lightweight, ship-mounted, rapid-fire gun system. The Mk 15 carries out search detection, threat evaluation, tracking, firing, and kill assessment and is expected to be used as a last-ditch defense against cruise missiles and other antiship missiles. The Mk 15 Phalanx comprises six parts: the radar-servo assembly, the gun assembly, the mount and train drive platform, the barbette equipment assembly, the electronics enclosure, and the control panel; these parts are supported by a digital computer. Currently in full production, Congress authorized 17 systems in fiscal 1991 at $62 million. Prime contractors are General Dynamics and General Electric.

©1991 Dataquest Incorporated January—Reproduction Prohibited

The navy plans to procure 713 systems at a total program cost of $3 billion.

Command, Control, Communications, and Intelligence (C^3I)

Overview

Command, control, communications, and intelligence (C^3I) is increasingly seen as the potential deciding factor in any future military engagement. Over $20 billion annually is spent on systems that allow a soldier in the field to communicate with the commander and allow the commander to communicate with and direct support to combatants and to coordinate overall management of the battle.

After Operation Urgent Fury in Grenada in 1983, U.S. armed forces realized that although the individual services were each pursuing advanced C^3I systems, they were vastly deficient in their abilities to operate together. This discovery led to the founding of the Joint Tactical Command, Control, and Communications Agency (JTC3A) to orchestrate increased service interoperability and the technological advancement of C^3I systems.

Defense-wide command, control, and communications support systems will grow in value during the next few years. Defense-wide programs span all services and include the Tactical Communications Program (TRI-TAC) and the Worldwide Military Command and Control Information System. Strategic programs include systems such as the Over-the-Horizon radar and modernization of the North American Air Defense command center; tactical C^3I programs include Mobile Subscriber Equipment (MSE) and a variety of air- and ground-based radio systems.

One factor common to all services is the increasing use of satellites for C^3I. Indeed, an overlap exists between space and C^3I programs, such as the MILSTAR satellite program. Increasingly, efforts will be made to link existing ground-based and air-based communications systems with satellites. Other areas of technological emphasis will be survivability, greater integration, and interoperability.

C^3I programs can be divided into three major categories: warning and attack assessment, command and decision, and strategic communications. Under warning and attack assessment, the DOD is funding programs to increase the survivability of early warning satellites, mobile ground terminals, advanced warning concepts (particularly in space), and modification of the Ballistic Missile Early Warning System (BMEWS). For command and decision programs, funding covers hardened airborne command and control posts, mobile command centers, and improved survivability for fixed command centers. In strategic communications, programs include the Ground-Wave Emergency Network (GWEN), new aircraft for communicating with strategic submarines, MILSTAR, LF/VLF receivers on bombers, DSCS-III satellites, ELF communication with submarines, and FLTSATCOM.

System Development and Procurement

A number of programs initially developed in the early 1980s are now in full production.

Mobile Subscriber Equipment (MSE)

MSE provides secure static and mobile voice, data, and facsimile services to principal commanders and key staff officers, enabling them to exercise command and control of forces in a rapidly changing battlefield environment. The basic commercial equivalent would be a telephone system with mobile radio and data capability.

The backbone of the MSE is message switching and relay equipment; subscriber equipment includes the digital subscriber voice terminal and digital nonsecure voice terminal field telephones, the line-of-sight AN/TRC-190 radio, and the AN/UXC-7 facsimile machine.

The initial award for MSE production was made to GTE in December 1985. GTE was awarded its latest contract in June 1990 for $879 million. The total program cost is expected to be $4.3 billion for 48 complete systems. Significant subcontractors include AM General, A.R.E. Manufacturing, ATACS Corp., Bendix, British Marconi, Cubic Communications, Ericsson Radar, Genisco, Honeywell, Litton, Magnavox, Motorola, Raytheon, RCA, Thomson-CSF, and Unisys.

Total U.S. electronics content of the MSE is about 75 percent; French companies are building the system control center, the AN/VRC-97 mobile subscriber radio telephone terminal, and the radio access unit. In

©1991 Dataquest Incorporated January—Reproduction Prohibited

addition, French companies are collaborating with U.S. companies on the node center switch and the large extension node switch. British, Swedish, and Canadian companies are also participating in the program.

Army Data Distribution System (ADDS)

The ADDS is a control station that performs data management functions. The ADDS will provide secure, jam-resistant data communications and position/location, navigation, and identification capabilities to support the army's concept of an automated battlefield. The system comprises two components, JTIDS and Ehhanced Position-Location Reporting Systems (EPLRS), discussed below. The Forward Area Air Defense Command, Control, and Intelligence System (FAADC^{2}I) system planned by the army is heavily dependent upon the ADDS network for data distribution.

Joint Tactical Information Dissemination System (JTIDS)

JTIDS is designed to provide a jam-resistant link between aircraft and ground forces. JTIDS-equipped aircraft will automatically send information on their location and status into the network through the Tactical Air Navigation (TACAN) signal processing unit in the receiver-transmitter. This information includes target data, altitude, ground speed, direction, fuel reserves, weapon reserves, and radar signature returns. The JTIDS program has experienced developmental problems that have resulted in significant schedule slippage.

The prime contractor for the system is Plessey. In March 1990, Grumman was awarded $28.7 million to integrated the program into the E-2C Hawkeye. In July 1990, Rockwell was given $42 million for long-lead items for 1,200 class Z terminals, 20 of which will be placed on-board F-15 aircraft.

Enhanced Position Location Reporting System (EPLRS)

Hughes originally was awarded $107 million for this system, which provides secure, jam-resistant data communication to identify the position and location of field units and provide navigational support. In September 1990, Hughes was awarded an additional $48.7 million for the follow-on production 600 additional systems. Hughes is considering using VHSIC in the system to enhance its performance and potential for further upgrades.

Joint Operational Planning and Execution System (JOPES)

JOPES is run by the Joint Chiefs of Staff and is designed to help theater commanders develop and execute war plans in a timely and efficient manner. The program is currently undergoing several changes, including a $16.4 million software completion that was awarded to GTE in December 1989. Systems Research Applications was awarded an additional $9.2 million in July 1990 to provide continuing technical support for the program.

Single-Channel Ground and Airborne Radio Systems (SINCGARS)

SINCGARS are frequency-hopping VHF-FM radios planned to replace the AN/VRC-12, AN/PRC-77, and the AN/ARC-54-131 family of radios. SINCGARS will be the army's main combat radio and the primary means of communicating with infantry, armor, airborne, and artillery units. Total program costs are expected to exceed $10 billion. In 1978, three contractors were chosen for the competition: Cincinnati Electronic, Marconi Space and Defense, and ITT's Aerospace and Optical. ITT was chosen as the prime contractor in 1983 and awarded a production contract. General Dynamics is now serving as the second source. The General Dynamics team intends to build a different, but interoperable, radio that will match the form, fit, and function of the original model, but in 1990 the company posted nearly $50 million in cost overruns for the program.

SINCGARS are available in six versions for ground operations and three for airborne systems. By 1990, the second generation of SINCGARS with an internal communications security subsystem became available. In the meanwhile, first-generation radios remain in production. By the first quarter of fiscal 1991, 44,100 ground units were to have been delivered. Current army plans call for a total of 364,925 radios at a total program cost of $6.8 billion.

Army Tactical Command and Control System (ATCCS)

ATCCS experienced considerable delays throughout the 1980s, but its major components are now ready to enter production in the 1990s. The system is composed of six elements: the Maneuver Control System (MCS), the FAADC^{2}I, the Advanced Field Artillery Tactical Data System (AFATDS), the All-Source Analysis System

©1991 Dataquest Incorporated January—Reproduction Prohibited

(ASAS), the Combat Service Support Control System (CSSCS), and Common Hardware and Software (CHS). The total cost for these elements is expected to be slightly more than $7 billion.

R&D funds for integration of the ATCCS have been near $30 million annually; in fiscal 1991, the army was authorized $23 million. Block A of the contract is scheduled to run through 1991, during which time the Initial Force Level Control Capability software will be run with the AFATDS, FAADC²I, and CSSCS. Block B of the program will last from 1992 to 1996, during which the remainder of the components will be integrated, with the exception of the common hardware system computers being developed by Miltope Corporation. In October 1990, the army restructured several program elements. ASAS will be delayed for at least the third time until further testing can begin, which is likely to be sometime in fiscal 1992.

ATCCS will connect the six components by using interoperable, off-the-shelf microcomputers and through information channels such as MSE, SINCGARS, and JTIDS. Miltope received an initial $38 million contract in 1989 to deliver equipment for evaluation under the CHS program for ATCCS. The total program value could be as high as $600 million; the army wants to purchase approximately 27,000 microcomputers. Miltope has teamed with the following contractors: Analytics for support services and training, Ford Aerospace for software engineering, GTE for adaptive programmable interface units, Hewlett-Packard for the HP9000 Series 300 computer, and Tadiran of Israel for hand-held terminals. The system will use the Bobcat, a ruggedized HP 9000 Series 300 32-bit computer, which uses a Motorola 68020 microprocessor and 68881 floating-point coprocessors.

Maneuver Control System (MCS)

MCS is the first component of ATCCS and is expected to be fielded in fiscal 1992. It will be followed by AFATDS at the end of 1992, FAADC²I in 1993, and CSSCS in 1994. The MCS will provide automated collection, coordination, and dissemination of information at the corps, division, brigade, and battalion levels. Procurement of common computer hardware for the MCS will be delayed by two years because of about $20 million in funding cuts in fiscal 1991. Lockheed demonstrated the first phase of the maneuver planning systems under a three-year, $19 million contract for the army and DARPA. The program is aimed at demonstrating the capability of an expert system to speed mission planning.

Advanced Field Artillery Tactical Data System (AFATDS)

AFATDS, a computerized decision aid, will provide field artillery units with fire control, target analysis, and intelligence and will broaden and modernize the army's fire support command, control, and communications TACFIRE system. The system will be used by fire support teams, maneuver commanders, operations staff, logistics staff, and intelligence officers. The army awarded Magnavox Electronic Systems a contract in June 1990 to produce Version 1 of the system in fiscal 1993. The FDS contract is worth $60.5 million.

Forward Area Air Defense Command and Control System (FAADC²I)

FAADC²I will track aircraft and provide data to air-defense units. The prime contractor is the Jet Propulsion Lab, with Martin-Marietta serving as systems integrator. Principal subcontractors include American Development Corporation, Analytic Inc., BDM International, Boeing Aerospace, Cyberchron Corp., Electrospace Systems Inc., Emerson Electric, Ford Aerospace, GE, HRB Singer, Informatics General, McDonnell Douglas, Mitre Corp., TRW, and United Technologies.

All-Source Analysis System (ASAS)

This much-delayed system is intended to act as the central nervous system to guide field commanders as they prosecute battlefield engagements. The system will use near-real-time information to create a picture of the enemy situation and guide employment of forces and systems.

Total program cost for the ASAS is estimated to be $840 million for development and $1.6 billion for procurement. A production decision is now scheduled to be made in fiscal 1992. Procurement will include a number of nondevelopmental items including computers, disk drives, video displays, power supplies, and communications equipment.

The prime contractors in the program include Martin-Marietta, Jet Propulsion Laboratory, and Ford Aerospace. The fiscal 1991 authorization was cut back to $33 million from the army's request of $59 million.

Combat Service Support Control System (CSSCS)

This system will provide timely logistical information necessary for planning by tactical and theater

©1991 Dataquest Incorporated January—Reproduction Prohibited

commanders. The program will use off-the-shelf portable computers produced under the CHS program. CSSCS development began in 1989 and used Hewlett-Packard HP-330 hardware. Fielding of the system is not expected until 1993 and may be delayed until 1994.

Common Hardware and Software (CHS)

This program is designed to identify nondevelopment items from the commercial market that have the capability to perform in the military environment. A CHS contract was awarded to Miltope in August 1988 for hand-held terminals. Common hardware is expected to comprise three computer types. The first will be a transportable system based on a 68020 processor operating at 16.67 MHz. The second is a portable computer based on the same configuration. The third will be a hand-held unit based on an 80C286 6- or 12-MHz processor.

Information-Processing System

The air force is developing a new command and control system for the Military Airlift Command to automate tracking of airlift aircraft and crews worldwide. The air force selected Computer Sciences in 1989 to develop the software for the information processing system, which is scheduled to replace the existing manual tracking system. The current system is composed of a 158-node network, including 42 systems at fixed sites and 116 deployable systems. Competitors for the project included Contel Federal Systems, GTE, and TRW. Computer Sciences will spend two years and $31 million developing the software. GTE was awarded a $14 million contract in mid-1989 to integrate air force systems with the Worldwide Military Command and Control Information System (WIS) and modernize air force C2 systems and acquire hardware and software.

The air force hopes to deploy the entire information processing system by 1994. Computer Sciences recommended Digital Equipment Corporation's MicroVAX 3 processors to manage databases and Zenith 248 terminals, although the air force's Electronic Systems Division has not made a final decision. Total value of the contract, with hardware, is estimated at about $111 million.

The information processing system's terminals will be linked to the NAVSTAR global decision support system. Digital currently is developing a multilevel security system to be used with the Global Decision Support System, which will be completed in 1991.

Joint Advanced Special Operations Radio System (JASORS)

This system has many highly classified components but is known to be designed to provide tri-service special-operations forces with interoperable, secure, jam-resistant tactical communications. Six teams are currently competing for the program, which is estimated to be worth $300 million for the production of 2,500 radios. The teams are led by TRW, Harris Long Range Radio Corporation, Raytheon, Hughes, E-Systems, and General Dynamics. JASORS is considered a valuable contract because of the highly advanced nature of the components involved.

HAVE QUICK

The HAVE QUICK program is a frequency-hopping, ultrahigh-frequency communications system. Magnavox Electronics Systems was selected as the initial producer of the airborne radio and already has produced over 15,000 units. Boeing received $68 million to produce an improved version of the HAVE QUICK A-NET system. The contract includes 11 ship sets for AWACS aircraft.

Three versions currently exist. The first two versions, the HAVE QUICK and the HAVE QUICK II, both were produced by Magnavox. These systems included the AN/PRC-113 manpack, the AN/URC-83 vehicle radio, and the AN/ARC-187 airborne unit used in platforms such as the P-3C.

The latest version is the HAVE QUICK IIA, which began production in 1988. Rockwell is the lead contractor with these later radios, which include the AN/GRC-171(A)4, the AN/ARC-210(V), the AN/GRZ-XXX, and the AN/VRC-XXX. The air force has decided to proceed with procurement of up to 9,000 of these systems in 1992. They will be worth a possible $800 million in lifetime contracts.

Other contractors involved in the HAVE QUICK program include Motorola, E-Systems, and Harris.

Tactical Communications Program (TRI-TAC)

The DOD has been pursuing TRI-TAC for almost 15 years. TRI-TAC provides common, ground-based, tactical digital communications for all the services. These digital communications include mobile and transportable systems for voice and data communications.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Contractors include General Atronics Corporation, Martin-Marietta, GTE, and Raytheon. The total program cost is estimated at approximately $2 billion for 555 systems. Fielding of the systems will continue through 1995. As part of the TRI-TAC program, AT&T was awarded a two-year, $23 million contract to supply new fiber-optic cables to connect TRI-TAC and the Patriot air defense system. Fibercom, under a $15 million contract with the DOD, supplied modules to convert electronic signals into light, which will pass through the cables.

Equipment in the TRI-TAC system includes the AN/TTC-39A nodal control switch, AN/TYC-39 message switch, AN/TTC-46 large extension switch, AN/TTC-4 8 small extension switch, AN/TRC-138A radio repeater set, AN/TRC-173 radio terminal set, AN/TRC-174 radio repeater set, AN/TRC-175 radio terminal set, AN/TRC-170 V2/V3 troposcatter radio, AN/TYQ-30 (V) I communications system control element, and AN/TYQ-31 (V) I communications system control element.

Troposcatter System

This navy system is the equivalent of a civilian portable microwave telephone link. It is capable of transmitting 150 miles over the horizon. Raytheon was awarded $58.1 million for 69 AN/TRC-170 systems in February 1990, and Unisys was given $40.2 million for 47 systems.

Worldwide Military Command and Control Information System (WIS) and Worldwide Military Command and Control System Automatic Data Processing Modernization (WAM)

The WIS was to provide crisis planning and execution aids to the National Command Authorities and specified and unified commands, using particular hardware systems. The software component of the program is known as WAM. WIS was canceled in 1988 after an investment of $346 million over eight years.

Program management for WAM was transferred from the air force to the Defense Communications Agency (DCA) in 1988. The DCA restructured and renamed the program to accommodate technical and financial difficulties. WAM, the prime contractor of which is GTE, received $47.5 million in 1990 and will receive close to $50 million in 1991.

In September 1990, Contel was awarded $36 million to provide the necessary computer maintenance for the program. Also in September, the DCA published plans to spend up to $270 million through 1994 to upgrade software.

Ground-Wave Emergency Network (GWEN)

The GWEN will provide U.S. strategic forces with critical communications (despite high-altitude nuclear bursts) by proliferated radio relays using ground wave radio equipment. GWEN, which reached FSD in 1988, consists of unmanned low-frequency radio sites hardened against electromagnetic pulses. The system comprises 8 input/output stations, 30 receive-only stations, and 56 tower relay nodes. The prime contractor is RCA, which was awarded $5 million in 1989 for interim support and data. In October 1990, Contel was given a one-year $37 million contract to maintain and operate the system.

The fiscal 1991 authorization budget prohibits the expenditure of any funds for site preparation until the National Academy of Sciences has completed a report on the health effects of the low-frequency communications.

Over the Horizon Backscatter (OTH-B) Radar

The OTH-B Radar will provide wide-area, long-range, all-altitude surveillance of all three U.S. coasts by bouncing high-frequency waves off the ionosphere to achieve over-the-horizon coverage between 500 and 2,000 miles. The air force successfully demonstrated 180-degree coverage of the OTH-B in Maine in 1989. The radar previously covered only 120 degrees in two 60-degree sectors. The new radar, the AN/FPS-118, was developed by the prime contractor, General Electric, and eventually will be placed in Maine, Alaska, a site on the West Coast, and a site in the southern United States.

Each radar uses 28 VAX 11-730, 11-750, 11-780, and 11-785 computers with more than 1 million lines of software. In October 1990, General Electric was awarded an additional $26 million for the East Coast system, and Aydin was awarded a contract to develop displays for the program.

The navy also began installing the first operational relocatable OTH radar (R-OTHR) on Amchitka Island in the Aleutians in 1990. Twelve systems are expected

©1991 Dataquest Incorporated January—Reproduction Prohibited

to be procured for a total of $1.9 billion. The R-OTHR, manufactured by Raytheon, is designed to track both ships and aircraft at a range of 1,800 nautical miles, with 60-degree coverage.

NORAD Modernization

The $1.5 billion NORAD modernization program is designed to upgrade the Cheyenne Mountain complex's software and hardware. The program is several years behind schedule and several hundred million dollars over budget. Prime contractors include Ford Aerospace, Logicon, and Mitre.

Upgrades include the Survivable Communications Integration Program. This program, worth $190 million, will develop a multimedia management for missile warning data. The FSD prime contractor is E-Systems, with Raytheon and Tolerant Systems as subcontractors. Initial operations are expected to begin in mid- to late 1992.

The communications upgrade element will allow circuit control and a message-processing facility to validate information. GTE is serving as the prime contractor for approximately $325 million.

The Common Center Processing and Display upgrade will enhance NORAD's displays. TRW is serving as the prime contractor for the program, estimated to be worth $325 million. Digital and OAO Corporation are serving as subcontractors.

An estimated $125 million program is under way to provide an alternative center to the Cheyenne Mountain complex. The details of this new underground facility, as with most other elements of the NORAD modernization, are highly classified.

Granite Sentry is another upgrade designed to enhance NORAD's computer capabilities. Martin-Marietta, Digital Equipment, and Idaho National Engineering Labs are the prime contractors in this $190 million program. The operational date is expected to be 1995.

COBRA DANE

In 1989, the air force awarded two concept-definition phase contracts for modernizing the COBRA DANE radar system. COBRA DANE collects intelligence data on Soviet ballistic missile tests and supplements the DSP satellites. The system is also being touted as a possible tool for arms control verification. The modernization program will replace computers and signal processing equipment. General Electric and Raytheon won $4 million and $3 million contracts, respectively.

In April 1990, a $62 million contract was awarded to Raytheon to provide new signal and data processing as well as computer displays and 300,000 lines of Ada-based computer software. The software will be written by TRW under a $15 million subcontract.

Military Computing Technology

Overview

In fiscal 1991, Congress again asserted its desire to see a single agency take the lead in coordinating this vital area of advanced military development. Reports by both House and Senate Armed Services Committees recommended that DARPA assert greater influence in coordinating development of a wide range of high-performance computing technologies. DARPA has played a leading role in computer technology since 1961, when it began research into time sharing. The advanced computer work now under way by DARPA, as well as work planned over the next five years, will often determine the success or failure of many advanced weapon systems.

To assist DARPA in the pursuit of these essential technologies Congress authorized a special line item in the fiscal 1991 budget for high-performance computing and granted $138.5 million for the program.

In addition to exploring cutting-edge R&D programs, the DOD procures computers for a wide assortment of tasks from specialized battlefield uses to more normal office and laboratory applications. Management information systems (MIS) have become ubiquitous in all four services. Computer-aided design (CAD), modeling, and other automated tools are used to oversee new system development and for testing and evaluation.

The DOD spends close to $9 billion annually on automated information systems with a growing emphasis on quality management systems and controls. This amount is expected to remain relatively stable through the mid-1990s. Acquisition of such systems is managed by the Major Information Systems Review Council in the Pentagon, which reviews every program worth more than $100 million.

©1991 Dataquest Incorporated January—Reproduction Prohibited

In addition, the DOD is placing greater emphasis on the purchasing off-the-shelf computer hardware and software developed in the civilian market. These systems, often referred to as nondevelopmental items (NDI), will increase commercial computer access to the DOD throughout the 1990s and open new vistas for corporations specializing in the battle hardening, or ruggedization, of civilian computer hardware components. According to some estimates, the DOD may purchase up to $1.5 billion worth of commercial computer hardware in fiscal 1991.

Data Processing and Training Systems

Dataquest has examined the computer elements of specific programs in previous sections of this booklet. In addition, the DOD continues to purchase an increasing number of general-purpose computers.

The Air Force Computer Acquisition Center (AFCAC) at Hanscom Air Force Base, Massachusetts, currently manages about $2 billion in computer contracts. Zenith continues to be a major player in this area after winning four major contracts from the air force to supply microcomputers. The follow-ons to these systems will eventually push Zenith's sales to the air force past the half-billion-dollar mark.

The 1989 NYSER-Net Inc. contract from DARPA continues in an effort to construct a national networking testbed in order to tie together aerospace, defense, and government research computers. The $7 million fiber-optic network will supplement the current Arpanet network.

In the area of secure data processing computers, Mesa Technology was awarded a three-year contract in mid-1989 to supply Tempest microcomputers to the DOD. The $16 million contract includes a first delivery of 54 systems and 26 spare-parts kits. The microcomputers use Intel processors. In addition, companies are finding a market in making DOD computer systems more secure. As the DOD becomes ever more dependent on computer capabilities for a multitude of tasks, this market is likely to increase by several factors. In October 1990, for instance, Odyssey Research Associated Inc. received a nearly $2 million DOD contract to develop technologies capable of verifying the security of computer systems.

In mid-1990, the Defense Logistics Agency, in an effort to upgrade and modernize its computerized information system, contracted with Grumman to manage hardware and software program integration in a contract expected to be worth close to $100 million over its 12-year life cycle. Current plans call for IBM to supply a 3090 mainframe with NCR developing the communication systems, while Wilson-Hill will develop the training system.

Computer Sciences was chosen by the air force in late 1989 to provide the Military Airlift Command with a command and control information processing system. Under a $31 million contract, Computer Sciences will install both hardware and software worldwide. The potential value of the contract is $111 million over seven years if the air force exercises all options. The system will use the DOD's standard Ada programming language. Electrospace Systems will provide the communications subsystem.

In addition to these programs, each service has a number of programs that entail major computer upgrades, as shown in Table 3.7. Most funding for automated data processing (ADP) improvements comes from operations and maintenance accounts or industrial funds.

Software Programs

Software is another fundamental element to nearly every major defense system. Moreover, advanced systems increasingly rely on sofware to reduce hardware replication costs and increase flexibility.

The DOD continues to spend upward of 10 percent of its budget on software with rework, evolution, and maintenance accounting for more than 80 percent of these costs. To coordinate these efforts more effectively, the DOD requested $47 million this year, which was authorized, for the Consolidated Software Initiative.

The Consolidated Software Initiative consists of the Ada program, the Software Technology for Adaptable, Reliable Systems (STARS) program, and the Software Engineering Institute (SEI). These programs along with several minor programs, constitute the DOD's attempt to achieve interoperability in several critical technological areas including reusable software, automatic software generation, secure software, software for parallel and heterogeneous distributed systems, and real-time fault-tolerant software.

During the next several years, the Ada program will concentrate on moving systems to the Ada language to meet current requirements. STARS, the prime contractors of which are IBM, Boeing, and Unisys, will focus

©1991 Dataquest Incorporated January—Reproduction Prohibited

Table 3.7

Major Service ADP Programs—Contract Value
(Millions of Dollars)

Program	Value
Army	
Standard Depot System	545
Reserve Component Automation System	500
CALS/TIMS	250
Corps of Engineers Automation Plan	178
Integrated Procurement System	163
Department of the Army Information Network	NA
Supercomputers	NA
Commodity Command Standard System	76
Trans Coordinator Auto C2 Information System	NA
Theater Auto C2 Information Management System	50
EUCOM Intel Support System	25
Navy	
Engineering Data Management Information and Control System	200
Personnel and Pay Systems Follow-On	93
DON Office Automation and Communication System	40
Basis and Stations Information System	300
Shipyard Upgrades—Numerous Programs	NA
Paperless Ship Programs	NA
Consolidated Communications System Replacement	NA
Information Engineering Automated Support Tools	45
Hardware/Software Material Planning Depots	62
ADP Support AIR-41	49
SW Support NALCOMIS	30
Hardware/Software Replacement Casis II	20
Air Force	
AF Command and Control System	437
AF Capability Assessment Program	250
SAC Ware Planning System	242
HQ Replacement Program	200
Logistics Information Management Support System	170
Intelligence Data-Handling System	80
AF Logistics Modernization Programs	40
Depot Maintenance MIS	150
Contract Data Management System	30
Pacific Distribution System	30

NA = Not available
Source: EIA 10-Year Forecast, 1989-1999

©1991 Dataquest Incorporated January—Reproduction Prohibited

on the development of production-quality Ada reuse repositories and software engineering environments. A 1990 STARS application of reusable Ada software for a navy command-and-control system, for instance, reduced a 50,000-hour software engineering effort to 10,000 hours by reusing software from an army system. The SEI program was established in 1985 and attempts to create less labor-intensive methods of developing software by pressing for industry-wide standards and encouraging automation and greater interoperability. Located at Carnegie-Mellon University in Pittsburgh, Pennsylvania, the SEI is a federally funded R&D center with an annual budget of close to $20 million.

Total DOD funding for software producibility was estimated to have been $420 million between fiscal 1986 and 1990. Current plans call for the annual amount spent for this purpose to increase to $150 million by fiscal 1996, with a total of $870 million to be spent between fiscal 1991 and 1996.

Very High Speed Integrated Circuits (VHSIC)

The goal of this now-completed DOD program was to develop very large scale ICs to be used in military systems. The $1 billion, ten-year program resulted in faster chips that will be used for real-time processing of images and signals, automatic target recognition, IR focal plane staring and scanning arrays, and fusion of sensor data. The VHSIC program was conducted in three phases. Phase I resulted in 1.25-micron chips with functional throughput 100 times greater than that of commercially available ICs and operating speeds of about 25 MHz. Phase I contractors included Honeywell, Hughes Aircraft, IBM, Texas Instruments, TRW (teamed with Motorola), and Westinghouse (teamed with National Semiconductor).

The first operational installation of VHSIC was in the F-111D signal transfer unit, replacing 102 ICs with one VHSIC chip. Reliability of the unit increased by a factor of 125, and the cost dropped from $24,000 to $2,000.

In mid-1989, Westinghouse delivered the first of six VHSIC avionics modular processors. The avionics modular processors, part of the Pave Pillar advanced modular architecture studies, consist of a MIL-STD-1750A processor and external I/O modules. The system has four central processing modules that operate at 2 mips and two fiber-optic high-speed data bus modules, which transfer data at a rate of 50 mips.

Phase II of the program produced 0.5-micron chips that increased processing power 1,000 percent. IBM was the first to produce a functional Phase II chip (in 1988); it contained 37,000 logic gates and operated at 100 MHz, four times faster than Phase I chips. Other Phase II contractors included Honeywell and TRW, along with Motorola and Westinghouse.

TRW and Motorola demonstrated their Phase II superchip, the CPUAX, in late 1988. This VHSIC team demonstrated the first of 8 macrocells for digital signal processing; the superchip contained 142 of these macrocells on a 1.5 x 1.7-inch space. Incorporating 4 million devices, the superchip operates at 200 million floating-point operations per second (mflops), the speed of a Cray supercomputer. Other features of the superchip include self-contained spare parts (almost one-half of the 4 million devices are spares), built-in testing, and the ability to be reconfigured using software. In 1989, Honeywell demonstrated its Phase II chip, the PI-Bus interface, which can link avionics modules together. IBM also demonstrated its Phase II acoustic beam-forming module in 1989; the module will be used to process sonar signals.

In 1990, numerous programs and system upgrades that will include VHSIC chip sets were announced. The more prominent programs include Hughes' APG-70 radar system, which was approved for the export version of the F-15E; the Update IV avionics suite, which will use Honeywell VHSIC chip sets; and Northrop's and McDonnell Douglas's YF-23A ATF entry, which reportedly will use a Unisys 16-bit VHSIC version of the company's MIL-STD-1750A computer. In addition, VHSIC will be central to other advanced programs such as the Pave Pillar advanced systems technology and the INEWS.

More than 40 efforts are under way in 1991 to use VHSIC chips in military systems, including the MIL-STD-1750A on-board computer built by Texas Instruments; the AN/APG-70 radar built by Hughes for the F-15; and the AN/UYS-1 advanced signal processor built by IBM for the navy. The UYS-1 reportedly doubled its sonobouy processing capability with the VHSIC insertion. The common signal processor uses Phase I technology, capable of 1.8 billion floating-point operations per second (flops) and adaptable for radar, electronic warfare, communications, and many other applications. IBM also received a $14 million FSD contract from McDonnell Douglas for VHSIC computers for the F-15. It was announced in 1990 that the new central computer, designated the AP-1R and the first of its kind

©1991 Dataquest Incorporated January—Reproduction Prohibited

to use VHISC technology, will be installed on new aircraft through June 1992.

It was also announced in late 1990 that Rockwell Collins and IBM will join to produce advanced digital signal processing devices incorporating VHSIC. Rockwell Collins plans to provide IBM with the VHSIC designs for a polyphase processor to be used in airborne ASW systems.

With the success of the VHSIC program, it is likely that numerous missile systems soon will begin to incorporate the technology to boost performance levels beyond their current capabilities. Immediate candidates for upgrades include Raytheon's Patriot air defense system.

Commercialization

Some estimates suggests that commercially available computers could perform up to 90 percent of military requirements at costs between 10 and 20 percent of what the armed services spends to procure systems that meet more rigorous military specifications.

This realization, along with the budget crunch and the ever-increasing demand for computer systems within the military, has led to increasing procurement of NDIs. These systems are basically commercial computers purchased on the open market and, when necessary, "militarized" either through hardening or ruggedizing.

The lightweight computer unit (LCU) is potentially the largest of these NDI programs. This U.S. Army project began in mid-1990 with the U.S. Army's Communications and Electronics Command expected to spend an estimated $500 million during the program's life. The army plans to procure two versions of what is to become the standard battlefield computer for light infantry divisions. The LCU (v) 1 is to be an off-the-shelf system. The LCU (v) 2 is a ruggedized version of the first unit. The RFP, which was released in September 1990, calls for the system to weigh approximately 20 pounds and contain a 32-bit microprocessor (MPU), an 8MB RAM, a floating-point processor, a removable 100MB hard drive, a 3.5-inch floppy disk, internal video graphics array (VGA), DOS 4.1 with Windows capability, and a rechargeable and removable battery.

Many corporations are capitalizing on this trend toward commercial purchases. For instance, GTE is developing a device to allow commercial computers to communicate easily with army battlefield systems under an $11 million 1990 subcontract from Miltope called the Adaptive Programmable Interface Unit. Miltope is taking the lead as the prime contractor for the program, which will provide the army with ruggedized versions of Hewlett-Packard microprocessors for the battlefield.

In mid-1990, Raytheon was awarded several contracts for the air force's Rapid Execution and Combat Targeting (REACT) program. Under the contract, Raytheon will provide hardened versions of commercial systems to GTE for the REACT program. The systems will use components designed by DEC to assist the air force in aiming and targeting missile systems. Under the same program, Raytheon will deliver 17 military versions of Digital's VAX model 810.

Smaller companies are also trying to capitalize on the ruggedizing market. Codar Technology, for example, has joined Digital to ruggedize VAX and PDP range computers for the battlefield. In addition, SAI Technology of San Diego and Paravant Computers of Florida are adapting commercial laptop computers to military standards.

Ongoing Research

Advanced research continues to focus on increasing speed, reducing weight and size, and increasing capabilities under adverse conditions such as radiation or extreme heat and cold. Research conducted by the DOD through DARPA is continuing in architecture, ICs, optoelectronics, and software. Solutions to defense problems may lie in one or more of these research areas. For example, increased speed may be achieved through computer architectures such as parallel processing, optoelectronics, new semiconductor, or even superconductor materials.

In basic computer architecture, research is focusing on three areas: artificial intelligence, parallel processing, and neural networks. In ICs the DOD continues to focus on near-term solutions through an emphasis on manufacturing technologies while continuing to explore the capabilities of more exotic nonsilicon-based materials such as GaAs. Optoelectronics will become a key technology for making the most of current IC designs such as VHSIC and MIMIC and could pave the way for all-optical computation in the late 1990s.

In addition to its own research projects, the DOD will continue to build on commercial developments. The most prominent of these is Intel's introduction of its 80860 "supercomputer on a chip," which is based on reduced-instruction-set computing (RISC).

©1991 Dataquest Incorporated January—Reproduction Prohibited

Artificial Intelligence (AI)

AI is being pursued under DARPA's strategic computing program. According to 1990 testimony by DARPA's director, the program will place emphasis in 1991 on systems that can plan and schedule and systems that can learn to improve their work and performance automatically. Such systems will find tasking applications in advanced surveillance and target acquisition systems.

Radars, optical, and IR systems must be able to distinguish their targets from ground clutter and other signals, even in the midst of complex, rapidly changing battlefield environments. Begun in 1983, this program relies heavily on technology and experienced gleaned from other DARPA research, particularly programs involving parallel computing.

In 1991, with funding of over $100 million, the program will also concentrate on achieving a number of milestones, including the following:

- Demonstrate a new generation of vision system that integrates motion detection modules, terrain modeling modules, and sensor fusion processing in near-real time
- Develop a system for real-time continuous speech recognition with a 1,000-word vocabulary, which adapts rapidly to a new speaker
- Develop a computing system capable of 100 billion operations per second (bops)
- Develop a scalable parallel computing system combined to yield heterogeneous parallel computers
- Develop a flexible planning and scheduling system capable of rapid modification in resource-constrained dynamic applications

Organizations involved in this DARPA program include: General Electric, Bolt, Beranek and Newman (BBN), Carnegie-Mellon University, Stanford University, Intel, David Sarnoff Labs, and Texas Instruments.

Parallel Processing

The average speed of computers has increased 50 percent annually for the last 30 years. As the hard fundamental speed limits of materials used in computers is approached, researchers are consistently moving toward parallel systems. By late 1990, the parallel computing market was estimated to exceed $180 million and, according to a variety of estimates, growing at a rate of 20 to 50 percent annually. The DOD, which spent only $250 million on parallel architecture from fiscal 1986 through fiscal 1990, now plans to spend $860 million during the next five years.

DARPA began pursuing parallel processing technology in 1983, and its programs have been remarkably successful to date. For example, by mid-1990 DARPA-sponsored parallel computers were 35 times more cost effective, 143 times more power efficient, and 7 times more volume efficient than was the AT&T Aspen DS P3 conventional supercomputer.

These systems are finding military applications in two broad fields. First, these powerful machines are used in advanced weapon systems design. Second, in the near future, large platforms will be able to carry parallel computing systems to execute calculations unimaginable a few years ago while in an operational status. These calculations can be used to identify, track, and, if necessary, coordinate attacks on unknown targets. These systems will also be necessary if the ideas of smart skins and smart hulls ever become a reality.

A handful of companies currently dominate the military parallel computer market, but as the nondefense market segment expands in aerospace and petroproducts, competition, as in the conventional computer market, is likely to become increasingly stiff.

In 1990, BBN had a great deal of success in marketing its TC parallel-processing machine series. Lawrence Livermore Laboratories is using the TC1200 as part of a three-year $10 million program to explore the uses of multichip computers. In addition, Livermore Lab gave BBN $4.5 million to assist in the development of a new computer with 126 chips. BBN also received a contract from CERFACS, a French research institute, to deliver TC2000 systems.

Harris continues to provide multiprocessing computers for a variety of defense-related functions. The Harris Night Hawk series of computers is a new generation of multiprocessing computers with real-time performance. They are compatible with industry standards and Ada programming language. All three models (1200, 3000, 7000) use the Motorola MC 68030 processor, which operates at 25 MHz. More than 100 Night Hawk 1200 supermicrocomputers were supplied to the air force in 1989 as part of a Quintron Corp. contract. In 1990, an award was made to use Night Hawk 1200 computers to modernize air force simulators in the undergraduate pilot training instrument flight simulator program. The potential value of this contract could be more than

©1991 Dataquest Incorporated January—Reproduction Prohibited

$3 million. Night Hawk computers also will be used in aircrew training systems for the C-17 transport aircraft as part of a $421 million contract from the air force. In 1989, Harris was awarded a contract from McDonnell Douglas to supply a minimum of 40 Night Hawk 3000 supermicrocomputers to be used as weapon system trainers, flight trainers, and cockpit trainers. In 1990, it was announced that the navy's A-12 simulator program will use Night Hawk computers.

Night Hawks also have found a receptive foreign market. In March 1990, MBB announced its purchase of the 3000 series under a $1.5 million contract. The systems will be used for long-term training and simulation programs.

Sandia National Laboratory also employs numerous parallel computing machines. In 1990, this lab purchased an NCUBE Corporation 1,000 processor machine to compile a Soviet aircraft radar image library. According to press reports, the system accomplished its task in 2 minutes compared with the nearly 15 minutes taken by a Cray supercomputer, which cost about 13 times more.

Also in 1990, Active Memory Corporation produced a 4,096 processor massively parallel machine to be fitted into a Black Hawk helicopter for the Army Corps of Engineers. The system, which reportedly was purchased for over $350,000, is part of an experiment to use parallel processing machines to assist in the field detection of land mines in real time. This field use is just one of hundreds that parallel processing potentially can provide.

Other 1990 deliveries of parallel processing computers included a 64,000 processing Connection-Machine supercomputer to the Army Engineer Topographic Lab to support its image exploitation system. Connection-Machine also delivered the same computers to CINC-PACFLT to assist the navy in air threat planning. This computer allows the navy to perform calculations in seconds compared with the hours of calculation previously demanded. In 1990, Iwarp Corporation's multiprocessor signal processors were being used in seven defense areas, including Wright Patterson Air Force Base for relocatable target calculations, upgrading the F-15 with automatic target recognition, and at NADC for airborne early warning calculations and ASW signal processing.

The SDI program has been another source for the development of parallel computers, particularly miniature supercomputers. Currently two types of minisupercomputers are actively being pursued by Rockwell and Texas Instruments; these devices will play a key role in kinetic energy weapons of the future, such as HEDI and Brilliant Pebbles. These computers are no larger than a deck of playing cards and weigh just 75 grams, yet they can deliver computing capability equivalent to nearly 500 home computers and perform at 500 mops. These data compare with the fastest current-generation missile computers, which weigh over one-half of a kilogram and can deliver only 4.5 mops.

Another 1990 SDI program, which is under the direction of General Dynamics, took delivery of a 1-bop signal processor built by Space Computer Corporation. The processor, called the SCC-100, will be used to analyze and interpret data gathered by advanced IR sensors being developed by the SDI.

Future research expenditures will focus on the next generation of parallel processors, which DARPA hopes will achieve a 100-gflop performance by 1992. These systems will serve as the springboard for TeraOp computers, which will perform over 1 trillion operations per second by the mid-1990s and employ advanced microelectronic packaging such as hybrid wafer-scale integration, optoelectrics, GaAs, and ultralarge-scale integrated (ULSI) components.

Close to $350 million already has been spent on this next generation of computing systems, but some estimates indicate that the program could run as high as $1 billion. The Touchstone project, run by the TeraOps project office in DARPA, seeks to develop a processing system capable of 100 bops, or 2,000 times faster than the CRAY-1 supercomputer. Intel received an $8 million contract as part of the program in 1989. The Touchstone supercomputer will use Intel's i860 microprocessors. DARPA intends to use up to 2,000 of these microprocessors in a network. Development funds will be used for system software, a high-speed communications network, and advanced packaging technology that will allow the computer to operate in an air-cooled environment in contrast to the liquid-cooled environments that most advanced supercomputers operate in today. Intel expects to spend $20 million of its own on the computer, scheduled to complete the prototyping phase in 1991.

Another future program goal will be to reduce the size of these advanced systems. DARPA officials believe that computers with gflop capability can be reduced to the size of a soup can for placement in smart weapons by the end of the decade.

©1991 Dataquest Incorporated January—Reproduction Prohibited

While the capability of processors steadily increases, the capability of memory is becoming another potential constraint; advanced processors require equally advanced memory in order to operate effectively. In 1969, AT&T scientists discovered 3-D magnetic bubble memory. In 1990, the effective and efficient use of 3-D bubble memory became a DARPA goal to be achieved in five years. Other advantages to this technology include the facts that there are no moving parts, and that the memory is both nonvolatile and inherently radiation hardened.

Neural Networks

These systems use massively parallel computing architectures patterned after the structure and functioning of the human brain. To date, these systems have been concentrated on recognizing and classifying patterns such as sonar signals, voice recognition, target recognition, and word spotting in communications intelligence.

Neural networks will be exploited increasingly to provide a critical edge as a force multiplier in smart weapon systems, surveillance systems, and command-and-control systems of the future. In addition, neural networks can be combined with processors for complex speech recognition, which could aid future combat pilots.

Neural networks are a kind of knowledge representation and processing scheme. Based on the biological paradigm for computing, neural networks consist of many processing units (nodes or neurons) that are connected to each other and operate simultaneously, in contrast to the CPUs used in classical Von Neumann digital processors today, which calculate in a serial fashion. Neural networks, in contrast to pure parallel processors or expert systems, do not use algorithms or calculating rules, but rather compare inputs and outputs, developing their own mechanisms for transforming inputs into correct solutions. This process may succeed where digital processing and algorithmic processing have failed, particularly in the fields just mentioned. The neural network is able to screen out unnecessary or poor input based on what it has learned from human experts.

This "automatic learning" frees human programmers from many of the fine details that make software development so labor-intensive and problematic. In addition, neural networks exhibit noise tolerance and automatic generalization properties, both of which make neural networks ideal for intelligence monitoring.

DARPA continues to focus funding into four types of neural networks: the spatial situation recognizer, the missing parts reconstruction mode l, the time-line recognition model, and a combination of these three. Rome Air Development Center has funded the first type of neural network, and the navy has awarded funding to AT&T for the Aspen project to develop a neural network for speech recognition. Lincoln Laboratory is continuing DARPA-sponsored work in automatic target recognition.

Other ongoing neural network projects include research at the Jet Propulsion Lab into an analog-digital hybrid neurocomputer, and TRW's Mark III Neural Network. The Jet Propulsion Lab project uses high-density random access memory (RAM) to store information and analog "neurons," or processors. TRW has designed the Mark III as a coprocessor for the VAX/VMS. The Mark III will implement networks of up to 65,000 neurons, with 1.1 million interconnects and speeds 25 times greater than that of a MicroVAX II. The Naval Research Lab currently is working on a sixth-generation computer, which will incorporate 100,000 neural network nodes, optical computing, and superconducters. The goal of the program is a processing speed of 10 billion flops.

Semiconductor Materials and Microelectronic Circuits

DOD research into this area ranges from developing advanced compound semiconductor materials to developing manufacturing processes such as X-ray lithography. The DOD breaks down semiconductor-related funding into five basic areas: materials, manufacturing, test and assembly, design, and applications.

Semiconductor Manufacturing Technology (SEMATECH)

SEMATECH continues to be one of the most successful and popular DARPA programs. The SEMATECH consortium focuses on developing manufacturing tools and processes such as X-ray lithography and, more generally, submicron lithography, for the near term. The program, established in 1987, has consistently been funded at $100 million by the government and will be again in 1991.

In 1991, the SEMATECH program plans to construct and equip a Phase III factory to develop 0.35-micron

©1991 Dataquest Incorporated January—Reproduction Prohibited

DRAM and SRAM unit processors and develop additional programs with materials and equipment vendors to develop next-generation materials consistent with 0.35-micron production. The manufacturing milestone for this advanced production is scheduled for August 1994 and is reportedly is on time and within budget.

Microwave/Millimeter Monolithic Integrated Circuits (MIMIC)

A growing number of military systems depend on sophisticated sensors for operation, but analog circuitry for such sensors continues to be very expensive. The MIMIC program, launched in 1986, is meant to reduce the cost of these components by making advanced sensor technology more widely available and affordable. The means for this improvement is monolithic solid-state technology using exotic materials such as gallium arsenide (GaAs). In addition to operating at higher frequencies (1 to 300 GHz), GaAs offers the advantages of greater radiation hardness than does silicon, extremely low-noise signal amplification, and wide temperature operating ranges. Industry observers predict that individual defense programs could require as many as 200,000 GaAs chips per month by the late 1990s. One of the earliest commitments for use is for the HARM missile program, which alone could account for 1,200 MIMIC chips per month through the mid-1990s.

Like VHSIC, MIMIC technology will have broad applications in several military systems, as shown in Table 3.8. EW systems engineers are looking at GaAs MIMICs, particularly for their wider bandwidth capability, higher frequencies, and multifunction capability. Additionally, GaAs MIMICs offer better performance, functional integration, reduced system size and weight, and cost-effective production. Part of the success of the MIMIC program has been its active pursuit of applications for MIMIC technology.

The MIMIC program has been divided into four phases. Phase 0 consisted of a one-year study to determine the technological developments needed for successful design and manufacture of MIMIC products and identified the most promising system candidates. Phase 0 was conducted by 48 companies that grouped into 16 teams and was completed in February 1988.

Four teams were selected to participate in Phase 1, the first three-year hardware development phase. This phase will culminate in demonstrations of MIMIC hardware in an operational environment. Phase I tasks include material and technology development; design, fabrication, and demonstration of modules; development of CAD tools; identification of affordability barriers; and system brass-board demonstrations. Second sources will be selected for all components in this phase. Each Phase I team is to produce 79 MIMIC chip types, 23 assemblies of chips into circuit modules, and 16 assemblies of the modules into system demonstration brass-boards.

The teams and the amounts granted are as follows:

- Hughes/General Electric with E-Systems, AT&T, M/A Com, Harris Microwave, EEsof, and Cascade ($50 million)
- ITT/Martin Marietta with Alpha, Harris Government Systems, Pacific Monolithics, and Watkins-Johnson ($49 million)
- Raytheon/Texas Instruments with Aerojet, Airtron, Compact, Consilium, General Dynamics, Magnavox, Norden, and Teledyne ($59 million)
- TRW with Honeywell, Hittite, and General Dynamics ($57 million)

In late 1990, Westinghouse announced that it was joining the TRW team in preparation for the Phase 2 awards to be issued in 1992.

The MIMIC program is already achieving impressive results. By mid-1990, the cost of MIMIC chips was reduced from $20 per square millimeter to between $3 and $8 per square millimeter. Advanced MIMIC CAD workstations are now commercially available. Eighty MIMIC chip designs have been completed, and one-half have been fabricated with yields approaching 95 percent.

Another three-year phase (Phase 2) is continuing technological improvements in MIMIC, using more exotic materials with additional technology demonstrations. Phase 3 is running concurrently with Phases 1 and 2 of the program. Its activities center on ancillary research, including computer-aided circuit design and new testing approaches.

Like SEMATECH, MIMIC is very popular on Capitol Hill. Funding for the program continues to ramp up from about $50 million in fiscal 1988 to a fiscal 1991 authorized level of $106 million—$20 million over the requested level. Congress is hoping that the program can be accelerated.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Table 3.8

MIMIC Applications

Company	System Type	Army	Navy	Air Force
Allied-Bendix	Communication radar	Mark XV fuse Patriot	Mark XV	Mark XV
Ball	Communication radar	MILSTAR	MILSTAR airborne multimode	MILSTAR
Eaton	EW	MEDFLI	ALR-77	ALQ-161
E-Systems	Communications	GPS	GPS	GPS
Loral (Ford Aerospace)	Smart weapons	HARM, low-cost seeker	AMRAAM	
	EW	APR-39	Expendable decoys APR-39	ALR-46, -62, -74 APR-39
	Radar	Phased array	Phased array	Phased array
Harris	Communications	MILSTAR, GPS, anti-jam data links, JTIDS	MILSTAR, GPS, anti-jam data links, JTIDS	MILSTAR, GPS, anti-jam data links, JTIDS
Hittite	Smart weapons	MOFA		
Hughes	Smart weapons	TOW	OABM	AMMW
	EW		ASAP, expendable decoy	
	Radar	Firefinder	SBR	ATF, ATSR, SBR
ITT	EW	ALQ-136, LHX	ALQ-136, 165, INEWS	ALQ-165, INEWS
	Radar	ETAS Firefinder		ATSR, SBR
Loral	EW	RWR, expendables	RWR, expendables	RWR, expendables
Martin-Marietta	Smart weapons	SADARM, MLRS TGW	Low-cost seeker	Terminal guidance
Raytheon/TI	Smart weapons	SADARM, MOFA	HARM	Terminal Guidance
	EW			Active arrays
	Communication	MILSTAR, GPS	MILSTAR, GPS ICNIA	MILSTAR, GPS ICNIA
	Radar	ETAS, Patriot	SBR, shared aperture	ATSR, SBR
TRW	Smart weapons	SADARM, MLRS-TGW	Standard Missile	AMRAAM
	EW	MEDFLI	INEWS	INEWS
	Communication	MILSTAR, GPS	MILSTAR, GPS ICNIA	MILSTAR, GPS ICNIA

(Continued)

©1991 Dataquest Incorporated January—Reproduction Prohibited

Table 3.8 (Continued)

MIMIC Applications

Company	System Type	Army	Navy	Air Force
Unisys	Smart weapons	MLRS-TGW SADARM, STAFF		AMMWS
	Communications	Tactical radio	Tactical radio MMW spacelinks	Tactical radio MMW spacelinks
Westinghouse	EW	INEWS	ASPJ, INEWS	ASPJ, ALQ-131, INEWS
	Communications	GPS, JTIDS	GPS, JTIDS ICNIA	GPS, JTIDS, ICNIA
	Radar		ATA, ASAP	ATF

Source: Defense Electronics

Gallium Arsenide Research

Spurred by MIMIC's success, DARPA is pushing for speedy introduction of GaAs circuits in current military systems. This program seeks to demonstrate the near-term military utility of digital GaAs for upgrading currently fielded systems.

Fiscal 1991 funding for the program dropped marginally and stands at nearly $20 million. The fiscal milestones DARPA hopes to meet include demonstration of an AN/PRC-126 small unit radio, demonstration of an AN/APS-137 radar capable of double the current resolution, and demonstration of the fieldability of GaAs radio frequency memories to allow army and navy tactical aircraft to jam a new class of threat radars. In addition, DARPA will be placing a GaAs-based on-board processor into a classified military spacecraft.

Commercial businesses that focus primarily on digital GaAs systems include Vitesse, TriQuint, and Gigabit. Other contractors working with DARPA include Rockwell, Westinghouse, Texas Instruments, McDonnell Douglas, E-Systems, Martin-Marietta, AT&T, and Honeywell.

Although many of these companies got their GaAs start from military business, GaAs circuits are finding their way into advanced commercial applications. For example, the new CRAY 3 supercomputer will get its chips from Gigabit and Rockwell.

The air force also is sponsoring GaAs research. The Materials Lab at the Aerospace Systems Division is conducting a research and manufacturing program designed to improve the yield of GaAs chips and establish an optimal process for growing GaAs substrates. In the exploratory development stage, contractors include Cominco (now a division of Johnson Matthey Ltd.), AT&T, and Westinghouse. The air force has a separate program for GaAs manufacturing technology; here, Applied Solar Energy Corporation and Westinghouse are the contractors.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Chapter 4

Western European Military Electronics

Background

For over 40 years, the possibility of a major conventional war in Europe between forces of the Warsaw Pact and NATO has driven the defense spending of several European nations. In the West, each of the three most powerful European members of NATO—Germany, France, and Great Britain—has pushed its industrial sectors to produce more capable weapon systems on the cutting edge of technology so as to obtain comparative advantage over the numerically superior forces of the Warsaw Pact in time of war. During this period, the defense industries in these countries have enjoyed a unique status featuring stable and secure markets; in many cases, they are protected from competitive pressures from abroad.

Beginning with Soviet President Mikhail Gorbachev's December 1987 announcement of unilateral reductions in Soviet forces deployed in Europe, a series of dramatic events have greatly changed Western thinking and diminished popular concerns in Western Europe about the military threat posed by the Soviet Union and what remains of the Warsaw Pact. The transformation of East European Communist regimes into democratic political systems and free market economies, the unification of Germany, the emergence of seriously taken secessionist movements in the Baltic states of Latvia, Lithuania, and Estonia, and the stirring of democracy and economic reform in the Soviet Union itself have all contributed to the now nearly universal belief that whatever military dangers Western Europe faced in the past, those risks are now greatly reduced if not entirely gone.

Announcements of plans to reduce Soviet and East European military forces and slowdowns in military modernization programs, the successful demands by Hungary and Czechoslovakia to withdraw all Soviet forces from their countries, and repeated concessions by the USSR in arms negotiations in Geneva and Vienna have reinforced the impact of these political and economic upheavals on popular perceptions. People in Europe overwhelmingly believe that there is no risk of a European war and that resources used to deter or prepare for such contingencies can now be used for other purposes.

As a result, planning for military demobilization in Europe is taking place on a scale not witnessed since the draw-down of forces following World War II. Even before the negotiations on Conventional Forces in Europe (CFE) were concluded successfully, unilateral measures were being planned by virtually all nations that would go beyond the limits described in the treaty signed in Paris in November 1990, resulting in substantial decreases in force levels in the Central region.

Longer-Term Reductions

Even in the absence of further changes in the political structure of Europe, it is likely that much deeper cuts than those codified in the current CFE agreement will be implemented. The Soviets, for example, have already suggested a ceiling of 700,000 on all NATO and Warsaw Pact troops in all of Europe. (NATO alone currently has slightly more than 1 million.) In July 1990, President Gorbachev and German Chancellor Helmut Kohl agreed that a unified Germany would have armed forces of not more than 370,000 compared with more than 660,000, which comprised the armies of what had been the two German states.

Domestic economic needs and President Gorbachev's foreign policy strategy will cause the USSR to press for follow-on negotiations for deeper cuts. But arms control negotiations will not be the only factor causing reductions in U.S. and West European arms production requirements in the long term. For over 45 years, NATO has been dedicated to the defense of Europe from an expansionistic communist threat. With Soviet conventional military capabilities in clear decline and the Red Army increasingly preoccupied with maintaining order within the USSR itself, with the Warsaw Pact soon to be disestablished, and with Germany reunified, the very purposes of military deployments in Europe are being questioned. Such questions are certain to be raised in the new Congress, where the need for maintaining such a large presence in Europe has been debated for years.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Traditional export markets will also show signs of contraction throughout the 1990s. The United States defense industry currently relies on exports to account for about 24 percent of production; the export figure for the European industry is nearly 64 percent. For Europe, this figure accounts for nearly a $20 billion annual surplus in defense manufacturing sales to the developing world. With worldwide defense spending down, including in the developing nations, and with decreased production runs forcing per unit costs upward, both European and U.S. manufacturers will find the contracting export market increasingly competitive and less attractive.

Transition Period

European defense industries will undergo an enormous transformation over the next decade. In parliaments and capitals from Ankara to Oslo, politicians have begun reassessing the military threats posed to their nations' security and, more importantly to defense manufacturers, the military capabilities needed to meet those threats.

The likely fundamental transformation of European armed forces will not occur overnight. Although some of the elaborate and costly weapon programs planned during the buildups of the early 1980s will be stripped from national defense budgets in the early 1990s, few will be killed outright. A more probable outcome for West European armed forces is the same slow but steady decline in defense spending that is likely to be experienced in the United States. To some extent, this decline is due to the multiyear financial commitments required to develop defense systems; contractually, in Europe, cancellations often cost more than they save. But residual uncertainties about the course of events in the USSR also will cause many West European governments to delay potential cutbacks.

The following two subsections highlight major European weapon development programs. The first subsection describes the larger cooperative multinational programs that became so popular in the 1980s; the future of these programs is particularly grim. The second section highlights the direction of the larger defense programs in specific European nations. Table 4.1 summarizes these major European programs.

Table 4.1

Status of Principal European Programs

Missile Programs			
Missile	**Prime Contractor**	**Guidance**	**Status**
ALARM	British Aerospace	Marconi	Enter British service mid-1990s
ANS	Aerospatiale/MBB	-	In development to replace Exocet
Apache	Matra/Aerospatiale	-	In development
AS30 Laser	Aerospatiale	Thomson-CSF	French orders, exports expected
AS15TT	Aerospatiale	Thomson-CSF	
ASMP	Aerospatiale	Thomson-CSF	Upgrade planning under way
ASRAMM	British Aerospace/Hughes	-	Development continues, U.S. buy unlikely
Aster	Aerospatiale	Thomson-CSF	French naval use
Blowpipe/Javelin	Short Brothers	Short Brothers	British army, marines, export production
Crotale	Thomson-CSF/Matra	Thomson-CSF	Upgrade planning under way
Eryx	Aerospatiale	-	French production continues
Exocet	Aerospatiale	EMD	Continued production
Hades	Aerospatiale	SFENA	Replace Pluton by 1992, development continues
HOT	Euromissile	SAT/Eltro	Upgrade day/night launchers

(Continued)

©1991 Dataquest Incorporated January—Reproduction Prohibited

Table 4.1 (Continued)

Status of Principal European Programs

Missile Programs

Missile	Prime Contractor	Guidance	Status
M4	Aerospatiale	SAGEM/EMD	Deployed in 1994
Magic	Matra	SAT	Magic 2—possible U.S. aircraft use
MICA	Matra	ESD	Under development
MUSASRAAM	Euromissile (Aerospatiles/MBB)	SAT/Eltro	Milan 2 in production, 1991 exports to Kenya, U.S. evaluation
MISTRAL	Matra	SAT	Deliveries under way
Otomat	Matra/OTO Melera	Thomson-CSF	French-Italian use, upgrade planned
Rapier/2000	British Aerospace/Plessey	-	Upgrade development continuing
RBS.15	Saab/Bofors	-	Swedish and Finnish navel use
RBS.15 Bill	Bofers	-	Swedish army use, U.S. evaluation
RBS.90	Bofers	-	First deliveries in 1990
RM-5	Aerospatiale/MBB/Matra		Development continuing
Roland	Euromissile	Sagem, SAT	In production
S3 SSBS	Aerospatiale	EMD-Sagem	Upgraded, S4 planned
Sea Dart	British Aerospace	GE, Sperry	British use being upgraded
Sea Eagle	British Aerospace	Marconi	In service in Britain, India
Sea Skua	British Aerospace	Marconi	Ship-launched version in development
Sea Wolf	British Aerospace	Marconi	British use, new version ordered
Seacat	Short Brothers	Short Brothers	Export orders
Skyflash	British Aerospace	Marconi	Active radar upgrade
Starstreak	Starstreak	-	1990 production for Britain
Super 530D	Matra	ESD	In production
Swingfire	British Aerospace	-	Produced in Egypt
TriGAT	Euromissile Dynamics	-	In development

European Aircraft

Aircraft	Manufacturer	Status
Alpha Jet	Dassault-Breguet/Dornier	Cockpit, armament changes, possible exports
AMX	Aeritalia/Embraer/Aermacchi	Production continues
Egrett-1	Grab/E-Systems	Texting continues 1991, including "PRISMA"
EAP	British Aerospace	EFA text bed
Epsilon	Aerospatiale	Production continues
EFA	4 Nations	In development
HS.1102 Hawk	British Aerospace	Production continues, export sales
J35 Draken	Saab/Scandia	J versions to be upgraded
JAS-39 Gripen	Saab	Procurement decision postponed until mid-1991
Jaguar	Sepecat/Hindustan	Production continues in India
MB-339C	Aermacchi	Upgraded version available
Mirage 3/5/50	Dassault-Breguet	Retrofit market
Mirage 2000	Dassault-Breguet	Funds for 301 aircraft approved

(Continued)

Table 4.1 (Continued)

Status of Principal European Programs

Aircraft	Manufacturer	Status
	European Aircraft	
Mirage F1	Dassault-Breguet	Closing out production
Refale	Dassault-Breguet	Development continues
S.211	Siai-Marchetti-Agusta	In production
SF.260	Siai-Marchetti-Agusta	In production
SF.600	Siai-Marchetti-Agusta	Certified
Super Entendard	Dassault-Breguet	Navel version in development
Supersonic V/STOL	British Aerospace	Under study
Tornado	Panavia	Production continues
Tucano T.MK	Short Brothers/Embraer	In production
	Transport	
C-23 Sherpa	Short Brothers	In production
C212	CASA	Upgraded
CNN235	CASA/IPTN	French to procure 6 in 1991, Turkey orders 50 in 1990
DO.228-100/200	Dornier	152 ordered, Indian production
	ASW Patrol	
ATL 2	Dassault-Breguet	In production
CN235-MP	CASA/IPTN	In development
	Helicopters	
A109	Agusta	In production
A129	Agusta	In production
ALH	MBB/Hindustan Aero.	In development
BK.117	MBB/Kawasaki	Production of 3/month
BO.105 CB	MBB	Production of 3/month
BO.108	MBB	Prototypes
Ecureuil 2	Aerospatiale	50 to be procured through mid-1990s
EH-101	EH Industries	British, Italian, Canadian orders
Lynx	Westland	Upgrade available
NH-90	NATO	Definition complete
PAH-2/HAC-3/HAP	MBB/Aerospatiale	In development
SA330 Puma	Aerospatiale/Westland	In service
SA342 Gazelle	Aerospatiale/Westland	In production
SA365 Dauphin	Aerospatiale	In production
Sea King	Sikorsky/Westland	Phasing out by 1990
Super Puma	Aerospatiale	In development

Source: Dataquest (January 1991)

©1991 Dataquest Incorporated January—Reproduction Prohibited

Cooperative Multilateral Programs

Overview

Nearly 85 cooperative projects were begun in the 1980s, a time when NATO was striving to coalesce around common goals and develop armed forces that could function together effectively. Apart from the projects' impact on military capabilities, politicians from many member countries, particularly the United States and Britain, felt that cooperative programs added a necessary cohesion to NATO at a time of great flux in Europe.

In the United States, defense cooperation with the European allies was catapulted from a few token programs to nearly 85 after the passage of legislation sponsored by Senators Sam Nunn and John Warner in 1985, which set aside incremental defense funds for codevelopment programs with NATO allies. In Europe, the continuing movement toward economic cooperation and even integration, combined with domestic fiscal constraints, led to a rapid increase in joint ventures that often excluded direct North American participation. As intra-European trade barriers were lowered, this cooperation became increasingly company to company rather than government to government. The recent trend has been toward the creation of multicorporate ventures that cross national boundaries in Europe and away from government-inspired cooperative projects in which national companies contribute different elements of a common project but share little information or technology in doing so.

Economic pressures and the dramatic developments in Eastern Europe have played havoc with many of the largest cooperative programs, slowing nearly all and canceling many others. As nations are forced to reduce defense expenditures, they often look first to reducing multinational cooperative programs to ease the impact of cuts on domestic industries. This trend has already caused the cancellation of such major programs as the NATO frigate, the NATO Anti-Air Warfare System (NAAWS), the Autonomous Precision Guided Munition (APGM), and the MSOW, all of which were described just a year ago as surviving precariously.

The following paragraphs describe the major cooperative efforts under way that involve a significant investment in electronics.

European Fighter Aircraft (EFA)

The EFA is being developed jointly by Germany, Italy, Spain, and the United Kingdom. A multirole fighter, the EFA will feature fly-by-wire controls, stealth characteristics, composite materials, look-down-shoot-down radar, terrain-following capability, and multiple target-acquisition systems.

Development work on the aircraft has been divided among the four members of the Eurofighter consortium, according to the percentage of planes each country plans to buy: British Aerospace of the United Kingdom (33 percent), MBB of Germany (33 percent), Aeritalia of Italy (21 percent), and CASA of Spain (13 percent). A four-country agreement was signed in May 1988 authorizing FSD of the EFA, with contracts worth close to $8 billion signed in early 1989. By the end of 1990, it was estimated that nearly 75 percent of these development contracts had been let. Total development cost is $10.8 billion. Electronics manufacturers are the main beneficiaries of the EFA program, because avionics systems are expected to account for at least 60 percent of the total cost.

A four-country consortium has been formed to bid on design and production of the EFA's digital fly-by-wire flight control system. The consortium is made up of Aeritalia, Bodenseewerk Geratetechnik (Germany), GEC Avionics (United Kingdom), and Inisel (Spain). A group led by FIAR of Italy also was formed to develop the IR search and track system for the EFA. Other members of the group include Eltro of Germany and Thorn-EMI of the United Kingdom. A third consortium, including GEC Avionics, Teldix (Germany), Selenia (Italy), and Ceselsa (Spain), was awarded $100 million in 1990 to develop the head-up display; this contract is worth an estimated $360 million over its lifetime.

Of the EFA's components, its multimode pulse-Doppler radar has been the most controversial. The Eurofighter consortium planned to award a development contract in September 1988, but it was delayed for nearly two years. Two multinational industry teams competed for the program, which is worth $500 million in development alone through 1996. The first team was led by Ferranti Defense Systems (United Kingdom) and the second by AEG (Germany) and Marconi Defense Systems (United Kingdom). Ferranti's proposal, the ECR-90, was based on radars developed for Sweden's JAS-39 Gripen program that are now in service with Royal Navy Harriers. The ECR-90 uses a high-power signal processor that incorporates Ericsson's 32-bit D80A chip and has a computational throughput that is six times greater than the Hughes (United States) APG-65, the basis of the AEG proposal. The award for the advanced radar development was given to the Ferranti team in the summer of 1990. The total program cost of the radar will approach $1.8 billion.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Selecting a contractor for the EFA's aircrew training system has been more straightforward. Rediffusion Simulation (United Kingdom) won a contract from the U.K.'s Ministry of Defense for the second stage of a three-phase study in training analyses. The company will look at the most cost-effective way of integrating training devices with actual flight training.

It was also decided in 1990 that SD-Scicon Plc. will develop the Ada-based software for the aircraft under an $8.5 million contract, while DEC VAX/VMS systems will be used as the standard hardware platform for all software development.

Production of the EFA is scheduled to begin in 1995 with initial deployments in 1996, but procurement of the aircraft may be problematic. The program calls for 765 aircraft to be produced through 2005, with a strong possibility of additional sales to nations outside of Europe. Procurement of the 765 planned EFA is estimated to cost $36 billion.

In 1990, there was considerable concern that Germany would drop out of the program for a variety of internal political reasons. The prospect of financial penalties and political liabilities led to a renewed commitment to see the EFA at least through development. Procurement may be something else, however. Both Britain's and Germany's aircraft needs are declining as quickly as pressures are rising for defense budget cuts in both nations. Competition from the United States ATF and France's Rafale will limit foreign sales, moreover. Procurement prospects must be considered slim.

PAH-2/HAC-3GT/HAP Tiger Franco-German Helicopter

France and Germany continue to work together to develop and produce a new combat helicopter that is planned to be produced in the late 1990s. The Eurocopter team is led by MBB and Aerospatiale of France. The cost of the program (not including inflation) is projected at $8.5 billion, with development costs of $1.8 billion and production costs of $6.5 billion (tooling and finance costs round out the total). Taking price rises into account, the total cost will be $16.9 billion.

Two versions of the helicopter are to be produced—one for antitank missions and one for escort and fire support. Germany plans to purchase 212 PAH-2 antitank versions, and France expects to purchase 140 HAC-3GT antitank versions and 75 HAP escort versions. These targets are likely to slip, however, as the European political situation takes shape in the early 1990s. It was announced in mid-1990 that the helicopter's first flight was pushed back to April 1991.

Of the real procurement costs, $1.3 billion is earmarked for mission equipment packages, including navigation aids, observation equipment, weapon sights, fire control gear, and a mast-mounted avionics package. Three teams bid for the avionics and mission management development contracts valued at more than $100 million. ESD (France) and Litef (Germany); Bodenseewerk Geratetechnik, and Societe Francaise d'Instruments de Mesure (SFIM) (France); and a team made up of Crouzet (France), MBB's Dynamics Division, SFENA (France), and Teldix. In 1990, the contract was awarded to the third team with the following division of labor. Crouzet will produce the sextan strap-down inertial navigation computer and sensors; SFENA, the laser ring gyros; Teldix will produce the CMA 2012 pulse-Doppler radar; and MBB will produce the compact radio altimeter. France and Germany also will jointly develop IR charge-coupled device technology for the helicopter's optronic systems.

Deliveries are scheduled to begin in 1995 and 1996, but the program already has a long and difficult history. Both France and Germany are rumored to be waning in their support because of cost projections, which are much higher than originally expected. The increasing cost of the program, in fact, led Eurocopter to begin negotiations with the United Kingdom in 1990 to join the program. The United Kingdom has expressed a desire to procure 125 combat helicopters and is looking at the AH-64 Apache, the PAH-2, and the A-129 Agusta as alternatives. Eurocopter has aligned itself with Westland to enter the Tiger program in the U.K. competition; a win here may save the PAH program.

Tonal Light Attack Helicopter (LAH)

The Tonal LAH helicopter was in trouble for nearly two years before it was canceled by the four nations remaining in the program in late November 1990.

Italy, the Netherlands, Spain, and the United Kingdom announced the collapse of the program, which was to produce an improved version of the Italian Agusta A-129 Mangusta helicopter. A feasibility and cost-definition contract was awarded in May 1987 to Joint European Helicopters, a joint venture of Italy 's Agusta (38 percent), the U.K.'s Westland Helicopters (38 percent), the Netherlands' Fokker (19 percent), and CASA (Spain) (5 percent).

©1991 Dataquest Incorporated January—Reproduction Prohibited

Most decisions on major design options, including the choice of an avionics package, were to have been made in late 1988 but were delayed over disagreements on technical requirements.

Under the strain of defense budget cuts that equal one-half its $22 billion procurement budget, Italy sought a less expensive design than the one proposed by the United Kingdom and the Netherlands. In particular, Italy wanted to stick close to the A-129 Mangusta. It was announced in 1990, however, that the A129 is too light to carry the TriGat antitank missile and Stinger air defense missiles for which the LAH was originally designed. Meanwhile, Spain announced in 1990 that it may no longer need such a large investment in an antitank helicopter.

Technical dissaggrements, poor project coordination, a reduced threat, and increasingly tight defense budgets all contributed to the demise of this program.

NATO Helicopter for the 1990s (NH-90)

France, Italy, the Netherlands, and Germany are cooperating in the development of the NH-90, a twin-engine helicopter designed for both army utility missions (such as troop transport) and naval missions (such as ASW). Contractors for the project are Aerospatiale (36 percent), Agusta (36 percent), MBB (23 percent), and Fokker (5 percent).

The NH-90 program already has been delayed by funding uncertainties, particularly on the part of the German government. In 1988, for instance, the then-West German parliament cut 50 percent of planned funds for the NH-90. The project definition phase was authorized in 1989, but new concerns arose in early 1990 that the Italian government would not be able to meet its funding obligations. Also in 1990, it was announced that FSD costs had risen to $2.3 billion, with the first flight test still nearly two years away and initial operating capability not expected until 1997.

Current plans call for 712 NH-90 helicopters to be procured, with flyaway costs for the utility and naval versions projected at $11 million and $20 million, respectively. France was to have received 210, Germany 264, Italy 214, and the Netherlands 24. These figures were altered, however, by a November 1990 Italian decision to reduce its stake in the program from 36 percent to just 20 percent. In order to save the program, France decided to increase its own share to compensate for Italy's decrease.

The development program for the NH-90 focuses on the air vehicle and mission systems; engines will be supplied by the governments involved. Aerospatiale is building the main rotor, hubs, and blades, flight control, and mission systems for the utility version; Agusta is the prime contractor for the main gear box and mission systems for the naval version; MBB is building the tail rotor and avionics.

AEG, FIAR, NRC, and Thomson-CSF (the Netherlands) will compete for the naval radar, while AEG, Elettronica (Italy), and Thomson-CSF have formed a team to develop the EW system. Aerospatiale began flight trials in April to evaluate a fly-by-wire systems, SFENA supplied the computers for the system, and SAMM supplied the servocontrols.

Although the program has been wounded by the political situation throughout Europe and by internal budgetary constraints, it is likely to proceed, albeit at a slower rate and perhaps with fewer total purchases.

Battlefield Remotely Piloted Vehicle (Brevel)

In November 1990, the French and German governments announced their intention to proceed with this program despite a lack of funding from the Bundestag. Matra (France) and MBB formed a team in 1989 to develop this remotely piloted vehicle to perform battlefield reconnaissance; the team is known as Eurodrone.

The Brevel will use television cameras and/or forward-looking IR technology and will have a range of 30 to 50 kilometers. The system is also designed to provide battlefield intelligence for MLRS targeting. Matra will develop the ground system and optronic sensors, and MBB will design the vehicle. Total FSD costs are now estimated to exceed $350 million. Between 200 and 300 vehicles are expected to be procured.

TriGat Antitank Missile Program

A third-generation antitank missile (TriGat) is being developed by France, Germany, and the United Kingdom to replace existing Milan and HOT missiles by the mid-1990s. The program is being run by the Euromissile Dynamics Group, a Paris-based joint venture of British Aerospace, Aerospatiale, and MBB. Belgium, the Netherlands, and Spain joined the TriGAT program in 1989. Together they will contribute $43 million, or 5 percent of the development costs.

©1991 Dataquest Incorporated January—Reproduction Prohibited

A development contract was awarded in September 1988 for $1.3 billion. Two variants of the TriGAT are being pursued: a man-launched, medium-range (2.5km) version that will use a laser designator and be built by Aerospatiale, and a helicopter-launched, long-range (4km) version to be built by MBB. The medium-range version will incorporate a thermal imaging sight; the long-range version will have a passive IR seeker produced by Sofradir of France. The Satel group, which comprises Thorn-EMI, Eltro, and SAT, will develop the thermal imaging system. Work on the optronics for both systems has been awarded to British Aerospace; the contract for the firing units and active warheads has gone to MBB.

The medium-range missile will be in development for several more years at a cost of $300 million and is expected to enter service in the mid-1990s. Development of the long-range version will take longer and is not expected to enter service until the late 1990s at a cost of $900 million. The helicopter-launched version of the TriGAT was to be employed on the Franco-German PAH and Tonal LAH helicopters, but, as discussed above, such deployments may now be problematic.

Modular Standoff Weapon (MSOW)

This program is another large multinational cooperative effort. At one time, it involved seven nations, whose national support has slowly fallen apart.

Begun in 1986, this sophisticated air-to-surface missile was expected to be installed on Tornados, Hawks, F-15s, F-16s, and AV-8B Harriers. Three variants of the missile were ultimately to be produced: A short-range version (18 to 30 miles), a long-range (more than 100 miles) version for use against fixed targets, and a version for use against mobile targets.

The R&D phase was to begin with a contract award in September 1988 and last two and one-half to three years, but with the departure of France and Canada from the program in mid-1988, the schedule slipped to 1989. By mid-1990, nearly $400 million had already been invested in the program, with another $7 billion needed to fulfill the original procurement target of about 30,000 missiles. In late 1989, however, Italy dropped out of the program, as did both Britain and the United States; the three countries were to make close to 50 percent of the planned buy. Now only Germany and Spain are officially committed to the program, which is not likely to survive 1991.

Advanced Short-Range Air-to-Air Missile (ASRAAM)

The ASRAAM, currently in the concept-definition stage, is a wingless, IR-guided, fire-and-forget missile with an estimated range of 15km. Under development by European contractors as the next generation of air-to-air missiles for close combat, the missile is already five years behind schedule.

The ASRAAM was originally intended to replace the AIM-9 Sidewinder on Western tactical aircraft such as the EFA and ATF and was to complement the AMR AAM being developed by the United States. The program is led by the British Aerospace Corporation and includes Bodenseewerk Geratetechnik, Garrett (Canada), and Raufoss Ammunisjonsfabrikker (Norway). British Aerospace recommended moving to FSD in 1989, but the program was not, and still has not been, endorsed by the United States, which has a potential requirement for more than two-thirds of the planned 60,000 missiles to be produced. In mid-1989, a six-month-long major redesign of the $800 million program was authorized in order to address weight and drag problems.

The European partners are anxious to pursue the program, but without U.S. backing, the feasibility of doing so is problematic at best. By the end of 1990, the United States was sending strong signals that, although not definitely ruling out the purchase of ASRAAM, a decision to purchase the missile would not occur in this decade.

The signal came in the form of a U.S. Air Force and U.S. Navy agreement in October 1990 to develop long-range plans for upgrading the Sidewinder into the AIM-9R configuration. This announcement was a departure from earlier statements and is clearly an acknowledgment of both services' desire to avoid commitment to the ASRAAM. In addition, the Defense Authorization bill provides funds to develop an entirely new Sidewinder-based missile for the ATF.

The ASRAAM program is likely to linger through 1991, but with no definitive direction or scope and will eventually either assume a new, less ambitious form or be scrapped altogether by the remaining partners.

Multiple Launch Rocket System (MLRS)

The MLRS, built by LTV and deployed in South Korea, the United States, and Germany, carries 12

©1991 Dataquest Incorporated January—Reproduction Prohibited

conventionally armed rockets and supplements cannon artillery fire. A European consortium was formed in 1988 to build the MLRS for the European market and includes France, Italy, the United Kingdom, and Germany. France plans to buy 80 systems; Italy, 20; the United Kingdom, 67; and Germany, 200.

An international joint-venture company consisting of Diehl GmbH (Germany), Martin-Marietta (United States), Thomson-CSF, and Thorn-EMI completed component field tests for the terminally guided MLRS warhead in 1989. Diehl was responsible for the terminally guided, submunition signal processor electronics during the 51-month component demonstration phase.

The system's automated test equipment will use Hewlett-Packard's ATS 1000 system. Another development for the European MLRS is the incorporation of a new signal processing technique, Doppler-beam sharpening, to increase the resolution of the mm-wave radar. In June 1990, Huntington Engineering Limited (U.K.) was given $470 million to integrate the warheads for the second phase of the program. This program is solid.

Family of Antiair Missile Systems (FAAMS)

Europe is persuing FAAMS in order to break the U.S. monopoly on air defense missiles. Eurosam, a French cooperative effort including Thomson-CSF and Aerospatiale along with British Aerospace and Ibermissile, a Spanish consortium consisting of Construcciones Aeronautics, Celesa, Inisel, and Ensa, have joined forces in the effort. Designed to replace Raytheon's Hawk missile system over the next ten years, the program has a potential worth of about $10 billion.

In addition to FAAMS, which is just beginning Britain and Spain are examining a derivative known as the Local Area Missile System (LAMS). This system would provide antiair cover within a ten-mile range and may if produced fill both Spain's and Britain's needs for a new surface-to-air missile.

The FAAMS is still in a relatively formative stage, with Britain beginning a 24-month study in 1990 to determine if it wants to remain in the program. In short, the program will continue to garner a limited amount of R&D funding in the early 1990s, but it is unlikely that any decision to proceed with FSD would occur before 1995.

European National Programs

Virtually every nation in Europe can produce some types of sophisticated military hardware. Some of the key national programs are described in the following paragraph. Table 4.2 is a summary of non-U.S. NATO defense spending.

France

Overview

Mounting pressure by the National Assembly has forced the 1991 French defense budget to decline marginally from its 1990 level of $32.5 billion, the first such decline in many years. Plans are now under way to reduce midterm spending projections substantially. Approximately 30 percent of the French defense budget ($10 billion) is spent on R&D, 48 percent ($16 billion) on procurement accounts, and 22 percent ($7 billion) on operations and maintenance.

Like the United States, France has opted in the short term to stretch existing programs to accommodate restrained budgets rather than to cancel develop mental or procurement programs outright. Longer-term reductions may cause the cancellation of major strategic programs, however, including a previously planned intermediate-range ballistic missile and a nuclear-capable strike aircraft.

Rafale Aircraft

France dropped out of the EFA program in 1986 to pursue its own new fighter, the Rafale, for both domestic use and export sales. The Rafale will serve primarily in an air-defense capacity for France, which will rely on the Mirage 2000 for strike roles. The Rafale will be armed with an antiradar missile, laser-guided air-ground missiles, and the MICA and Magic 2 air-to-air missiles. The Rafale also will incorporate terrain-avoidance capabilities, with track-while-scan radar and simultaneous ground attack/air defense scan modes.

The aircraft is being developed by Avion de Combat European (ACE) International, a joint company established by the four primary Rafale contractors—Dassault-Breguet (60 percent), SNECMA (20 percent), Thomson-CSF (10 percent), and Electronique Serge Dassault (ESD) (10 percent). Dassault-Breguet is building the airframe, and SNECMA is manufacturing the M88 engine for the Rafale.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Table 4.2

NATO National Defense Spending
(1990 Conversion to Billions of Dollars)

Nation*	1988	1989	1990
Belgium	2.80	2.58	2.89
Canada	8.83	9.48	10.19
Denmark	2.01	1.92	2.19
France	30.70	28.58	33.03
Germany	29.17	27.46	31.02
Greece	2.49	3.17	3.79
Iceland	NM	NM	NM
Italy	16.13	16.69	18.98
Luxembourg	0.07	0.08	0.09
Netherlands	7.05	6.69	7.47
Norway	2.93	2.97	3.35
Portugal	1.27	1.25	1.24
Spain	6.54	6.91	7.98
Turkey	2.04	1.83	3.28
United Kingdom	33.76	33.41	33.40

*In order to secure the most current figures, this table is based on individual national definitions of defense budgets and not on the NATO standard definition.
NM = Not meaningful
Source: IISS Military Balance

In 1990, a $440 million contract was given to Thomson-CSF and Electronique Serge Dassault to develop the Spectra ECM system. With a potential lifetime worth of more than $1.5 billion, the current contract covers prototypes and flight testing. The Thomson-CSF and ESD RBE 2 radar will feature a passive, electronically scanned Radant antenna. Based on a programmable signal processor operating at 1 gflops, the radar will have simultaneous bidirectional scanning. Avionics will include a GPS navigation receiver by Crouzet, a main mission computer by ESD and Sagem, a Sigma RL 90 gyrolaser for the inertial navigation system by Sagem, and a holographic head-up display, eye-level display, and radant antenna by Thomson-CSF.

Rafale development is expected to cost approximately $6.4 billion, with close to one-half that amount to be spent by the end of 1991. The first prototype is scheduled to fly also in 1991, with FSD beginning in 1994 and introduction to operational units in 1996.

Production of 336 aircraft is estimated to cost close to $16 billion; contractors can count on exports to raise their revenue base significantly. This program is solid.

Atlantique 2 Maritime Aircraft

Manufactured by Dassault-Breguet, the Atlantique 2 (ATL 2) aircraft is a much-upgraded version of the original plane that has been flying in the French fleet since the 1960s.

Procurement of new subsystems is proceeding; however, with the general slowdown in defense spending, the program is being stretched and may now extend beyond the year 2000. The new equipment on the aircraft will include a GEC Avionics AQS-902C sonobuoy processing system and a Thomson-CSF Lguane radar system.

Mirage 2000

This system was selected in 1975 as France's primary combat aircraft through the 1990s. The air force plans to acquire 169 air-superiority 2000Cs and 23 2000B two-seat trainers. At the beginning of 1991, funds had been committed for 146 2000C and all 2000B aircraft. Another version, the 2000N, is a tandem two-seat attack aircraft intended for nuclear as well as conventional

©1991 Dataquest Incorporated January—Reproduction Prohibited

roles. A total of 180 2000Ns are still planned by the French government, although this amount should now be considered fluid; 132 2000Ns had been funded through 1990.

Mirage 2000s are now equipped with SNECMA M53-P2 afterburning engines and RDI pulse-Doppler radars. The aircraft are also equipped with a Sagem Uliss 52 INS, Matra Spiral passive countermeasures, Thomson-CSF Serval radar warning receivers, and Thomson-CSF and ESD electronic countermeasure jammers and chaff and flare dispensers.

Annual procurement dropped from 32 to 28 in 1991, with additional slippage possible.

Major Missile Programs

In 1975, France began to explore the possibility of breaking into the expansive international air defense market, which was until then dominated by U.S. weapons. In 1983, Thomson-CSF and Aerospatiale were assigned to conduct a series of surface-to-air missile feasibility studies and, in 1986, the French government decided to proceed with program development.

A 1987 decision outlined three missile systems to be explored: the SAAM, a short-range surface-to-air missile; the SAMP/T, a land-based, medium-range surface-to-air missile; and the SAMP/N, a navy version of the SAMP/T. Contracts were originally awarded for all three systems to the two companies that conducted the 1983 study, but in June 1989 Aerospatiale and Thomson-CSF joined with Selenia to form EuroSam.

In mid-1990, the French government authorized EuroSam about $1.8 billion to complete development of the SAAM and SAMP/T within ten years and about $20 million to complete development of the SAMP/N within the same time frame. Selenia will receive 50 percent of the contract, with the remainder to be split evenly between the two other companies.

The fates of two other major missile programs, the S-4 mobile land-based strategic system and the Hades short-range missile, have diverged. Both programs have nuclear roles. In August 1990, President Francois Mitterand decided to proceed with the short-range nuclear missile, to the surprise of many. The program originally called for 120 missiles but reportedly has been scaled back to 50. The missile will be produced by Aerospatiale with Thomson-CSF producing the communications equipment. In October 1990, the French Defense Ministry decided to cancel the S-4 in order to avoid budgetary pressures in the late 1990s.

France continues to remain committed to upgrading its fleet of sea-launched ballistic missiles (SLBMs). The current fleet is being upgraded so that each submarine will carry 16 M4 missiles, each of which carries six independently targeted warheads. The M4 will replace the current-generation single-warhead M20 nuclear missiles. When the program is complete, France will have a total of 496 SLBM warheads.

Ships and Shipboard Equipment

The first *Charles de Gaulle*-class nuclear-powered aircraft carrier was originally scheduled for commissioning in 1996 but it appears that its introduction into the French Navy will be delayed until at least until 1998. The first sections were assembled at Brest Naval Dock yard in mid-1989. France plans to procure two carriers of this class to replace the *Foch* and Clemenceau conventionally powered aircraft carriers.

France's nuclear-powered attack submarine program will continue apace in 1990 with all 13 *Rubis*-class SSNs now on order. The final submarine of the class will enter into service sometime after 1995; a follow-on program is planned for the next century. DCN is the program manager; other contractors include Technicatome for the nuclear reactor, Thomson-CSF for the communications equipment, Sagem for the control station, search-and-attack periscopes, integrated navigation system, and data management, Creusot-Loire for the sheet steel, and Merlin Gerin for the electric equipment.

The first of a new generation of nuclear-powered ballistic missile submarines, *Le Triomphant*, is under construction and is planned to enter service in mid-1994.

LeClerc Main Battle Tank

The fiscal 1991 budget witnessed another reduction in the LeClerc tank program. The original goal was to procure 1,400 tanks, but that figure has now dipped to 1,050 and may fall again during 1991 as East-West tensions continue to ease. Expected to enter service in December 1991, 65 percent of the $4.5 million tank's cost is allocated for electronic systems. GIAT is the prime contractor. Major subcontractors include Thomson-CSF for electronic integration, ESD for the main computer, CSEE for the on-board video equipment and electric motors, Sagem for the gunner's sight, and the LaCroix defense division of GIAT for the countermeasures system.

©1991 Dataquest Incorporated January—Reproduction Prohibited

United Kingdom

Overview

The United Kingdom issued its five-year defense plan in July 1990, emphasizing flexibility and mobility in both systems and procurement planning along with a 3 percent real decline in defense spending for 1991. Overall, the plan called for approximately $1.2 billion in defense cuts. The army will absorb nearly $320 million in cuts, the navy $340 million, and the air force nearly $400 million. A further $140 million will be taken from the research and general defense budget accounts.

As is the case for other European nations, a large portion of the proposed cuts will be taken in manpower; the British Army of the Rhine in Germany is slated to be halved into two divisions over five years with an overall reduction of 60,000 in troop strength by 1995.

Current plans call for the Royal Navy to retain three aircraft carriers, although the replacement once sought for the light carrier, HMS *Invincible*, now is likely to be delayed. The navy also plans to settle on a target figure of approximately 40 destroyers and frigates; necessary cuts will be accomplished by phasing out older vessels while stretching delivery of the *Duke*-class frigates being launched by Yarrow Shipbuilders.

The impacts of budgetary cuts on major procurement programs are highlighted in the following paragraphs.

Tornado Aircraft

In mid-1990, the British government announced cancellation of a previously planned purchase of 33 new Tornado attack aircraft. Modifications of existing Tornados are continuing, however.

The midlife update program for the Tornado GR.1 strike/attack aircraft will cost approximately $204 million in development over several years; the aircraft will be designated GR.4 when completed. Among the improvements are a GEC forward-looking IR system, Ferranti night-vision goggles, a Smith head-up display, a Marconi radar warning receiver, a GEC Spartan terrain navigation system, and a Ferranti terrain-following system. All weapons will be compatible with the MIL-STD-1760 architecture. Marconi also will supply new radar and the Sky Shadow jammer to upgrade the Tornado's EW capability. The upgrades are scheduled to be fielded beginning in mid-1991.

The air-defense version of the Tornado, known as the Tornado ADV, also will continue to be upgraded through 1991. A total of 170 aircraft are in the RAF fleet, but at this time it is unclear how many will not be upgraded as a result of the July 1990 announcement of the intent to limit the number of ADVs quadrons to seven. The upgrade for the ADV is scheduled to include a new computer and tracking system software.

Harrier Aircraft

It was announced in late 1990 that the planned upgrade of 58 RAF Harrier G.5 aircraft to the G.7 configuration also will continue. The upgrade remained in doubt for some time and is good news to British Aerospace, which received a $32 million contract in 1990 to provide new avionics and all-weather day/night capability to the aircraft. Other contractors involved in the upgrade include GEC Sensors for the FLIR, GEC for displays, Ferranti for crew night vision equipment, and Smith's Industries for the head-up displays.

Additionally, in March 1990 British Aerospace received an order to begin construction of ten more Sea Harriers in a $170 million contract. These aircraft are to be outfitted with the Ferranti Blue Vixen radar.

Sea King and Lynx Helicopters

Upgrades of the Lynx and Sea King helicopters will continue in 1991. Ferranti was awarded a $17 million contract to provide Lynx helicopters with the AWARE radar warning receiver. The Lynx also will receive new sensors such as the GEC Sea Owl thermal sensor and the CAE/Normalair-Garrett magnetic anomaly detector. The Mk 6 version of the Sea King began service in mid-1989 with the addition of GEC's AQS-902G-DS processing system and Plessey's Type 2069 improved dipping sonar.

ALARM

The key British missile programs currently in development are the air-launched antiradiation missile (ALARM), the antiradiation drone, and the low-level laser-guided bomb. British Aerospace developed the ALARM for Harrier, Jaguar, and Tornado aircraft, but it has encountered several setbacks. Since the failure of the original motor to meet specifications, the introduction date for the missile has slipped to the mid-1990s. The missile will use a Marconi seeker and be equipped with a Thorn-EMI laser proximity fuze and MBB high explosives.

©1991 Dataquest Incorporated January—Reproduction Prohibited

Main Battle Tank

For over two years, the Ministry of Defense has debated the follow-on to the aging Vickers Challenger main battle tank. Three foreign companies—General Dynamics with its M-1, GIAT with its LeClerc, and Drauss-Maffeiwith its Leopard 2—all are vying for a chance to sell up to 400 tanks to meet Britain's tank requirements in the 1990s.

In 1988, the ministry granted funds to Vickers to develop the Challenger II, which was to compete with the foreign tank manufacturers in a winner-take-all program. Since that time, nearly $300 million in additional funds have gone to Vickers in an effort to make the Challenger II more competitive against its well-established foreign competition.

The final decision was to be reached in December 1990, but in November the Ministry of Defense announced yet another delay, perhaps until mid-1991. This delay should help Vickers, which will likely be able to complete full development of the Challenger II before then.

Training Systems

The government announced in April 1990 its intention to embark on a comprehensive campaign to procure advanced training systems for land-based forces, one of the few new programs to emerge from the British Ministry of Defense in 1990. At the time of the announcement, nearly $445 million had been earmarked to pursue the program. The initial purchase will be the Direct Fire Weapon Enhancement Simulation (DFEWS), which is to be a laser-based, eye-safe trainer.

Four teams have announced their intention to bid on the system. Loral Solartron (United States), the maker of the MILES training systems; the British Aerospace subsidiary, Royal Ordinance; Marconi C2 Systems, based on the Dx175 training system used in France; and SAAB Training System of Sweden.

Germany

The German defense situation is in complete flux. The disappearance of the Berlin Wall and the disintegration of the Warsaw Pact, combined with the economic upheaval associated with the integration of the former East Germany, have created a great deal of uncertainty in Germany's defense priorities. The main determinants of decisions in 1991 will be increasing internal pressures on the Bonn government to drastically reduce defense spending, commitments to the USSR to reduce the size of the combined German armed forces, and a thorough antimilitarism within Germany itself.

Chancellor Kohl met with Soviet President Gorbachev in mid-1990 and agreed to limit the overall size of German forces, including the former East German soldiers accepted into the Bundeswehr, to under 370,000. By the end of 1990, however, it was evident that troop strength would almost certainly fall below that number. In 1989, the combined strength of East and West German armed forces exceeded 600,000.

Precise figures for the 1991 defense budget remained unresolved at the end of 1990 with estimates ranging from $30 billion to $40 billion. The final budget is likely to be closer to the lower figure, representing a real decline of several billion dollars.

The programs to be hit the hardest will be long-term procurement accounts such as the Leopard II main battle tank, which has already been halved from a planned procurement of 600. Germany's decision to remain in the EFA consortium, at least through development, will drain a great deal of potential financial resources from other programs over the next several years.

One of the only large procurement programs likely to proceed anywhere near schedule is the Frigate 123 program. Four of these advanced ships were approved in late 1989 at a cost of $308 million each. The first ship will be delivered in 1994. In mid-1989, Hollandse Signaal Apparaten (the Netherlands) was selected to provide radar equipment for the frigates after intense competition with Hughes Aircraft and Plessey. Signaal's system combines the LW08 high-power, long-range, D-band surveillance and target indication radar with the SMART F-band acquisition radar and the Signaal Track and Illumination Radar.

In 1990, Unisys was selected to install the shipboard computers built by Krupp Atlas Elekronik. Other contractors include AEG for the FL-1 800S Step II Electronic Warfare system and optical laying devices, Anschuetz and Teldix for the navigation systems, Krupp Atlas Elektronik for the sonar system, and Hagenuk, Rhode, & Schwarz for the communication equipment.

Italy

Overview

The Ministry of Defense had ambitious plans for defense spending as recently as late 1989, calling for

©1991 Dataquest Incorporated January—Reproduction Prohibited

real increases throughout the early 1990s. But Italy, like other European countries, will experience a real decline in defense expenditure in 1991. Italy's government had originally announced a cut of $970 million from total procurement spending of just $4.1 billion, but even this amount was not enough. Toward the end of 1990, the cut was increased to $1.4 billion—more than one-third of the total.

Hard programmatic decisions are being postponed with the government opting instead to slow and stretch programs. The only major system to be canceled outright was the planned procurement of 16 Panavia Tornado Electronic Combat and Reconnaissance aircraft, which will preclude the eighth lot from being produced. This sale would have been worth $852 million.

AMX Fighter Aircraft

The largest Italian procurement program is the AMX tactical fighter, developed jointly with Embraer of Brazil. The Ministry of Defense continues to preserve this program despite forced cuts elsewhere. A total of 17 aircraft are on order by both Italy and Brazil. Aeritalia and Aermacchi contracted FIAR to provide the GRIFO ASV multimode radar for the Italian version of the fighter. Italy had hoped that the AMX would be in service in 1991, but this date is likely to slip to mid-1992. The AMX will supplement the Tornado attack aircraft in the maritime strike role.

C-1 Ariete Tank

The Ariete main battle tank marks a decisive move for Italy away from the foreign licensing practices of the past. The first prototype of the C-1 was manufactured in 1986; all six prototypes were completed by 1989. OTO-Melara, the prime contractor, has teamed with Iveco Fiat for full-scale production. Melara will be responsible for the body of the tank, and Fiat will focus on the turret and weapons. The C-1 will incorporate the Officine Galileo Tank Universally Reconfigurable Modular System. The Italian Army plans to begin initial production in 1992, with total procurement between 200 and 250 tanks. Although the Ministry of Defense has made no indication regarding this program's possible cancellation, there is wide speculation that, at minimum, it will be slowed and scaled back.

SICRAL

Italy also remains publicly committed to invest $637 million to launch the Satellite Italiano per Comunicazione Rapide e Allarmi (SICRAL), its first military telecommunications satellites, by 1994. Development of the satellite, the prime contractor for which is Selenio Spazio, carries an estimated cost of $159 million; procurement and launch will run another $478 million. The two planned satellites will use UHF, SHF, and EHF bands. The satellites also will serve as the national emergency telecommunications system.

CATRIN

Last year, a consortium of six major Italian companies was awarded a $650 million contract to design and develop CATRIN, an advanced network of sensors and communications gear for surveillance, targeting, fire control, and data management on the battlefield. Italtel, Marconi Italiana, and Telettra are responsible for the communications subsystem (SOTRIN), Agusta and Selenia for the air defense subsystem (SOATCC), and Aeritalia for the surveillance and target acquisition subsystem (SORAO). The Italian defense budget continues to call for approximately $90 million to be spent for CATRIN in 1991, although this figure is considered fluid.

Norway

Overview

Norway historically has expended more per capita on defense than any other Western European nation. However, Norwegian defense expenditures also are likely to fall precipitously in 1991. In addition to the international situation, domestic politics will weigh heavily on defense procurement decisions. In November 1990, the Conservative government lost power to a coalition controlled by the Socialists, who have typically been more willing to lower defense expenditure. Still, programs already under way, such as the F-16 upgrade that will feature General Dynamics upgrade kits with Westinghouse APG-66 radars, can be expected to continue. Two other well-established programs are described as follows.

Norwegian Advanced Surface-to-Air Missile System (NASAMS)

The NASAMSs will adapt Hughes' AIM-120 AMRAAM for surface-to-air use as part of the Norwegian southern air-defense system upgrade. The system will comprise four fire units, each containing a mounted fire-direction center, produced by Norsk

©1991 Dataquest Incorporated January—Reproduction Prohibited

Forsvarsteknologi A/S (NFT) and equipped with a Hughes TPQ-36A tactical air defense radar. Three of the units to be procured will each control three separate launchers capable of firing six AMRAAMs; the fourth will operate with Bofors L/70 guns.

The second phase of this $215 million contract was authorized in April 1990 and will lead to a production decision in 1992. HKV, a joint venture of Hughes Aircraft and NFT, is the prime contractor. Hughes will act as the systems integrator, conducting flight tests and analyses and developing system specifications. NFT will analyze and modify software and develop launcher specifications.

Penguin Mk 3

NFT began series production of the air-launched Penguin Mk 3 antiship missile in mid-1989. This third-generation antiship weapon will be used on Norway's F-16 A/B aircraft. The Penguin Mk 3 features a passive IR seeker and a 265-pound high-explosive armor-piercing warhead with a range of more than 25 miles.

Sweden

Sweden considers itself a neutral nation and therefore does not belong to NATO. Heavily armed for its size, Sweden's defense budget was nearly $5.5 billion in 1990. Sweden also supports an independent arms industry to ensure its neutrality. The 1991 defense budget is expected to decline to about $5 billion.

By far the most significant Swedish program is the much troubled, fourth-generation fighter program known as the JAS-39 Gripen. The program was already behind schedule and over budget when a prototype plane crashed and burned on landing in 1989. The accident rekindled domestic debates about the wisdom of developing a Swedish fighter rather than procuring an outside aircraft such as the U.S. F-16. However, the program survived. It is now estimated that the total program cost could approach $8 billion. In November 1990, faced with a changing Europe, domestic political difficulties, and a constrained budget, the government announced a postponement of a procurement decision until 1991.

The prime contractor, Saab-Scandia, will also act as systems integrator. In 1990, it was announced that the plane will use Ericsson's new Ps-05 multimode pulse-Doppler radar in the x-band. Ericsson will also provide the computer, which is capable of performing at 6 to 7 mops, and software; the D80 computers are based on a 32-bit multiprocessor. One each will be used for the radar, electronic countermeasures, and the central processing unit, and two will be used for the control display system.

In 1990, the government also approved a $24 million deal with Saab to allow the company to investigate the development of a guided missile for the Gripen. Other contractors include Volvo-Flygmotoer for the engine and Lear-Siegler for the flight control system.

A second major Swedish procurement program is Bofors' RBS 90 surface-to-air defense missile; first deliveries were made in 1990. RBS 90 consists of Ericsson Radar Electronics' helicopter/aircraft radio detection system (HARD), the Giraffe 75 command, control, and communications system, and the RBS 70 Mk 2 missile. In early 1989, Ericsson Radar Electronics was awarded a $70 million contract for Giraffe systems, which will track, identify, classify, and designate targets.

©1991 Dataquest Incorporated January—Reproduction Prohibited

©1991 Dataquest Incorporated January—Reproduction Prohibited

Chapter 5

Other Nations' Military Electronics

Overview

Only a small group of nations outside of Europe spend any significant amount on their armed forces, especially on defense electronics. Mostly these expenditures are dedicated to expensive imported systems such as fighter aircraft, advanced radars, and command, control, and communications equipment.

The nine nations outside of Europe with the largest volumes of military imports are listed in Table 5.1.

All of these countries depend heavily on imports for their military equipment that incorporates advanced technologies; only Israel, Japan, and South Korea are partial exceptions. Of particular note is the fact that, for the first time, countries of Asia surpassed those of Europe in aggregate weapons import totals in 1989, the latest date for which data are available.

India

India is the largest importer of advanced weapons in the world. This trend will continue to grow, despite likely changes in trade relations with the Soviet Union, India's main weapons supplier. India has been active in building a modern military force throughout the 1980s, spending nearly $10 billion in 1990. The Indian arsenal is impressive, with advanced aircraft, such as the Mig-29, two aircraft carriers, long-range 155mm Bofors cannons, and a multitude of advanced missile systems.

The Indian Defense Ministry continues to seek codevelopment projects and technology transfer deals for electronic components. A program of particular focus is the Light Combat Aircraft (LCA), India's first attempt to build an indigenous, state-of-the-art fighter. Concern in the U.S. Congress and the Bush Administration over the Indo-Pakistani competition, as well as the increasing visibility of Indian nuclear and missile programs, will continue to lead to careful scrutiny, if not outright prohibition, of transfers of certain U.S. electronic systems.

Japan

Japan has been moving rapidly to build up the Japanese Self-Defense Forces (JSDF), spending a total of over $30 billion in 1990. If spending rates continue along current patterns, Japan will soon surpass Great Britain as the world's third-highest defense-spending nation.

Table 5.1

Military Imports
(Millions of Dollars)

Country	1989	Cumulative 1985-1989
India	3,819	17,345
Iraq	418	11,989
Japan	3,062	10,554
Saudi Arabia	1,196	8,764
Egypt	152	5,795
Turkey	1,134	5,275
Taiwan	263	2,946
South Korea	607	2,794
Israel	93	2,687

Source: SIPRI Yearbook 1990

Japan has focused much of its defense spending, which rose at rates of between 5 and 7 percent annually during most of the 1980s, on expanding its defense electronics industry. This spending is likely to increase through the development and production of the FSX fighter.

Mitsubishi Heavy Industries, the prime contractor for the FSX fighter, was awarded an $82 million contract in May 1989 and another for $240 million in March 1990. The FSX has been the most highly visible and controversial Japanese procurement program in the United States in the long term. Based on the F-16, the FSX has been the subject of extensive negotiations between the U.S. and Japanese governments on issues such as workshares and technology transfers. Japan plans to procure between 130 and 170 FSX fighters. The entire program will cost close to $8 billion.

General Dynamics is the major U.S. contractor in the FSX program and expects to receive more than $2.0 billion in revenue. The development cost of the FSX has been estimated at $1.2 billion; General Dynamics will receive between 35 and 40 percent of that total and the same percentage of the estimated $5.0 billion in production. General Dynamics will provide the engines and part of the fuselage and codevelop the wings and frame with Japan; Japan will provide the electronics and the missiles. More specifically, Japan, principally Mitsubishi Electronics Corporation (MELCO), will develop the phased array radar, the EW suite, the inertial navigation system, and the fire-control computer.

In recent months, reports of rapid growth in the FSX's cost and further controversy between General Dynamics and its Japanese partner have led to speculation that the program might be canceled. This seems unlikely, but it would not prevent Japan from building an increasing share of its avionics and other defense electronics domestically.

In December 1988, Japan ordered its first Aegis destroyer at a price of $914 million. About one-half of that amount will be allocated for the Aegis air-defense system manufactured by General Electric. An additional $65 million was awarded to General Electric in October 1990 to continue production.

Another notable purchase occurred in July 1990 when the JSDF ordered another three E-2C surveillance aircraft from Grumman to be delivered by January 1993. The order was followed in October 1990 with a request for two additional systems. With the 5 planes ordered in 1990, Japan's fleet of E-2Cs will equal 12.

With the U.S. cancellation of the P-7A, Japan is likely to look to upgrading its existing fleet of Lockheed P-3C long-range antisubmarine aircraft and can be expected to be first in line for export sales of the Update IV electronics suite and other P-3C improvements.

In May 1990, the JSDF sent a required equipment list to the Japanese Parliament, the Diet. The list included increased expenditure on EW platforms, aircraft, and missiles. Unlike the United States, which faces a constrained defense budget, Japan will be able to procure almost all of the items the Japanese Defense Agency requested in fiscal 1991, with the only possible mitigating circumstances caused by the oil shock resulting from the Middle East war.

Saudi Arabia

Since the Iraqi invasion of Kuwait in August, Saudi military imports have nearly doubled. Through the mid-1980s, Saudi Arabia relied nearly exclusively on U.S. manufacturers for high-technology armaments such as combat aircraft. Because of congressional restrictions, however, the U.S. share of the Saudi defense import market had dropped to approximately 50 percent by the late 1980s. The Europeans quickly stepped in to fill the void, with Britain taking the lead. The Iraqi action, however, is likely to reverse this trend and reestablish U.S. dominance in military sales to Saudi Arabia.

In the first sale, announced in August just after the invasion, the Saudis received 24 additional McDonnell Douglas F-15s, 200 General Dynamics Stinger missiles, and 150 General Dynamics M60 tanks. The total package cost about $2.3 billion.

A second package worth an estimated $7.5 billion was announced in November 1990. It includes 7 Lockheed KC-130 aerial tankers, 150 General Dynamics Abrams M-1 tanks, 200 FMC Bradley fighting vehicles, 150 Hughes TOW 2 missile launchers with 1,750 TOW 2A missiles, 155 Hellfire missiles, 6 Raytheon Patriot missile systems, 8 Sikorsky UH-60 Black Hawks, and 12 McDonnell Douglas AH-64 Apache helicopters. A third package is now being formulated, and additional sales can be expected throughout 1991.

Turkey

Turkey, whose 1990 defense budget stood at $2.3 billion, continues to pursue one of the most aggressive

©1991 Dataquest Incorporated January—Reproduction Prohibited

military buildups in the world. Current plans call for a total of 18 separate procurement programs, totaling over $10 billion, to begin entering service in 1992.

Contracts signed in 1990 include an FMC commitment to team with Turkey's Nurol Industrial Group to provide 1,698 armored infantry combat vehicles similar to FMC's M2 Bradley. Loral also received its largest contract award in history, worth $325 million, to provide the ALQ-178 Rapport III EW suites for 160 Turkish F-16s. Martin-Marietta signed a contract in 1990 to provide the LANTIRN system for the existing F-16 fleet for $53 million.

LTV was given $24 million for six MLRS platforms with 2,268 missiles, and General Dynamics received a request for 160 additional F-16 C/Ds that could total $4.25 billion. Sikorsky entered the Turkish market with a $60 million contract to provide six UH-60 Black Hawk helicopters for the Turkish police. The modernization of Turkish forces will continue through the mid-1990s.

Taiwan

Taiwan, with its 1990 defense budget of over $8.5 billion, continues to import large quantities of weapon systems. The largest procurement program in Taiwan is the indigenous defense fighter, known as Ching Kuo, which is based on the F-16. The R&D budget of the Ching Kuo originally was estimated at $1 billion, but it may eventually total as much as $5 billion. Designed as an air-superiority fighter with a secondary antiship role, the Ching Kuo could provide subcontracts worth $27 billion.

Beginning in 1991, 10 aircraft will be produced in a preproduction phase. General Dynamics will build the airframe, which will be equipped with General Electric's AGP-67 pulse-Doppler radar originally designed for the failed Northop F-20 Tigershark fighter. GEC Astronics will provide the fly-by-wire system, and Bendix will produce the display panels. Garrett will provide the engines with Litton providing the inertial navigation equipment.

In 1990, it was announced that a total of 250 aircraft were planned, with maximum production of six aircraft per month to be reached in 1994.

South Korea

Over the past five years, South Korea has been on a military hardware-buying frenzy, expending nearly $11 billion for force improvements. South Korea's defense electronics industry will continue to improve in sophistication and competitiveness through the 1990s. Most recently, South Korea has been working with McDonnell Douglas in a coproduction deal for a new fighter aircraft, the FX. South Korea hopes to use this project to gain the knowledge to develop an advanced indigenous aerospace industry. The prime contractor, Samsung Aerospace Industry, anticipates eventual production of 120 aircraft, although several obstacles remain before production can begin.

In June 1990, negotiations were completed for 120 aircraft to be produced in three lots. The first lot of 12 will comprise off-the-shelf systems built in the United States. The second lot of 36 will be assembled in South Korea, and the third lot of 72 will be constructed in South Korea under a licensed production agreement. The total price tag is estimated to be between $3 billion and $4 billion.

In November 1990, the agreement reached with McDonnell Douglas began to show signs of weakness. The problem reportedly stems basically from a South Korean perception that the North Korean threat is lessening and may no longer justify such a large expenditure. However, barring a real upheaval in South Korean politics, the program is likely to continue.

The South Korean Army began deliberations in 1989 to choose a medium-utility helicopter. The final selections were made, and in June 1990, Sikorsky was awarded a contract to provide the first three UH-60Ls Black Hawks as well as two additional General Electric T700-701C engines. Sikorsky won the contract over Bell and Westland.

Israel

Israel has an advanced and expanding defense industry but a relatively small internal market. Israel's total 1990 defense budget was $6.3 billion, of which $1.8 billion was provided by the United States in the form of foreign military assistance. As a result, Israeli aerospace and electronics companies have been competing ferociously for shares of U.S. defense markets, with some success. Israeli Aircraft Industries' (IAI) Elta division, for example, continues to market in the United States the integrated self-protection system it developed for the now-canceled Lavi fighter, and Elbit Computers has recently opened a U.S. subsidiary. IAI also has been working with Lockheed Missiles & Space Co. on the Israeli Arrow antitactical ballistic missile, which is

©1991 Dataquest Incorporated January—Reproduction Prohibited

funded in part by the U.S. SDI program. In addition, Israel continues to find a receptive, albeit small, export market for its more advanced systems in the developing world regions. Weapons have often been sent covertly to nations such as South Africa, China, and Iran.

China

With 1990 defense spending of $6.2 billion, China has a growing but less sophisticated arms industry than do most other European and Asian countries. China's sizable export industry is dominated by low-technology older weapons, although the transfer of CSS-2 medium-range ballistic missiles to Saudi Arabia is one notable exception.

Index

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

X

Y

Z

Dataquest Research and Sales Offices:

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
Phone: (408) 437-8000
Telex: 171973
Fax: (408) 437-0292

Technology Products Group
Phone: (800) 624-3280

Dataquest Incorporated
Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
Phone: (714) 957-0171
Telex: 5101002189 ICCDQ
Fax: (714) 957-0903

Dataquest Incorporated
Ledgeway Group
430 Bedford Street
Suite 340
Lexington, MA 02173
Phone: (617) 862-8500
Fax: (617) 862-8207

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: (02) 959 4544
Telex: 25468
Fax: (02) 929 0635

Dataquest Boston
1740 Massachusetts Ave.
Boxborough, MA 01719-2209
Phone: (508) 264-4373
Telex: 171973
Fax: (508) 635-0183

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
West Germany
Phone: 011 49 89 93 09 09 0
Fax: 49 89 930 3277

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
Phone: 0895-835050
Telex: 266195
Fax: 0895 835260/1/2

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: (1) 48 97 31 00
Telex: 233 263
Fax: (1) 48 97 34 00

Dataquest Hong Kong
Rm. 401, Connaught Comm. Bldg.
185 Wanchai Rd.
Wanchai, Hong Kong
Phone: 8387336
Telex: 80587
Fax: 5722375

Dataquest Israel
59 Mishmar Ha'yarden Street
Tel Aviv, Israel 69865
or
P.O. Box 18198
Tel Aviv, Israel
Phone: 52 913937
Telex: 341118
Fax: 52 32865

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo 104 Japan
Phone: (03) 5566-0411
Fax: (03) 5566-0425

Dataquest Korea
Daeheung Bldg. 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul, Korea 135
Phone: (02) 556-4166
Fax: (02) 552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 4597181
Telex: 38257
Fax: 4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sect. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: (02) 501-7960
Telex: 27459
Fax: (02) 505-4265

Dataquest West Germany
In der Schneithohl 17
6242 Kronberg 2
West Germany
Phone: 06173/61685
Telex: 418089
Fax: 06173/67901

© 1991 Dataquest Incorporated 1/91
0009183

Electronic Systems Markets

The following is a list of the material in this section:

- Worldwide Military Spending Overview
- U.S. Military Spending Overview
- U.S. Military Electronics Program
- Western Europe Military Electronics Program
- Other Nations Military Electronics Overview
- Civil Aviation
- Civil Space
- Equipment Production Forecast

© 1990 Dataquest Incorporated September

Worldwide Military Spending Overview

OVERVIEW

Despite a global trend toward reduced defense spending, defense electronics expenditure is forecast to continue to increase at a moderate rate during the next five years. Given the general relaxation of military tensions as well as worldwide fiscal constraints, national governments are likely to focus defense resources increasingly on quantitatively smaller but qualitatively more capable forces. This trend will emphasize procurement of defense electronics for new weapon systems, the modernization and upgrade of existing forces, and the development of force multipliers such as improved command, control, communications, and intelligence (C3I) systems.

U.S. DEFENSE CRUNCH

Barring the acquiescence of the Bush Administration to increased federal taxes, budget cuts mandated by the Gramm-Rudman-Hollings (GRH) deficit cutting law will require Draconian measures by the Federal government. The fiscal 1990 and 1991 defense program of Secretary of Defense Richard Cheney, the result of a White House-Congressional compromise, seeks to hold U.S. defense appropriations constant in real terms during the next two years, cutting $20 billion from the original Reagan Administration request for that period. The Cheney cuts fall with greatest emphasis on investment accounts; however, there has been a change of philosophy in apportioning the cuts. Unlike his predecessors, the new secretary has not opted to defer advance weapons in order to maintain the current production schedule. Instead, he has curtailed production of several existing programs in order to keep next-generation systems on schedule. Although the Cheney budget calls for a 50 percent increase—from $12 billion to $18 billion—in investment in strategic programs, the level of funding for big-ticket items such as the Strategic Defense Initiative (SDI) and the B-2 Stealth bomber is uncertain, as legislators are likely to transfer funds to preserve conventional programs.

Despite these cuts, the electronics content of U.S. defense spending is projected to increase at a gradual rate. Defense electronics currently constitutes approximately 40 percent of the Department of Defense's (DOD's) total procurement and R&D funding. Defense trends that favor increased electronics purchases include the importance of qualitatively superior forces to compensate for reduced quantities. Reductions in numbers necessitate increased capabilities for remaining weapon platforms through greater stress on surveillance, target acquisition, and C3I. Moreover, the proliferation of high-technology weapons in the third world requires that U.S. forces be prepared to contend with modern military forces in any contingency, and increased training and weapon costs have led to greater reliance on simulators and computer devices for training.

In support of these needs, the DOD continues to support programs to develop advanced computing capabilities, including Millimeter Wave and Microwave Monolithic Integrated Circuits (MIMIC), research into gallium arsenide (GaAs) applications, high-definition television (HDTV), and Sematech.

© 1989 Dataquest Incorporated October

Worldwide Military Spending Overview

U.S.S.R. "PEACE OFFENSIVE"

During 1988 and 1989, Soviet president Mikhail Gorbachev backed up his rhetoric of "New Thinking" in foreign policy with concrete actions that have had global repercussions. Mr. Gorbachev has taken steps to reduce the Soviet Union's armed forces unilaterally and offer forthcoming positions in arms-control negotiations. This "peace offensive" has resonated strongly throughout Western Europe, where decreased perception of a Soviet military threat is reinforcing fiscal pressures for reductions in defense expenditure. A conventional arms-control agreement that reduced U.S. ground and air forces, or a Strategic Arms Reduction Treaty (START) that reduced the U.S. nuclear arsenal by one-half, ironically would improve the prospects for accelerated modernization programs and defense electronics purchases by reducing fiscal pressures on investment accounts.

CHALLENGE FROM EUROPE

The European defense market accounted for roughly one-third of defense electronics spending in 1989. Although American fears of a "Fortress Europe" that would be impenetrable to foreign imports after European Community integration in 1992 are exaggerated, the consolidation and integration of European aerospace and electronics industries already under way will put these companies on stronger footing to compete with U.S. suppliers. Turning increasingly to the use of consortia—such as the four-nation European Fighter Aircraft (EFA) effort—European countries are eliminating redundancies and maximizing economies of scale, formerly big advantages for U.S. companies.

... AND FROM THE PACIFIC RIM

In the longer term, Japanese and South Korean international codevelopment programs for fighter aircraft—for the FSX and FX, respectively—as well as Taiwan's indigenous efforts to develop new aircraft will aid those countries in expanding their own defense electronics industries and competing in the U.S. and European markets.

THE STRATEGIC ENVIRONMENT

Worldwide defense spending peaked in real terms in 1987 at $922.8 billion. Of this amount, perhaps one-half ($450.0 billion) was spent to develop or acquire weapons and other types of military equipment. Almost one-fourth of this smaller total is devoted to electronic components and equipment.

© 1989 Dataquest Incorporated October

Worldwide Military Spending Overview

Global defense expenditure is dominated by the United States and the Soviet Union, which together make up roughly two-thirds of the worldwide total (see Table 1). Nearly 80 percent of global defense expenditure is accounted for when these countries' respective allies in the North Atlantic Treaty Organization (NATO) and the Warsaw Pact are added to the equation. Restricting the comparison to expenditure for hardware and eliminating manpower suggests an even narrower focus of global expenditure. Of the remaining 125-plus nations in the world, only Australia, China, India, Israel, Japan, Saudi Arabia, South Korea, and Taiwan constitute any substantial market for defense electronics.

Political, economic, and strategic trends in virtually all parts of the world are leading to cuts in the size of armed forces, slowdowns in weapon modernization programs, and reductions in defense budgets. The Soviet Union, beset with domestic problems and facing a relative and even absolute decline in its standard of living and economic prospects, has announced a nearly 15 percent cut in defense expenditure during the coming year. Soviet allies in the Warsaw Pact, facing similar problems, have announced similar reductions; moreover, Soviet Prime Minister Nikolai Ryzhkov declared in June 1989 that his country hoped to reduce its defense budget by one-third during the next few years. Repeated Soviet concessions in arms control negotiations and unilateral actions to reduce tensions in various parts of the world make it clear that at least the current leadership is serious about these announced goals.

Although cuts in Soviet military spending do not directly affect Western markets for defense electronics, the Soviet peace offensive is reinforcing a strong desire in Western nations to reduce the burdens of military preparedness on their own economies. The U.S. defense budget has declined in real terms each year since 1985; the trend seems likely to continue. With the exceptions of Great Britain and Japan, allied nations also are trimming defense budgets by cutting back weapon modernization plans and, in some cases, demobilizing units. Moreover, primary markets in third world nations remain relatively soft—due both to problems of international indebtedness and the relatively low price of petroleum. Short of an unexpected and drastic international upheaval, these trends seem likely to continue into the 1990s.

Even so, defense expenditure represents a considerable portion of public outlays in the West and still constitute a very substantial marketing potential. Moreover, virtually all nations are stressing increasingly the need to build and maintain as modern a military force as possible. The prevailing wisdom seems to be that smaller forces are acceptable—indeed desirable—as long as they are equipped with the most advanced military equipment. Military establishments throughout the West are testing the limits of technology, pressing their industrial and scientific establishments to provide increasingly capable components and weapon systems.

© 1989 Dataquest Incorporated October

Worldwide Military Spending Overview

Table 1

Military Spending by Nation and Alliance
1985 to 1987
(Billions of Dollars)

Country	1984	Percent of Total	1987	Percent of Total
USSR	$278.0	35%	$290.0	31%
East Germany	6.0	1	11.6	1
Romania	6.8	1	5.9	1
Other Warsaw Pact	10.0	1	11.6	1
Subtotal: Warsaw Pact	$300.8	38%	$319.1	35%
United States	$231.5	29%	$288.4	31%
West Germany	25.6	3	34.5	4
France	20.2	3	34.2	4
United Kingdom	23.4	3	31.7	3
Other NATO	34.6	4	51.7	6
Subtotal: NATO	$335.3	42%	$440.5	48%
Japan	$ 12.0	2	$ 25.4	3
Saudi Arabia	22.7	3	16.2	2
Iraq	13.8	2	14.0	2
India	7.2	1	9.6	1
Iran	20.6	3	9.0	1
South Korea	4.5	1	5.7	1
PRC	7.8	1	5.6	1
Australia	4.3	1	5.3	1
Israel	5.8	1	5.1	1
Taiwan	3.4	N/M	5.1	1
Other Countries	59.0	7	62.2	7
Total: Worldwide	$797.2	100%	$922.8	100%

N/M = Not Meaningful

Note: Columns may not add to totals shown because of rounding.

Source: International Institute of Strategic Studies

© 1989 Dataquest Incorporated October

Worldwide Military Spending Overview

This trade-off of quantity for technological quality favors the electronics industry. Advances in electronics, far more than in any other sector, are expanding the potential capabilities of military systems, providing force multipliers that can compensate for reduced numbers. As a result, even as the overall size of defense expenditure declines throughout the world, the electronic content of defense purchases will continue to rise and can be expected to do so at least through the next five years. The market for defense electronics thus should continue to remain strong in the midterm, although it will not be expanding as quickly as it did in the early and mid-1980s.

The longer-term prospect in the mid- to late 1990s may be less optimistic, but there are too many uncertainties to make firm predictions. Although worldwide defense budgets have leveled off and have begun to decline in response to Mr. Gorbachev's four-year effort to ease international tensions, as well as in response to progress in resolving regional conflicts in Africa, Latin America, and South and East Asia, firm solutions to underlying political issues have yet to be found. Arms control negotiations have made progress, but only the 1987 U.S./Soviet Treaty that eliminated intermediate-range missiles has so far been concluded. Truces have been declared in the Iran-Iraq War, in Angola, Namibia, and the Sudan, and some progress has been made toward resolving the wars in Cambodia, Afghanistan, and elsewhere, but no peace settlement is yet in sight for any of these situations.

Mr. Gorbachev remains in office and if nationalist unrest is held within bounds in the Soviet Union and Eastern Europe, it may be possible for the United States and the Soviet Union to continue to improve their political and economic relations and negotiate a far-ranging series of arms-control agreements in the process. These agreements, together with unilateral actions, could bring drastic cuts in U.S. and West European defense spending by the end of the century. Resolution of conflicts in the third world would reinforce any such trend, as well as easing incipient arms competitions in Asia, Africa, and Latin America.

But events in China in spring 1989 demonstrated clearly how fragile the trends toward moderation in the Soviet Union might be and how far conservative elements in the Communist world might be prepared to go to defend their vested interests. While causing a suspension of U.S. and Western military sales in the near term, the events in China probably presage renewed attention to that nation's military establishment, long neglected during the drive for civilian economic development. They also will head off any downturn in Japan's military outlook. More important, the bloody repression in China demonstrates the tenuousness of the political developments in the Soviet Union which are, of course, the key prerequisite for any wholesale change in Western military budgets.

© 1989 Dataquest Incorporated October

United States Military Spending Overview

OVERVIEW

In 1989, as in the previous three years, the U.S military posture has been determined mostly by the country's fiscal situation. The nation's continuing refusal to consider significant increases in taxes, reinforced by the apparent effectiveness of the tax issue in the 1988 election, ensures that deficits will remain high. Draconian cuts in federal outlays thus remain necessary even to approach the deficit reduction targets required by the Gramm–Rudman–Hollings (GRH) legislation. Unilateral reductions in Soviet military forces and the general "soft" line pursued by Soviet leader Mikhail Gorbachev ensure that cutbacks in defense expenditure should assume at least a proportionate share of the overall reduction in federal spending.

BUDGET REVIEW

The fiscal 1990 budget and fiscal 1990 to 1994 defense program developed under former President Reagan envisioned a 2 percent real growth in defense spending in 1990 and a 19 percent real increase during the full five-year period (see Table 1).

Table 1

U.S. Defense Budget by Appropriation Title
(Budget Authority in Billions of Constant 1990 Dollars)

	Actual	Reagan Proposed		Bush Proposed	
	1989	1990	1991	1990	1991
Personnel	$ 80	$ 80	$ 80	$ 79	$ 80
Operation and Maintenance	89	92	92	90	90
Investment Procurement	82	84	90	79	82
R,D,T, & E	39	41	41	40	37
Construction	6	5	6	5	5
Other	4	4	4	3	3
Total	$300	$306	$312	$296	$297

Source: U.S. Department of Defense

© 1989 Dataquest Incorporated November

These plans fell by the boards in March when U.S. President George Bush reached a budget compromise with congressional leaders that will hold defense appropriations constant in real terms during the next two years (see Table 2). The resulting $10 billion reductions in the planned fiscal 1990 and 1991 defense budgets were apportioned among individual programs by the new secretary of defense, Richard Cheney, in one of his first actions. Cuts fell disproportionately on investment accounts (see Table 3). Reductions in investment accounts made up more than 70 percent of Secretary Cheney's proposed cuts although they account for only 40 percent of the overall budget.

This decline continued a four-year trend. In real terms, U.S. defense investment doubled between fiscal 1980 and 1985; it then dropped 15 percent between fiscal 1985 and 1989. Procurement actually declined 22 percent in real terms during this latter period, while R&D continued to increase. The result has been quite marked in less politically visible appropriations. The munitions accounts were hit hard, for example, as were weapon accounts, army and marine corps procurement, and some activities in the "Other" procurement account category (see Table 4).

Under the Reagan program, this trend in investment was to be reversed; for example, procurement was to increase by 10 percent in real terms by 1991. Secretary Cheney's cuts already have deferred this increase until later in the five-year defense program. Additional reductions in defense spending that are likely to be made in 1990 and are now being considered within the Pentagon, will make them impossible.

Because of the previous cuts in less visible procurement accounts, Secretary Cheney was forced to cut back some big-ticket items in his review of the defense budget. The Strategic Defense Initiative (SDI), for example, was reduced from $5.6 billion to $4.6 billion in fiscal 1990 and from $6.7 billion to $5.5 billion in fiscal 1991; the B-2 Stealth bomber appropriation request was cut by $0.8 billion in fiscal 1990 and more than $3.0 billion in fiscal 1991. Secretary Cheney's cuts fell particularly hard on aviation. The V-22 Osprey helicopter program was cancelled outright and planned buys of the Army's AH-64 Apache and UH-60 Blackhawk helicopters were foreshortened. Anticipated purchases of variants of the Navy's F-14 Tomcat and Air Force F-15E Eagle fighters also were reduced.

MACROTRENDS IN U.S. DEFENSE SPENDING

Overview

The General Accounting Office has estimated that the revised Cheney five-year defense program would be underfunded by $150 billion in the defense budgets now planned by the Administration. Factors contributing to the underfunding include underestimates of certain program costs and unrealistic estimates of the

Table 2

Bush Budget Proposals, Fiscal Years 1990–1994
(Billions of Dollars)

Fiscal Year	Revenue	Outlays Defense	Outlays Nondefense	Deficit	GRH Target
1990	$1,059.3	$ 289.8	$ 862.0	$ 98.6	$100
1991	1,140.5	297.9	909.4	69.2	64
1992	1,212.2	306.8	937.6	34.3	28
1993	1,281.4	317.4	961.6	1.6	0
1994	1,345.0	329.5	982.1	33.4*	N/A
Totals	$6,038.4	$1,541.4	$4,652.4		

N/A = Not Available
* Surplus

Note: Columns may not add to totals shown because of rounding.

Table 3

Secretary Cheney's Reductions from the Reagan Defense Budget
(Budget Authority in Billions of Dollars)

	Fiscal 1990	Fiscal 1991
Military Personnel	$ 0.7	$0.8
Operations and Maintenance	1.5	1.5
Investment		
Procurement	5.4	4.7
Research and Development	1.5	1.8
Construction	0.5	0.4
Other	0.6	0.8
Total	$10.0	$9.9

Note: Columns may not add to totals shown because of rounding.

Source: U.S. Department of Defense

© 1989 Dataquest Incorporated November

Table 4

Forecast Trends in Selected Procurement Accounts
(Millions of Dollars)

	FY 1980	FY 1985	FY 1989	FY 1991
Total Procurement	$34,994	$91,382	$76,699	$87,830
		Winners		
Missiles, Army	$ 1,150	$ 3,167	$ 2,592	$ 2,662
Weapons, Navy	$ 1,993	$ 4,354	$ 6,093	$ 5,725
Shipbuilding and Conversion, Navy	$ 6,621	$11,636	$ 9,532	$ 9,551
Other, Navy	$ 2,607	$ 5,342	$ 4,625	$ 4,915
Missiles, Air Force	$ 2,144	$ 6,888	$ 7,120	$ 7,382
Other, Air Force	$ 2,653	$ 8,858	$ 8,154	$ 8,562
		Losers		
Aircraft, Army	$ 946	$ 3,942	$ 2,872	$ 2,906
Ammunition, Army	$ 1,136	$ 2,646	$ 2,005	$ 1,705
Other, Army	$ 1,480	$ 5,141	$ 4,660	$ 4,169
Weapons and Tracked Combat Vehicles, Army	$ 1,724	$ 4,504	$ 2,820	$ 2,724
Aircraft, Navy	$ 4,345	$10,897	$ 9,314	$ 8,826
Procurement, Marine Corps	$ 284	$ 1,816	$ 1,292	$ 1,197
Aircraft, Air Force	$ 7,911	$26,091	$15,619	$16,787

Source: U.S. Department of Defense

rate of inflation. If this estimate is accurate, and if the Administration and Congress continue to stress preservation of the size and readiness of U.S. armed forces at the expense of modernization programs, cuts will continue to fall disproportionately on procurement and R&D development.

Other than the possibility of an unexpected increase in federal revenue, the main factor that could alter this prognosis would be conclusion of arms control agreements, particularly an agreement requiring major reductions in U.S. forces in Europe. Such an agreement could lead to reductions in the size of U.S. ground and air forces, offsetting pressures on investment accounts to a degree. This possibility notwithstanding, the impact of any future cuts will depend strongly on the priorities that the new administration establishes among military missions, as well as the strategy it adopts for modernizing the U.S. armed forces.

Europe

The situation in Europe has evolved rapidly during the past year. In a December 1988 address to the United Nations General Assembly, Mikhail Gorbachev announced sweeping unilateral reductions in the Soviet armed forces, particularly those deployed in Europe. Overall, Mr. Gorbachev said, the USSR would reduce its military personnel by 500,000—10 percent of the total—by the end of 1990. Significantly, the focus of these reductions would be forces deployed in Central Europe east to the Ural mountains, the forces that NATO nations consider the most significant immediate military threat to the West. In Eastern Europe, the Soviets would withdraw six tank divisions, including 5,300 tanks, 50,000 troops, and 160 combat aircraft. In the entire Atlantic-to-the-Urals area, Moscow would reduce 240,000 troops, 10,000 tanks, 8,500 artillery pieces, and 800 combat aircraft. The announced Soviet cuts in Central Europe would amount to 10 percent of the troops, 20 percent of the tanks, 15 percent of the artillery, and 11 percent of the aircraft that the Soviets have deployed there.

The USSR's allies quickly followed suit. As shown in Table 5, the other members of the Warsaw Pact announced unilateral cuts in their defense budgets and armaments.

Although the Warsaw Pact will retain substantial quantitative advantages in Europe even after implementing these announced reductions, the pullbacks greatly diminish the threat of surprise attack or attacks following relatively brief periods of mobilization posed by the Warsaw Pact to NATO. In March, Philip Karber, a leading American expert on the military situation in Europe, testified on the danger of a Warsaw Pact surprise attack in Central Europe, saying "Gorbachev has focused his unilateral reductions on reducing this 'threat.' If his plan is carried out . . . he will succeed."

© 1989 Dataquest Incorporated November

Table 5

Announced Non-Soviet Warsaw Pact Cuts

	Percent of Defense Budget	Tanks	Troops	Aircraft	APCs	Artillery
GDR	10	600	10,000	50	N/A	N/A
Czechoslovakia	15	850	12,000	51	165	N/A
Hungary	17	251	N/A	N/A	30	430
Bulgaria	12	200	N/A	20	N/A	200
Poland	4	N/A	15,000	N/A	N/A	N/A

Note: East Germany also plans to reduce 15,000 reserve troops.
Polish troop cuts reportedly were implemented during 1988.

N/A = Not Applicable

Source: News Reports

The Warsaw Pact's unilateral actions gave credence to Gorbachev's repeated expressions of a desire to end the military confrontation in Europe and created a positive atmosphere at the Vienna negotiations for mutual reductions in conventional forces in Europe. When the talks opened in March 1989, the two sides' positions were surprisingly close. The gap was closed even more when President Bush surprised the world with a dramatic revision to the U.S. position at the NATO summit in May, calling for the conclusion of an agreement within a year and its implementation by 1992.

Although the negotiating timetable may be optimistic, the probability of an agreement should be considered great. It would equalize the two sides' ground forces in the vast region stretching from the Urals to the Atlantic at roughly one-half of the numbers of forces currently deployed by both Blocs, requiring massive cuts in Soviet forces. The developing agreement would result in the reduction and destruction of nearly 40,000 Warsaw Pact tanks, 42,000 Pact armored vehicles, and a withdrawal of roughly 350,000 Soviet troops from Eastern Europe. The Bush proposal, moreover, would place specific limits on U.S. and Soviet forces. Ten percent of U.S. ground forces would be removed from Europe and demobilized—a cut of 30,000 people. Although the specific content of the proposed cut has not been announced, it would include at least one division

 © 1989 Dataquest Incorporated November

and probably parts of a second. Fifteen percent of NATO, presumably U.S. tactical air forces also would be withdrawn and demobilized. Again, the specific units have not been identified, but air force spokesmen have pointed to A-10 squadrons as possible candidates, and Congress has identified an F-16 wing that was planned to be moved from Spain to Italy, at a cost of roughly $800 million in new construction as a logical choice.

These reductions could provide substantial budgetary relief, easing pressures on modernization programs. Assuming that commensurate cuts were made in support forces, demobilization of the forces just identified could save $10 billion to $15 billion annually once fully implemented.

Mission Priorities

The Reagan administration gave a high priority to strategic nuclear forces and, as a result, spending for these forces grew more rapidly during the 1980s than did the overall defense budget. Defined broadly (including such elements as relevant parts of the R&D budget and operations of relevant reserve forces, the strategic budget increased between 1980 and 1989 from roughly $30 billion to approximately $50 billion in constant dollars. In the process, it rose from 14 to 17 percent of the budget and, in fact, constituted as much as 20 percent of the budget during the middle part of the decade.

Under current plans, continued growth will be necessary. Investment in strategic programs is slated to increase from approximately $12 billion in fiscal 1989 to more than $18 billion in fiscal 1994—a 50 percent increase. In the environment of constrained budgets that seems likely during the next five years, any such growth would of course crowd out modernization programs for conventional armed forces and other initiatives.

Secretary Cheney's initial budgetary review seems to indicate that he will give a higher priority to conventional forces, however. The fiscal 1990 and 1991 cuts in the SDI and the B-2 bomber seem likely to be repeated in future years as further economies become necessary. In addition, the continuing indecision in the Congress and the Executive Branch over how to modernize the force of intercontinental ballistic missiles (ICBMs) seems likely to result in the eventual termination of at least one, and perhaps both, ongoing programs—the M-X rail mobile system and the Midgetman road-mobile ICBM. The amount requested for the latter in fiscal 1990, in particular, is a token sum intended to make possible continued support for the M-X, a transparent political tactic that may result in the death of both programs.

Successful conclusion of the Strategic Arms Reduction Talks (START) could ease these budgetary pressures. The draft treaty now on the table in Geneva could save as much as $15 billion per year (depending on how it is implemented) while permitting modernization programs to go forward. In addition, conclusion of a new agreement on strategic offensive forces would suggest perpetuation of the 1972 Treaty prohibiting deployment of antiballistic missile systems, meaning that the SDI would not move into procurement in this century. This could save another $15 billion annually toward the end of the next decade.

© 1989 Dataquest Incorporated November

Secretary Cheney also will be establishing priorities among conventional forces. The navy, for example, might not fare as well under the new administration as it has during the 1980s. The goal of a 600-ship navy already has been abandoned, and there are some pressures for further reductions in operational naval forces in order to avoid deeper cuts in the army and air force. Conclusion of an agreement on conventional forces in Europe, of course, would ease these budgetary pressures on the navy.

Modernization Strategy

One final macrotrend will have a first-order impact on future defense budgets. In the final years of the Reagan administration, as the cuts in defense spending began, then-Secretary of Defense Frank Carlucci and the Congress chose preferentially to protect efficient rates of production for weapon systems already being procured, even at the cost of delaying the introduction of new generations of weapon systems still in development. The army's program to develop a new LHX helicopter, for example, was restructured and its introduction delayed, while production runs of AH-64 Apaches and UH-60 Blackhawks were extended, and existing OH-58 Kiowa helicopters were modernized with new electronics as an interim measure.

As a general rule, the initial Cheney budget decisions seem to have reversed this modernization strategy. Key new programs such as the air force ATF and navy ATA fighters were protected from cuts, which some had predicted, even at the expense of foreshortening planned production runs of current-generation aircraft. Such a revised strategy fits with the current, relatively benign international environment. If near-term threats to U.S. security appear relatively inconsequential, it makes sense to curtail the production of current systems in order to ensure the timely introduction of new weapons that incorporate greatly advanced technological capabilities that will center U.S. military power in the next century. The strategy may be particularly effective if, as seems likely, the size of U.S. forces is reduced in the future, either because of unilateral actions or as a result of arms control agreements.

Effective or not, this new modernization strategy suggests that component and materials suppliers should take particular pains to identify the primary modernization programs that are likely to proceed successfully into procurement in the mid-1990s and to market their products effectively to the systems integrators and subcontractors that are most likely to emerge successfully from the procurement competitions.

KEY ELECTRONIC PROGRAMS

Fifty major defense programs with large and interesting electronics contents are listed in Table 6.

 © 1989 Dataquest Incorporated November

Table 6

Fifty Key U.S. Weapon Programs with High Electronic Content
(All Figures in Millions of Dollars)

Program	Planned FY 1989	Approx. FY 1990	Projected FY 1991-1994
Air Force Aircraft Programs			
B-2 "Stealth" Bomber	$5,200	$4,700	$18,000
B-1B Bomber Avionics	$ 200	$ 100	$ 700
C-17 Cargo Aircraft	$1,100	$2,100	$ 6,400
Advanced Tactical Fighter	$ 700	$1,000	$ 6,000
F-16	$3,300	$3,100	$10,500
F-15 Fighter	$1,600	$1,500	$ 2,500
Navy Aircraft Programs			
A-12 Attack Aircraft	$1,500	$2,600	$ 9,800
F/A-18 Fighter	$2,500	$2,400	$ 8,900
P-7 Antisubmarine A/C	$ 70	$ 200	$ 2,100
V-22 "Osprey" Helicopter	$ 600	$ 300	$ 800
Army Helicopter Programs			
LHX Light Helicopter	$ 200	$ 300	$ 2,400
AH-64 "Apache"	$1,100	$ 800	$ 3,100
UH-60 "Blackhawk"	$ 500	$ 400	$ 1,600
OH-58 Modifications	$ 200	$ 200	$ 500
Avionics			
INEWS/ICNIA	$ 70	$ 40	$ 800
Joint Surveillance Target Attack Radar System (JSTARS)	$ 260	$ 140	$ 600
Airborne Self-Protection Jammer (ASPJ)	$ 20	$ 20	$ 140
Advanced Tactical Air Reconnaissance System (ATARS)	$ 140	$ 290	$ 1,060
Joint Tactical Information Distribution System (JTIDS)	$ 40	$ 30	$ 180
Low-altitude Navigation and Targeting Infra-Red System for Night (LANTIRN)	$ 730	$ 200	$ 100

(Continued)

© 1989 Dataquest Incorporated November

Table 6 (Continued)

Fifty Key U.S. Weapon Programs with High Electronic Content
(All Figures in Millions of Dollars)

Program	Planned FY 1989	Approx. FY 1990	Projected FY 1991-1994
Strategic Missile Programs			
Trident II Submarine-Launched Ballistic Missile	$2,400	$2,000	$ 6,100
M-X Rail-Mobile Land-Based Ballistic Missile	$1,400	$1,800	$ 7,500
Midgetman Land-Mobile Ballistic Missile	$ 240	$ 200	$ 1,000
Short-Range Attack Missile (SRAM II)	$ 200	$ 230	$ 1,200
Tomahawk Sea-Based Missile	$ 700	$ 570	$ 2,000
Tactical Missile Programs			
AGM-65D/G/G Imaging Infra-Red "Maverick" Missile	$ 350	$ 380	$ 1,300
Advanced Medium-Range Air-to Air Missile (AMRAAM)	$ 840	$ 860	$ 3,900
AGM-88 HARM	$ 60	$ 350	$ 1,200
AIM-54 "Phoenix"	$ 400	$ 320	$ 950
"Harpoon" Antiship Missile	$ 170	$ 210	$ 600
SM-2 Navy Air Defense Missile	$ 590	$ 390	$ 1,400
"Patriot" Army Air Defense	$ 870	$ 800	$ 3,000
"Stinger" Army Air Defense	$ 380	$ 120	$ 800
"Chaparral" Army Air Defense	$ 20	$ 30	$ 160
Advanced Heavy Antitank Missile System	$ 180	$ 270	$ 1,200
Army Tactical Missile System (ATACMs)	$ 150	$ 200	$ 800
Space Systems			
Strategic Defense Initiative	$3,630	$3,900	$14,000
Space Boosters	$1,100	$1,000	$ 4,600
MILSTAR Satellites	$ 400	$ 400	$ 900
NAVSTAR System	$ 100	$ 100	$ 700
Defense Support Program Satellites	$ 300	$ 430	$ 1,200
Defense Meteorological Satellite Program	$ 100	$ 190	$ 500
Advanced Launch System	$ 100	$ 100	$ 750

(Continued)

Table 6 (Continued)

Fifty Key U.S. Weapon Programs with High Electronic Content
(All Figures in Millions of Dollars)

Program	Planned FY 1989	Approx. FY 1990	Projected FY 1991-1994
Ships			
Burke-Class Destroyer	$2,900	$3,700	$14,000
Seawolf-Class Submarine	$1,700	$1,800	$12,000
Ohio-Class Ballistic Missile Submarine	$1,300	$1,300	$ 5,600
Communications			
Mobile Subscriber Equipment	$ 950	$ 900	$ 2,200
Single-Channel Ground and Airborne Radio System (SINCGARS)	$ 300	$ 300	$ 1,300
Worldwide Information System (WIS/WAM)	$ 100	$ 100	$ 550
Army Tactical Systems	$ 300	$ 400	$ 1,800

Source: Defense Forecast

© 1989 Dataquest Incorporated November

(Page intentionally left blank)

 © 1989 Dataquest Incorporated November

U.S. Military Electronics Programs

AIRCRAFT AND AVIONICS

Overview

Aircraft rely heavily on electronic and optoelectronic devices to perform almost all functions: navigation, flight control, surveillance, target acquisition, and defensive functions. This is reflected in the estimate that avionics will comprise between 40 and 60 percent of the cost of next-generation aircraft. All the military services seek to integrate more closely and improve the commonality of avionics. Next-generation aircraft will use a new avionics systems architecture that divides avionics into three functional categories: mission management, sensor management, and vehicle management. Technologies for mission management include radars, fire control systems, and sensors for target surveillance and acquisition. Sensor management technologies are less established than those for mission management, as fully integrated programs like Integrated Electronic Warfare Systems (INEWS) are just beginning to be deployed. Although airborne computers have been used for quite some time, artificial intelligence methods will provide real-time options for the pilot and will be indispensable for future innovations like the mission adaptive wing. Vehicle management technologies are used for flight control instruments, such as cockpit displays and fly-by-wire or fly-by-light, and navigational aids, such as inertial navigation units and communications gear.

Trends in avionics for mission management lie in multimode and multispectral sensors and embedded transmitters and receivers, known as "smart skins." Improved methods of fire control are being explored through head-steerable targeting systems, for which weight- and size-reduction of components is critical, and through artificial intelligence aids for pilots such as "Pilot's Associate." In sensor management, emphasis is on improving the ability of systems to process, analyze, and distribute information from many components quickly, particularly with respect to parallel computer processing and improved pattern recognition. In vehicle management, research continues on fiber optics as a complement to and, eventually, substitute for, current methods, from fiber-optic gyros to fly-by-light and cockpit displays that project images directly onto the pilot's retina. Future cockpit displays will include the new wide-angle holographic Head Up Display (HUD), as well as helmet-mounted displays.

For the defense electronics industry, increased integration and commonality may well reduce the number of independent Department of Defense (DOD) projects, while increasing the value of those contracts that are let. This may imply greater vulnerability for electronics firms if the overall size of the defense budget and individual programs continue their erratic course. Competitive development and production contracts may offset this possible negative effect to a degree.

Over the longer term, the DOD is actively promoting new methods in all three functional avionics areas that will enhance aircraft survivability and reliability and improve pilot performance, among other things. Survivability will be the primary focus in the 1990s for military aviation. In particular, research programs will stress signature reduction, electronic countermeasures, and new kinds of decoys.

© 1989 Dataquest Incorporated November

Systems Development and Procurement

Aircraft procurement is proposed to increase by $4.2 billion in fiscal year 1990 to a total of $32.0 billion. For fiscal year 1991, an additional increase of about 11 percent is requested. Total spending on avionics equipment by the military services has been estimated to be about $20 billion, increasing at the rate of about 7 percent per year over the next few years. The fiscal year 1990 budget request for aircraft and avionics procurement is weighted significantly toward upgrading already existing aircraft models with electronic systems to enhance all-weather and night capability, to increase the striking range of missiles, and to improve defensive capabilities. In dollar terms, five of the seven largest aircraft procurement programs are upgrades of existing aircraft rather than new aircraft. This lull in new model programs will last until the mid-1990s when the next generation of fighters, close air support aircraft, and helicopters will enter full-scale production. This represents a two- to three-year delay from previous plans for several key programs, delays necessitated both by budgetary constraints and by technical problems.

In the meantime, older aircraft will benefit from the technologies developed for advanced aircraft like the Advanced Tactical Fighter (ATF) and Light Helicopter Experimental (LHX) and, in fact, are being modified to an extent to complement these next-generation aircraft. The air force recently suggested that, for its requirements, platforms are less important than the mission equipment packages (primarily avionics), although this view does not appear to be widely held within the DOD or Congress. Upgrading existing platforms is, however, a cost-effective short-term option and may become more attractive as DOD budget growth continues to decline. Table 1 shows requested aircraft procurement figures for fiscal year 1990 and fiscal year 1991, as compared to planned funding in fiscal year 1989.

Table 1

Requested Aircraft Procurement Forecast for Fiscal 1989–1991

Aircraft	Planned FY 1989	Amended Cheney Budget FY 1990	FY 1991
New Models			
V-22 Osprey	--	0	0
A-12			
B-2		TBD	TBD
C-17	4	6	10
E-8 JSTARS	--		

(Continued)

Table 1 (Continued)

Requested Aircraft Procurement Forecast for Fiscal 1989–1991

Aircraft	Planned FY 1989	Amended Cheney Budget FY 1990	FY 1991
New Variants			
AH-64 Apache	72	66	66
MH-60K SOF	--	11	11
F-15E Eagle	36	36	36
T-45 Goshawk	24	0	24
Upgrades			
UH-60 Black Hawk	72	61	61
MH-60G Pave Hawk	9	4	4
OH-58D AHIP	36	0	0
RC-12D Guardrail	6	5	10
AV-8B Harrier	24	24	24
EA-6B Prowler	12	0	3
F-14D Tomcat	12	6	6
F-16 Falcon	180	50	150
F/A-18 Hornet	84	66	66
CH/MH-53	14	3	0
E-2C Hawkeye	6	4	9
SH-60B MKIII LAMPS	6	6	6
SH-60F CV ASW	18	0	18

Note: TBD = To Be Decided

Source: U.S. Department of Defense
November 1989

New Aircraft Models

V–22 Osprey Tilt Rotor Aircraft. Before cancellation, procurement of V–22 Ospreys was planned to begin in fiscal year 1990, with a request by the navy and marine corps in the original Reagan budget of about $1.3 billion for 12 aircraft. Designed to meet all four services' requirements, the tilt–rotor aircraft is capable of many different missions and incorporates significant new technologies like composite materials (more than 60 percent of the airframe) and full integration of avionics. The total cost of research,

© 1989 Dataquest Incorporated November

development, and production of the V-22 is $60 billion. The marine corps planned to acquire a total of 552 MV-22s at an approximate cost of $22 billion for amphibious troop assault and assault support to replace the fleet of CH-46 Sea Knight helicopters currently in service. The air force originally required 80 CV-22s for special operations tasks, but has since revised that number to 55 aircraft. The army dropped out of the program in 1988 due to budgetary constraints, but is likely to fill its previous requirement for 231 MV-22s for medical evacuation and special operations. The navy has deferred development of the SV-22A antisubmarine warfare version of the tilt rotor, but has ordered 50 HV-22As for combat search and rescue.

Full-scale development of the V-22 began in May 1986 and will continue until all flight tests are completed in 1992, concurrent with production. Ground tests of the prop-rotor conducted in October were successful, but flight tests, which were to begin in summer 1988, were first conducted in mid-March. Schedule slippage and other problems have driven up the cost of each aircraft to between $23 million and $27 million. The primary contractor is a team of Bell Helicopter and Boeing Vertol. Bell has been responsible for the airframe and transmission and rotor and hub assemblies and integration of the Allison T406 engines. Boeing developed the fuselage and empennage and integrated the digital avionics and fly-by-wire system, cooperating with General Electric's Aerospace Control Electronics System on the latter. Honeywell provided digital control, display units, and the AN/AAR-47 missile warning system, and IBM led the cockpit interface design team. The V-22 also incorporates a Hughes AN/AAQ-16 forward looking infrared sensor (FLIR), an AN/APQ-174 terrain following multifunction radar by Texas Instruments, and two AN/AYK-14 mission computers by Control Data.

Secretary Richard Cheney deleted the V-22 from the Bush budget request, stating that the program was too costly and the technology did not offer advances proportional to the cost. Current plans are for additional (60) CH-53 helicopters and H-46 helicopters to take the place of the V-22. However, there are several strong supporters of the V-22 in the Congress, and V-22 funds may be taken from other programs, such as the B-1B modification program. Approximately $2.5 billion has been spent on the program already.

Although there is likely an additional one- to two-year slippage in the procurement schedule, this is a high-priority program for the marine corps and will probably produce 600 to 650 aircraft by the end of the 1990s.

Advanced Tactical Aircraft (ATA). The U.S. Navy began development of the Advanced Tactical Aircraft (ATA), or A-12, in 1985 to replace carrier-based A-6 attack planes and possibly F-111s. Details on capabilities, costs, and schedule of the program are classified, although some milestones have been made public. The navy began a demonstration/validation phase in late fiscal year 1988, with full-scale development beginning in late fiscal year 1990, first flights in the mid-1990s, and first delivery in 1997. The navy will probably procure about 450 aircraft if it expects to replace its

© 1989 Dataquest Incorporated November

current inventory of A-6s. McDonnell Douglas and General Dynamics were chosen as the prime contracting team in 1987 and awarded a $4.4 billion development contract. The development contractors for Navy Advanced Tactical Aircraft are listed below:

Firm	Subsystem
Amecon Division (Litton)	Electronic support measures
Garrett Controls (Allied Signal Aerospace)	Air data computer system
GE Aircraft Electronics	Missile warning set
Harris Corp.	Multifunction antenna
Honeywell	Flight control system
IBM Federal Systems Division	Mission computer
Litton-Honeywell	Integrated inertial navigation
Norden Systems Division (United Technologies)	Multifunction radar
SCI Technology	Avionics subsystems
Telesoft	TeleGen 2 including VAX/VMS host, MilStd 1750A software
Westinghouse Electric Corp.	Combined function FLIR

B-2 Stealth Bomber. Details on the cost and specific technologies of Northrop's Advanced Technology Bomber still remain classified, although the B-2 was officially unveiled in November 1988. First flight was planned for early this year, but was delayed until the summer of 1989. Total program cost has risen 16 percent from $36.6 billion for 132 aircraft to $68.1 billion ($42.5 billion in 1981 dollars). One-third of that amount will be expended in R&D; currently 70 percent of that R&D budget has been spent, according to air force officials. At present, each aircraft is estimated to cost $530 million.

The air force planned to begin multiyear procurement in fiscal year 1991 and continue through fiscal year 1995, but the program has been delayed by at least one year. Mr. Cheney cut about $1.1 billion from the fiscal year 1990 request, and although no production slowdown is scheduled, a $2.9 billion cut was proposed by Mr. Cheney in fiscal year 1991 funds. It is likely that further cuts will be made to the B-2 program by the Congress.

The B-2 industrial team is led by Northrop Corp. and includes Boeing Advanced Systems Co., GE Engine Group, and LTV Aircraft Products Group as key members. Other major subcontractors include Boeing Military Airplanes, Hughes Radar Systems Group, and Link Flight Simulation Corp. Initial operating capability is expected in early 1993.

© 1989 Dataquest Incorporated November

E-8 (JSTARS). Currently in the full-scale development phase, the Air Force-Army Joint Surveillance Target Attack Radar System (JSTARS) continues flight testing, to be completed in 1990. JSTARS is a wide-area ground surveillance radar able to detect, identify, and track moving and fixed targets in all weather conditions. Grumman was awarded the full-scale development (FSD) contract in September 1985, currently valued at $700 million; Norden will provide the side-looking radar. JSTARS is an essential part of NATO's modernization programs and although controversial, is likely to be continued. The Defense Acquisition Board approved the purchase of 22 E-8B aircraft; the air force requested $56 million in fiscal year 1991 funds for initial production.

C-17. The C-17, a new transport for inter- and intratheater operations, will replace C-130As and C-141s as they retire from service in the 1990s. Only six C-17s will be procured in fiscal year 1990, although more than $900 million has been requested for R&D. Production began in fiscal year 1988; software problems slowed the C-17's schedule by about four months. Twenty aircraft are expected to be procured in fiscal year 1992, and 29 in fiscal year 1994. A total of 210 aircraft are expected to be purchased through 2000 at a cost of $38 billion (1989 dollars). The major contractors are Douglas Aircraft and Pratt-Whitney.

Modernization Programs

Fighters. The following modernization programs apply to fighters:

- F-16 Falcon. The air force's F-16 Falcon is undergoing at least two different modification programs. The first of these, the Operational Capabilities Upgrade for F-16 A/Bs includes wiring for AIM-7 Sparrow, AIM-9 Sidewinder, or Penguin antiship missiles, expanded avionics memory, and radar improvements. In December 1988, Block 40 aircraft were delivered to the air force. These included a digital flight control system, Low-Altitude Navigation and Targeting Infrared for Night (LANTIRN), Global Positioning System (GPS), automatic terrain following, and a diffractive optics HUD. Block 50 aircraft of the upgrade program will be delivered in mid-1991. These new aircraft will include HARM/Shrike missile-carrying capabilities, radar and cockpit improvements, ASPJ, ALE-47 advanced chaff flares and an advanced threat warning radar (ALR-74 and ALR-56M). Loral was awarded a $20 million award in 1988 for the advanced radar warning receiver, the ALR-56M; a protest by Litton was disallowed at first, but an investigation by the General Accounting Office (GAO) yielded a recommendation to the air force to reconsider the award.

  The second modification program upgrades F-16As and F-16Bs for an air defense role by altering the APG-66 radar to make it compatible with AIM-7 Sparrow and AMRAAM missiles, and by installing launchers for two AIM-7s, GPS, and a long-range HF radio. These modifications will give the F-16 beyond-visual-range capability. A total of 270 Air Defense Fighter aircraft are expected to be operational in mid-1989. A further improvement, now being studied by General Dynamics, is called the Mid-Life Upgrade (MLU) and would

© 1989 Dataquest Incorporated November

retrofit F-16 A/Bs with Agile Falcon features such as engine upgrades, cockpit displays, computers, and EW equipment. In addition, consideration of the F-16 by the air force as the next tactical reconnaissance aircraft will require the addition of reconnaissance pods and probably new sensors and cockpit displays and controls.

The fiscal year 1990 budget request includes $34 million for development and $3.3 billion for procurement of F-16s overall.

- F/A-18 Hornet. The F/A-18 Hornet is replacing the F-4, RF-4, A-7, and the A4M in the marine corps and navy. The F/A-18D is a two-seat all-weather version for marine night attack and reconnaissance. Beginning in October 1989, all F-18s will have all-weather and night capability and will incorporate the Hughes AN/AAR-50 FLIR thermal imaging navigation set, as well as a Honeywell color digital moving map. Further upgrades include a program to begin in fiscal year 1990 that will improve the F-18's air-to-air capability. As part of this upgrade, Litton is providing the AN/ALR-67 airborne warning system. In addition, a derivative aircraft with engine, structural, and avionics upgrades is being explored under the Hornet 2000 project.

- AV-8B Harrier. The marine corps has requested procurement of 24 AV-8B Harrier V/STOL jets in fiscal year 1990 and 24 more in fiscal year 1991. The marines would like to buy 328 additional Harriers all told. In addition, $29.6 million has been requested in R&D funds, presumably to equip these Harriers with the ASPJ and night attack capability. The most recent contract was awarded to Litton for the AN/ALR-67 airborne warning system.

- F-15 Eagle. Procurement of the E variant of the F-15 continues at slightly lower levels than in fiscal year 1989; 36 aircraft have been requested for fiscal year 1990, down from 42 in fiscal year 1989. The air force, which hoped to procure a total of 392 F-15Es, requested $125 million in additional R&D funds this year. Procurement of F-15Es will likely continue at or near current rates until 1991; the total number will fall short of the air force goal by 78 aircraft according to the amended Cheney budget.

  Among the improvements to the F-15 are the installation of LANTIRN, the first VHSIC radar (APG-70), ECCM, ASPJ, and new missile systems. The prime contractor, McDonnell Douglas, recently received an $880 million contract for production of 42 F-15Es. Major subcontractors include Hughes, Loral, Martin Marietta, and Northrop. The APG-70 developed by Hughes for the F-15C/D/E is the first VHSIC-based production radar for operational tactical aircraft. Martin Marietta received an additional $208 million for 150 LANTIRN targeting pods in January 1989 and Loral will modify the internal radar warning system (ALR-56C) for $37 million. The ALR-56C is designed to detect and identify radar-guided threats, while LANTIRN enables night

© 1989 Dataquest Incorporated November

targeting. Northrop will provide the ALQ-135 internal countermeasures system, which has fallen behind its procurement schedule due to software problems. The most recent subcontract from McDonnell Douglas was awarded to IBM to develop a VHSIC central computer for the F-15.

The navy terminated the A-6E improvement and digital systems development programs in 1988. However, existing A-6Es will be upgraded using what would have been A-6G technology. Improvements include digital cockpit displays, advanced multimode attack radar, and a night navigation system, among others. Although Grumman was to have fitted A6Es with composite wings, the navy opted for cheaper metal wings in March 1989.

Bombers. The B-1B bomber is slated to receive new ECM antennas at a cost of about $20 million over the next two years. North American Rockwell recently received an additional $15 million to continue B-1B flight tests, to be completed in August 1992. Of the total $191.9 million requested by the air force for fiscal year 1990 and fiscal year 1991, about $116 million will be used to install and integrate the ALR-56 million radar warning receiver developed by Loral, $70 million will be used for anti-ice solutions. The installation of the ALR-56M comes in the wake of considerable controversy over the B-1B's defensive countermeasure system, the ALQ-161. The complete program to repair the B-1's deficiency is unlikely to be funded.

Helicopters. The SH60B LAMPS MK-1 will receive an Interface Converter Unit produced by Computer Devices Co. under subcontract to Kaman Aerospace. The equipment converts information from radar, sensors, and analog flight information to digital data form. The interface converter unit works in conjunction with the AN/ASN-150 tactical data handling system to present an aggregate picture of the threat situation. Other upgrades to the SH60B include a GPS receiver, Penguin antiship missiles, and the MK-50, or Advanced Lightweight Torpedo. Six SH60 LAMPS MK IIIs each year have been requested by the navy for fiscal year 1990 and fiscal year 1991. Block I improvements to MK IIIs are currently under way. These include an AN/ARC-182 UHF/VHF transceiver, an enhanced AN/AYK-14 computer, and the more versatile MilStd 1553B data bus. In 1991, a second development program is scheduled to begin under which the Mk III will acquire a standoff classification sensor for antiship surveillance and some advanced acoustical processing. The SH60F CV Helo, designed for aircraft carriers, will acquire a special integrated ASW mission avionics suite that includes a MilStd 1553B tactical data management system with dual AN/ASN-123 tactical navigation computers and a data link. Production of the SH60F has been cut in the fiscal year 1990 budget.

The army's CH 47 medium lift helicopter is currently being upgraded to the D configuration at the rate of about 48 aircraft per year. Boeing was contracted for $713 million to modernize 144 of these CH47s; the army requested $304.5 million for fiscal year 1990 for the program. Full lot production of 18 helicopters began in 1988.

© 1989 Dataquest Incorporated November

Surveillance Aircraft. The AWACS (E-3) aircraft is currently in the midst of its Block 30/35 upgrade, also known as Integration Contract, or ICON. ICON includes installation of an IBM CC2-3 computer with advanced bubble memory, Joint Tactical Information Distribution System (JTIDS), Global Positioning Satellite receiver, and ESM systems. Boeing recently received a $241 million contract to develop the U.S.-NATO cooperative electronic support measures system (ESM) for the AWACS, to be completed in mid-May 1990. AWACS will also benefit from a second upgrade program, known as the radar sensitivity improvement program (RSIP), which should be ready for production in fiscal year 1991. The RSIP program will be applied to modified Westinghouse APY-1 and APY-2 radar systems.

The E-2C Hawkeye carrier-based airborne surveillance aircraft will be improved with the APS-145 enhanced radar by fiscal year 1991 and will incorporate improved identification, friend or foe (IFF) measures. Beginning in fiscal year 1991, the navy hopes to procure nine new E-2Cs annually. Grumman will integrate JTIDS into the E-2C by the end of this year. Two contracts also have been awarded for upgrading the ES-3A and S-3B for radar systems and general modifications. Texas Instruments received a contract for $24 million for 33 AN/APS-237 radar systems, and Lockheed recently was contracted to modify S-3A aircraft into ES-3A at the cost of $56 million. Work should be completed in mid-1992.

The army plans to purchase 5 RC-12H/K Guardrail signal intelligence aircraft in fiscal year 1990 at $54 million and 10 in fiscal year 1991 at $107 million. In addition, the army requested $20 million total in fiscal years 1990 and 1991 to purchase two Grisly Hunter reconnaissance aircraft.

Transport and Trainers. The T-45, a derivative of the British Hawk, will replace the T-2 and TA-4 as the navy's trainer. The navy requested $413 million in fiscal year 1989 production funds, but flight testing revealed deficiencies causing the navy to withhold funding until Douglas Aircraft corrected them. The T-45 was expected to be operational in fiscal year 1990, but the flight test program was seven months behind schedule in January 1989. Subsequently, amendments to the budget by Mr. Cheney pushed production back to fiscal year 1991: the navy's request of $417.1 million for 24 aircraft in fiscal year 1990 was cut, and $603.6 million for 48 aircraft in fiscal year 1991 was halved. The navy hopes to buy a total of 302 aircraft at a cost of $4.9 billion.

Components. The air force program recently selected the team of Allied-Signal Aerospace Company (formerly Bendix) and Raytheon to produce the Mark XV IFF system, an upgraded version of the Mark XII. The Mark XV IFF could enhance survivability of aircraft by its improved ability to identify aircraft at great distances in adverse weather and hostile jamming conditions. The production award made in early 1989 covers 5 years of full-scale development followed by a 10-year production program, and could exceed $4 billion. The Mark XV IFF system is also the U.S. element of the NATO identification program and therefore holds considerable potential for other production contracts.

© 1989 Dataquest Incorporated November

LANTIRN. The LANTIRN system will provide the air force with the ability to conduct offensive tactical missions at night. Martin Marietta is producing the LANTIRN navigation pod under the terms of a $715 million contract awarded in December 1986 by the air force. The air force plans to install some 700 LANTIRN systems on F-15E and F-16C/D aircraft, with the first operational unit on the F-16 in 1989 and the F-15 model to follow shortly thereafter. LANTIRN consists of a navigation and a targeting pod. The first navigation pod was delivered in April 1987. In late 1988, Martin Marietta was delivering 1 navigation pod per month, with expectations for 10 per month in late 1989, and 20 per month by late 1990. The first targeting pod was scheduled for delivery in 1988. Targeting pod production will increase at the same rate as navigation pods, but lag one year behind, until all deliveries are complete in February 1991. Texas Instruments is a major subcontractor for LANTIRN, producing terrain-following radars for the navigation pods under a $101 million contract. The budget request for the LANTIRN for fiscal year 1990 was cut to $280 million, and for fiscal year 1991, to $247 million, keeping in line with F-15E cuts.

JTIDS. JTIDS is designed to provide a jam-resistant link between aircraft and ground forces. JTIDS-equipped aircraft will automatically send information on their location and status into the network through the Tactical Air Navigation (TACAN) signal processing unit in the receiver-transmitter. This information includes target data, altitude, ground speed, direction, fuel reserves, weapon reserves, and radar signature returns.

The JTIDS program is suffering from developmental problems that will result in significant schedule slippage. The team of Singer and Rockwell-Collins has delivered JTIDS terminals to the air force, army, and U.K. Ministry of Defence for testing. Singer was awarded a $12 million contract for program definition of the Multifunction Information Distribution System, the NATO version of JTIDS.

Basic Research

Overview

Research and development can be divided into programs that form the basis for or support new aircraft like the ATF, programs that develop technologies to upgrade a particular aircraft, and programs that develop a certain class of technologies not specifically related to platforms. The following discussion of planned and ongoing aircraft and avionics R&D programs is organized according to these three types of programs. Table 2 shows requested funding of avionics R&D for fiscal year 1990 and fiscal year 1991, as compared to planned funding in fiscal year 1989.

© 1989 Dataquest Incorporated November

Table 2

Estimated Research and Development Funding in Aircraft/Avionics
for Fiscal 1989-1991
(Millions of Dollars)

Program	Planned FY 1989	Cheney Proposal FY 1990	Cheney Proposal FY 1991
B-2 Bomber	$5,200	$4,700	$5,300
JTIDS	$ 49	$ 81	$ 81
JSTARS	$ 259	$ 193	$ 110
Advanced Materials		$ 12	$ 15
Aircraft Avionics	$ 25	$ 26	$ 33
INEWS/ICNIA	$ 37	$ 33	$ 31
ATARS	$ 144	$ 291	$ 265

Source: U.S. Department of Defense
November 1989

New Platforms

Advanced Tactical Fighter (ATF). The ATF will replace the F-15 as the air force's top fighter from the mid-1990s to the year 2020 and may eventually also serve the navy in place of F-14s. The air force expects to procure 750 ATF aircraft, whereas the navy estimates a need for 552 carrier-capable versions of the ATF. Through 1989, approximately $1.1 billion has been funded for engine, airframe, and critical subsystem R&D. Avionics is a critical element of the ATF. In 1987, the commander of the USAF Systems Command estimated that the air force would spend $900 million on avionics during the prototype phase, which is more than will be spent on either the engine or airframe. Development of such components as the radar and electro-optic sensor system is currently under way, with flight testing for radars expected in 1992 and electro-optic sensor system flight tests planned for the end of 1989. The project as a whole has slipped one year in its schedule as the contracting teams search for ways of meeting the air force's weight and cost requirements. This means that flight tests of the full-scale development aircraft would begin in 1993. Budgetary pressures, however, may cause an additional delay of one to two years in the program.

The two prime contracting teams, Lockheed-General Dynamics-Boeing and Northrop-McDonnell Douglas, have less than a year before prototype flights in 1990, after which a $7 billion full-scale development contract will be awarded (January 1991). At the end of this year, ground-based prototypes of the ATF's avionics must be completed for demonstrations. Both the Lockheed and Northrop teams chose a Westinghouse-Texas Instruments team to supply the ATF prototype active element,

© 1989 Dataquest Incorporated November

phased array radar; a General Electric and Martin Marietta team also has been chosen by both primary teams for the electro-optic sensor system, with General Electric as the lead for Lockheed and Marietta as the lead subcontractor for Northrop. Other Lockheed subcontracts are as follows:

Firm	Subsystem
Dupont	Thermoplastics
General Electric	Displays
GE/Marietta	IR
Harris	Avionics bus interface
Hughes	Common/avionics processor
Lear & GFC	Flight control
Litton/Honeywell	Inertial navigation unit
Sanders	
EW (INEWS)	
Texas Instruments	Mission processor
Westinghouse-Texas Instruments	Radar

Light Helicopter Experimental (LHX). The army's LHX program to replace AH-1, OH-58 (A,C,D), and OH-6 helicopters and complement the AH-64 has been scaled back considerably from the original concept defined a few years ago. Since the utility version was dropped last year, the number of aircraft to be procured fell to 2,096 from more than 4,100. An independent study has been conducted to determine whether competitive production is still warranted, given these lower numbers.

In November 1988, the army awarded two $158 million contracts to the contractor teams of Bell Helicopter Textron-McDonnell Douglas Helicopter Co. and Boeing Vertol-Sikorsky Aircraft for a 23-month demonstration/validation phase, ending September 1990. A full-scale development and production contract is planned to be awarded in December 1990 and initial operating capability is scheduled for 1996. Additional slippage in the program can be expected.

 © 1989 Dataquest Incorporated November

Approximately 75 percent of the demonstration/validation effort will be directed to mission equipment; avionics are expected to comprise 60 percent of the aircraft's cost. Boeing-Sikorsky unveiled its fan-in-tail design in October 1988 and McDonnell Douglas-Bell revealed its NOTAR (no tail rotor) design in February 1989. The McDonnell Douglas-Bell team has claimed greater experience in designing attack helicopters, but both tail rotor designs are innovative, and Boeing-Sikorsky have stated that they intend to use fiber optics in some areas, another innovative and relatively untested technology in operational aircraft. Listed below are the major subcontractors for the Boeing-Sikorsky team:

Firm	Subsystem
Boeing Electronics	Flight control computer
Boeing Military Airplanes Mission	Equipment package/avionics system integrator
Collins Avionics	Integrated Communication Navigation, Identification (ICNI), displays
Hamilton Standard	Flight control computer, helmet-mounted display
Harris	Super high-speed data bus, digital moving map/terrain data base technology, VHSIC
IBM	VHSIC-based processor
Martin Marietta	Target acquisition/designation system, pilot night-vision system
TRW	VHSIC-based signal and data processors, ICNI, electronic self-defense
Westinghouse	VHSIC-based computers, millimeter wave radar, electro-optics

© 1989 Dataquest Incorporated November

The McDonnell Douglas-Bell Helicopter team has subcontracted with the following firms:

Firm	Subsystem
AT&T	Signal-processing hardware
Eaton	Electronic warfare suite
GE-Honeywell	Integrated flight control
Hughes-Honeywell	Wide-angle helmet-mounted display
Hughes-Texas Instruments	Mission processor, EOTADs, night vision, pilotage
Litton Systems, Canada	Flat panel cockpit displays
McDonnell Douglas Aircraft	Mission equipment package integration
Northrop	Electronic defense package
Unisys	Common modules for mission processor

The weight restriction of 7,500 pounds and cost ceiling of $7.5 million per helicopter have created significant technical challenges for the contracting teams. The use of composite materials will reduce weight, but there also have been reports of abandoning ICNI/INEWS, reducing requirements for computer-aided target detection, and making some components optional rather than standard. In an effort to cut costs, Boeing-Sikorsky has contracted Augusta to use an A129 helicopter as a flying test bed for key mission equipment. The army also has made efforts to gauge European interest in LHX technology to defray costs, but with little success thus far.

Close Air Support Aircraft. The air force presented the results of a $4.9 million design study of close air support aircraft in November 1988 to the DOD officials. Such an aircraft would replace the existing A-10, scheduled for retirement in 1992. The fiscal year 1990 budget request includes $66 million and $55 million in fiscal year 1991 for close air support aircraft, but no airframe has yet been specified. Although Congress has directed the air force to conduct a fly-off between modified F-16s, AV-8Bs, and A-10s, the DOD is also considering new designs and does not anticipate a fly-off until the early 1990s. The A-16 development is estimated at $110 million, in contrast to the $2.5 billion for a new multimission aircraft.

© 1989 Dataquest Incorporated November

The air force has promoted a derivative of the F-16, designated the A-16, for the role, arguing that the airframe of the aircraft is less important than specialized systems such as terrain-following and night attack systems, stand-off weapons, and rapid target lock-on weapons. Some of the technologies demonstrated by General Dynamics to improve the F-16's close air support and battlefield interdiction capabilities include: Texas Instruments' Falcon Eye (head-steered FLIR), GEC Avionics' helmet-mounted display (HMD), Martin Marietta's Pathfinder navigation/attack FLIR pod, GEC Avionics' Cat's Eyes low-light-level night vision goggles, and British Aerospace's terrain profile matching digital navigation system (TERPROM).

One compromise suggested by a DOD official in early 1989 has been to use modified F-16s to replace A-7s while retaining and upgrading A-10s. Given overall budgetary constraints and the air force's lack of enthusiasm for the mission, this may be the most likely outcome.

Advanced Tactical Support Aircraft (ATS). The navy is also looking to upgrade its support aircraft capability with the development of the ATS to replace the EA-6B electronic warfare, the S-3 ASW, and E-2C airborne early warning aircraft. This system would perform surveillance and electronic warfare support missions requiring range and airborne loiter capability. Multimission capability would be achieved through software rather than hardware configurations. Several aircraft already have been suggested as the bases for ATS: Lockheed's S-3 with new wings and surfaces, the ATA (A-12), and the V-22 Osprey tilt-rotor. The navy requested slightly less than $1 million in fiscal year 1990 and $1.5 million in fiscal year 1991 to evaluate land-based, carrier-based, and off-board candidates for the role. The ATS and ATA probably will constitute much of the navy's aircraft budget within 10 years.

Long Range Air Antisubmarine Warfare Capable Aircraft (P-7A) ((LRAACA). In January 1989, Lockheed was awarded a $52 million contract for full-scale engineering development of two prototype LRAACA aircraft. The P-7A will replace early-generation P-3s beginning in 1994. Lockheed's design is based on the P-3C Orion, but incorporates new engines, composite propellers, Update IV ASW mission avionics systems, and a significantly improved payload capability. The Update IV mission avionics system includes a distributive processing system based on Motorola's 68000-series microprocessor, as well as the installation of the AN/UYS-2 enhanced modular signal processor (EMSP) developed by AT&T and Honeywell. These are significant improvements over the P-3. Listed below are the major subcontractors for the Update IV and P-7A systems:

© 1989 Dataquest Incorporated November

Firm	Subsystem
Allied-Signal	Garrett Auxillary Power Unit
Astronautics	Electronic Displays
Canadian Marconi	Microwave landing system
Control Data	Stores management system
Flight Dynamics	Head-up display
General Instrument	AN/ALR-66(V)5 ESM
Honeywell	High-density digital data recorder
M/A-COM Govt.	Satellite communication modem
Magnavox	Acoustic system
National Water Lift	Flight control actuators
Resdel	Sonobuoy receiver
Rosemount	Distributed air data system
Smiths Industries	High-resolution color displays Flight management system
Lear Astronics	Integrated flight controls
Texas Instruments	AN/APS-137 radar, Digital MAD

The first prototype delivery will be in July 1992, followed by a second in March 1993. The navy requested $205 million in RDT&E funds in fiscal year 1990 and $252 million in fiscal year 1991. The navy plans to buy 125 aircraft from 1994 to 2001.

Technologies for Aircraft Upgrades

AH-64 Multistage Improvement Program (MSIP). The army has requested $84 million in fiscal year 1990 and $61 million in fiscal year 1991 for the MSIP for the AH-64 Apache helicopter. The program will be conducted in two phases: Phase 1 will last one year and consist of a determination of near-term enhancements to the Apache; Phase 2 will last three years and include development of system processors, weapon processors, displays, air data computers, etc. Some of the subcontracts let within the

© 1989 Dataquest Incorporated November

MSIP program include $2 million to Honeywell for 1750A-based processors, software, and support, and $88 million to Martin Marietta for Target Acquisition Designation Sight/Pilot Night Vision Sensor (TADS/PNVS) and $3.7 million for electronic enhancements to improve air-to-ground and air-to-air targeting capabilities. In addition to MSIP, the Apache will incorporate the Airborne Adverse Weather Weapon System (AAWWS), revealed only last year by the army, and a new fire control radar. Production of the AH-64 MSIP is planned to begin in 1993.

MH-60K Black Hawk Derivative. Sikorsky Helicopters has been developing a derivative of the Black Hawk under a 38-month, $83 million contract awarded in January 1988. The MH-60K will incorporate air-to-air refuelling capability, a Texas Instruments AN/APQ 168 terrain following/terrain avoidance radar, and an integrated avionics package that includes a CRT display and a Hughes AN/AAQ-16 FLIR. The initial army requirement is for 22 of these Special Operations aircraft, with first flight sometime in 1990.

Experimental Aircraft. The Advanced Fighter Technology Integration (AFTI) F-111, which incorporates a mission-adaptive wing, concluded flight tests in 1988. A number of flight tests also have been conducted on the X-29, the F-15 STOL Demonstrator, and the Advanced Technology Tactical Transport. In addition, the navy awarded a contract to North American Rockwell for $47.3 million to complete design and fabrication of the X-31 Enhanced Fighter Maneuverability demonstrator aircraft, which will serve as a test bed for advanced fighter maneuverability technology.

Unmanned Aerial Vehicles (UAVs). At the request of Congress, the DOD developed the Unmanned Aerial Vehicle Program in 1988, a master plan to determine remotely piloted vehicle requirements. The overall plan calls for $1.6 billion from 1990 to 1994 for nonlethal vehicles.

There are two basic classes of unmanned vehicles: short range and midrange. The DOD has developed two other classes: endurance and close range. The short-range vehicle program, after the cancellation of the Aquila remotely piloted vehicle last year, is in the midst of defining requirements and seeking contractors. Short-range UAVs will operate at about 25 to 30 kilometers from the forward line of troops. In September 1989, teams led by Israel Aircraft Industries (IAI) and McDonnell Douglas won preproduction contracts to be complete by October 1991. McDonnell Douglas has teamed with Developmental Sciences Corp. on their $43.1 million contract; McDonnell Douglas will integrate, and Developmental Sciences will provide the Sky-Eye R4E-50 system. The IAI team will use the IAI Impact UAV with TRW Defense System handling integration and Teledyne propulsion in its $18.5 million contract. A total of 308 air vehicles with 38 ground stations is the estimated requirements from fiscal year 1989 to fiscal year 1994. A flyoff is expected in 1991.

The midrange UAV program, or Joint Service Common Airframe Multiple Purpose Set (JSCAMPS), is further along in the acquisition process. Four contenders for the UAV will perform reconnaissance missions as far as 700 kilometers from the edge of the battle: Northrop's NV-144R, Teledyne's Model 350, and designs by Martin Marietta and Beechcraft. Teledyne, teamed with Computing Devices, was awarded the multimillion dollar contract in mid-1989. A total of 775 medium-range UAVs is sought.

© 1989 Dataquest Incorporated November

The close-range and endurance UAV programs are still in the concept definition stage; a request for proposals for the endurance program is expected in 1991. At present, Leading Systems' Amber drone and Boeing's Condor are competitive systems.

The next-generation unmanned aerial vehicle, the Autonomous Air Vehicle (AAV), is in development by Martin Marietta for DARPA. AAV will integrate forward-looking infrared sensors and millimeter wave radars with image and signal processing, artificial intelligence, sensor fusion, and parallel processing techniques. The AAV is based on Martin Marietta's Geometric Arithmetic Parallel Processor. The goal of the program is to develop a UAV that will be able to find targets, such as ICBMs, in the midst of background clutter.

In lethal unmanned aerial vehicles, the key program is Tacit Rainbow, an air-launched cruise missile. Plagued by testing failures earlier that caused substantial delays, the program was more successful by mid-1989. The cost of the Tacit Rainbow program is estimated at $4.4 billion. Northrop is the prime contractor; a second source will be chosen next year.

Nonplatform-Related Research. Nonplatform-related avionics applied research is currently characterized by two trends: integration and commonality of systems, and efforts to reduce complexity for the pilot. The Pave Pillar (now known as Advanced Systems Architecture) and Pave Pace programs attempt to improve integration while the Pilot's Associate Program is geared toward improving human performance in conjunction with advanced avionics. One of the more specific programs is Agile Eye, a helmet-mounted display developed by Kaiser and McDonnell Douglas that began tests in 1987. In addition, TRW recently received a $5 million contract for avionics integration and support technology for the Aeronautical Systems Division. Details of specific nonplatform-related research follows:

- Advanced Systems Architecture (Pave Pillar). The Pave Pillar program is designed to improve availability, cost, and mission effectiveness through integration of electronic subsystems. The application of VHSIC and fiber-optic multiplexing technology are an integral part of Advanced Systems Architecture. Modular Systems Architecture, mentioned earlier, is built around a limited VHSIC chip set. One of the goals of the program, to establish a standard architecture, has been achieved with the introduction of the MilStd 1750A computer.

- Pave Pace. The latest DOD avionics initiative, Pave Pace, is aimed at creating the next generation of avionics technologies, including a 32-bit computer, parallel processing, artificial intelligence, neural networks, and optoelectronics. The system is planned to be fault-tolerant, allowing malfunctioning components to be bypassed without seriously degrading system performance. Funding of $150 million is being sought over the next 7 to 10 years.

 © 1989 Dataquest Incorporated November

- Pilot's Associate. The Pilot's Associate program seeks to balance automation and pilot experience in the cockpit, using expert systems for "adaptive aiding" and "information fusion," two key concepts in the Pilot's Associate program. Pilot's Associate is being studied by Wright Aeronautical Laboratories and both Lockheed and McDonnell Douglas, with respect to the ATF program. The McDonnell Douglas-Texas Instruments team demonstrated its system to the air force in February 1989. Originally planned to be a massively parallel, synchronized system, McDonnell Douglas reduced the level of parallel processing when DARPA decided to emphasize near-term applications in July 1988. The project is funded at about $20 million per year. DARPA told the House Armed Services R&D Subcommittee in 1989 that the full functional capability of the Pilot's Associate system should be demonstrated by the end of 1989, but that a real-time demonstration with Ada software and avionics hardware would not occur until 1991.

- Advanced Tactical Air Reconnaissance System (ATARS). ATARS will upgrade joint tactical reconnaissance capability. ATARS will replace current film-based sensor equipment and will include: TARS (Tactical Aircraft Reconnaissance System), UARV (Unmanned Aerial Reconnaissance Vehicles), and JSIPS (Joint Services Imagery Processing System) ground equipment package. Full-scale development of the UARV began in fiscal year 1989, and TARS is currently in full-scale development. TARS comprises Fairchild-Weston's electro-optical and Honeywell's infrared sensor suites that include sensors, digital data recorders, video management, and wideband data-link sets. Unisys Defense Systems' Unit won a $15 million subcontract for full-scale development of the data link from Control Data Corp. The contract itself calls for initial production options totaling $70 million. Unisys also won a $6.5 million subcontract for the JSIPS from E-Systems. Most recently, Control Data subcontracted to Datatape for the digital tape recorder. The ATARS may be used in F-16 and F/A-18 aircraft.

- Air Defense Initiative. The Air Defense Initiative is an umbrella program that includes not only air defense systems for aircraft but also strategic air defense measures. Under this program, Aerospace Avionics accounted for $73 million in fiscal year 1989, covering nine projects. The electro-optics technology project funded optical signal processing methods and an initial feasibility study of Gallium Arsenide (GaAs) optical waveguide development as well as a carbon dioxide laser demonstration. The microwave technology program was the largest of the avionics R&D projects at about $7 million. Its purpose was to develop technology to produce, control, and apply millimeter/microwave power using solid-state sources and amplifiers, thermionic devices, and phased array antenna techniques, among others. Such technology would be applied to radars, communications, and ECM. The project for technologies for reconnaissance and targeting developed sensors for improved target detection and identification and explored computer optimization of IR focal plane arrays. Other projects included R&D in inertial guidance, avionics data transmission and reception, fire control, passive ECM, all-weather reconnaissance, and active electronic countermeasures.

© 1989 Dataquest Incorporated November

- Other basic and applied research. In addition to aircraft in the research and development phase and ongoing R&D programs, studies currently are being conducted on technologies needed to develop the next generation of aircraft. One such study is the classified Advanced Counter Air Systems conducted by IBM and Grumman for the Army Aviation Systems Command (AvsCom) to determine enabling technologies for a Future Attack Rotorcraft, or FAR. The studies, to be completed in 1989, will include assessments of speed, altitude, controlled signatures, and advanced sensors for the FAR, as well as scenarios of engagements against the Soviets' antihelicopter helicopter, the Ka-Hokum. By 1996, AvsCom will decide whether to proceed with the FAR or replace the AH-64s currently in the inventory with upgraded AH-64s resulting from the MSIP. DARPA also has funded research into a small, highly agile antihelicopter, fixed-wing aircraft. Another recent solicitation for proposals was issued by the Air Force Wright Aeronautical Laboratories for "evolutionary concepts that would be applicable to electronic support measures or electronic countermeasures." Such concepts would be applied to weapon systems fielded in the next 5 to 10 years, preferably in the areas of radio frequency, laser, infrared, electro-optical, and ultraviolet. Further, General Electric recently received a contract to design a smart skins integrated processor/transceiver, and the Photonics Lab at Rome Air Development Center has expanded its facilities this year to increase its research in photonics.

  Photonics, or fiber-optic systems, offer significant improvements over current systems. With a fiber optic system, the elimination of copper wiring will reduce weight and space and decrease generated heat. Further, fiber-optic systems are immune to electromagnetic interference, electromagnetic pulse, and radio frequency interference. One use of fiber optics emerging from the laboratories is in inertial guidance. Fiber-optic gyros (FOG) are currently being developed by Honeywell and Litton, among others. Three types of FOG are now under development: open-loop interferometric, closed-loop interferometric, and resonant FOG. The open-loop interferometric is the least accurate but also the least expensive and will be used principally as an angular-rate sensor. The closed-loop design is more complex and could be available soon, whereas the R-FOG is currently a very young technology. In addition to industry efforts, MIT's Draper Laboratory is active in R-FOG technology development and received a $26 million army contract in 1987 for a five-year effort.

© 1989 Dataquest Incorporated November

ELECTRONIC WARFARE

Overview

The electronic environment on the battlefield continues to grow more hostile, and a wider range of jamming equipment is being fielded than ever before. In the past, most electronic warfare equipment, such as radar warning receivers and jammers, operated at radio frequencies. Improved Soviet capability in heat-seeking missiles, which operate in the infrared range of the electromagnetic spectrum, as well as in other systems operating in the visible range of the spectrum, have spurred the military services to create a broader array of countermeasure programs.

The U.S. inventory contains more than 400 signals intelligence and EW systems. The market for EW systems grew at an average rate of 25 percent from fiscal 1982 to 1985, but has since leveled off at approximately $6 billion annually. Procurement of electronic warfare equipment may even suffer some small cutbacks in the near term. The acquisition of spares, however, will continue to grow as electronic equipment is used more widely than ever before. Overall spending on electronic warfare is likely to increase in the early 1990s, moreover, when the next generation of EW systems goes into production.

Until recently, the electronic warfare portion of the avionics budget has resisted standardization efforts, but this has been more the result of technical difficulties in countering a class of threats than satisfaction with the number and cost of systems being procured. In fact, Congress criticized the breadth of DOD programs in electronic warfare last year and requested a more detailed Electronic Warfare Master Plan. The DOD is moving slowly toward integration and commonality. The air force spent almost $200 million on common ECM equipment in 1988. Programs like Litton's ALR-74 or ITT-Westinghouse's Airborne Self-Protection Jammer (ASPJ), which attempted to counter a broad range of Soviet radar threats, however, have encountered technical problems because of the demanding requirements placed on them. Yet further integration will require even more sophisticated software and faster signal processing. The navy is apparently developing generic software algorithms to address this problem, but no easy solutions are in sight.

Conventional electronic warfare comprises three basic missions: electronic countermeasures (ECM), electronic support measures (ESM), and electronic counter-countermeasures. Electronic countermeasures can be either active or passive. The most common form of active ECM is jamming (noise or deception). Passive ECM can include maintaining radio/radar silence, or using low-observable (stealth) technology. The most common and least expensive passive ECM is the use of chaff and/or decoys. Electronic support measures include listening to enemy radars and radios. Radar warning receivers are a type of ESM. Electronic counter-countermeasure systems encompass ELINT, SIGINT, and other measures to ensure friendly access to portions of the electromagnetic spectrum. Antijam capability is built into the equipment; about 15 percent of electronic warfare funds are allocated to this technology, although most of it is classified.

© 1989 Dataquest Incorporated November

Systems Development and Procurement

Electronic warfare equipment is fielded in a bewildering variety of systems. The lists of air force electronic warfare programs below is to give an idea of the number of programs involved:

F/FBE/F-111 Self-Protection

EF-111A Upgrade Program

F-4G Wild Weasel PUP

TEREC/ALQ-125

Technique 101 Subsystem

AFEWES Testing-FMS

AFEWES Upgrading

ASPJ

ASPJ/F-16 Integration and Test

ALQ-131 (V) ECM Pod (R/P)

Countermeasures Systems (QRC 85-04)

EW Area Reprogramming Capability (ARC)

INEWS

MJU-10/B Infrared Flare

Real Time Electronic Digitally Controlled Analyzer and Processor (REDCAP)

RR-180 Dual Chaff

IRCM/Have Charcoal

AN/ALE-47

Much of the funding for EW equipment falls under aircraft modification programs. Among these are the F-4, F-111, and EA-6B programs, as well as the Tactical Protective program to upgrade F-15s and F-16s.

© 1989 Dataquest Incorporated November

Aircraft Modifications and Upgrades

F–4G Performance Update Program. The F–4G Wild Weasel has been the mainstay of air force electronic countermeasures platforms. The F–4G's capabilities are being enhanced with improved receivers and signal processing capabilities. Total funding for F–4G modifications was $95 million in the fiscal year 1990 budget request, and $108 million in fiscal year 1991 request. Under a 1986 contract to McDonnell Douglas, some 150 new units, including spares, will be produced for 119 F–4G aircraft.

The F–4G currently is fitted with the AN/APR–38 Radar Attack and Warning System. The APR–38 includes an IBM superheterodyne receiver, Texas Instruments' HAWC central processor, Loral's CIS control and display system, and GE's AN/APQ (MOD) pilot's sight.

The HAWC processor will be replaced by a Unisys signal processor under a $55 million Phase I subcontract. This Weasel Attack Signal Processor (APR) has improved reliability as well as 5 times greater signal processing speed, 10 times greater data processing speed, and 8 times more memory. The last WASP was delivered in the summer of 1989; a total of 50 units was purchased at $55 million. With the WASP, the APR–38 upgrade to the APR–47 is complete.

Phase II of the F–4G performance upgrade program was planned to include the development of the Directional Receiver Group (DRG) to improve power in the ALQ–99E jammer, as well as new antenna arrays to increase frequency coverage and improved software. E–Systems developed the DRG to replace the IBM receiver. The DRG is a steered channelized receiver made of five line–replaceable units. The air force declared the E–Systems contract in default in June 1988, however, and the upgrade will probably be left to the Follow–On Wild Weasel program.

The Follow–On Wild Weasel will replace the F–4G in the mid–1990s; the air force is expected to issue a request for proposals at the end of 1989. The air force is considering the F–15E, F–16 C/D, the Tornado ECR, and the ATA and ATF as candidates. The two–year demonstration/validation phase of the contract will start in 1990, and first deliveries of the aircraft are tentatively scheduled for 1999. It is likely that any follow–on to the Wild Weasel will be supplemented with unmanned vehicles, such as the AGM–136 Tacit Rainbow.

F–111. The program to upgrade the entire F–111 fleet, including the F–111, FB–111, and the EF–111, with new self-protection avionics equipment was canceled in 1987. Nevertheless, some other improvements are being made. Rockwell International's Collins Government Avionics Division delivered integrated communication navigation sets under a $1.9 million contract with the USAF Sacramento Air Logistics Center in late 1988. With options, total value of the contract could reach $7.5 million. Other upgrades include the ALR–62I radar warning receiver and the ALQ–97/137 self–protection jamming system. Production has begun on the ALR–62I, and the air force is currently procuring ALQ–131/184 pods for the F–111. The EF–111 will retain its ALQ–94/137 internal jammer, but there are plans to upgrade this system in 1992.

© 1989 Dataquest Incorporated November

EF-111A. In fiscal 1988, the air force began a series of upgrades to the 42 EF-111A Raven electronic combat aircraft. The Raven is designed to provide stand-off jamming within its own airspace or to accompany bombers while jamming enemy radar; the Raven would also destroy enemy radar sites with radiation-seeking missiles. The purpose of the upgrades is to improve tactical jamming gear to increase reliability and maintainability.

The first improvements to the Raven will be in computer processing. The 1750A processor, manufactured by Delco under subcontract to Eaton AIL, is a year-and-a-half behind original schedule; Operational Test and Evaluation (OT&E) was scheduled to begin in January 1989. Although the 16-bit 1750A standard is being modified to include new requirements, it may be dropped as the Pentagon moves to 32-bit instruction set architecture. Other improvements will update the radio receiver and antennas. Grumman is a prime candidate, given the work Grumman performed on the EA-6B.

EA-6B. Capabilities of the navy's EA-6B tactical support aircraft were enhanced under the Improved Capability Program (ICAP II) by Boeing Aerospace, which was awarded an $11 million contract. Grumman subsequently received an $18 million contract in January 1989 to perform the next upgrades on the EA-6B. Additional modifications will be made under the Advanced Capability Program (ADVCAP), scheduled to begin in fiscal 1990. The ALQ-99 is the backbone of the ADVCAP. Litton was selected by Grumman to produce the ALQ-99 and flight testing was conducted last year; full-scale development is expected in 1991. An improved electronic countermeasures set for the EA-6B, the Lockheed Sanders Associates AN/ALQ-149, has been delivered to the navy, increasing the radar and radio frequency jamming coverage of the aircraft. The Sanders contract included options for 95 sets. The ALQ-149 consists of eight line-replaceable units, including antennas, receivers, signal recognizers, computers, and controls.

At the end of 1988, Sanders Associates delivered the last of the engineering models of the AN/ALQ-149 to the navy for the EA-6B. The ALQ-149 will detect, identify, evaluate, and jam hostile communication signals, as well as long-range early warning radar systems. Composed of eight replaceable assemblies, the ALQ-149 is expected to be deployed on the ADVCAP version of the EA-6B in the early 1990s. Full-scale production is expected to begin in 1991.

Beginning in fiscal year 1991, new procurement of the all-weather electronic countermeasures EA-6B will be terminated while Grumman and Pratt-Whitney remanufacture existing aircraft. The remanufacture program will convert existing Prowlers into ADVCAP variants, increasing their frequency coverage.

© 1989 Dataquest Incorporated November

Tactical Protective Systems. This program includes upgrading the self-protection and electronic combat capabilities of the F-15 and F-16. The F-15 upgrades include incorporating the ALR-56C radar warning receiver, the ALQ-135 internal jammer, and the ALE-45 chaff dispenser. The ALQ-135 jammer is being produced in fourth and fifth lots. This jammer counters the full range of modern SAMs, antiaircraft artillery, and interceptor radars. Lot IV deliveries are scheduled for November 1990 through December 1991; Lot V deliveries should begin in December 1991 and continue through 1993. The ALQ-135 program has suffered a setback in its schedule; Undersecretary of the air force for acquisition John Welch cited problems with software, which could delay the ALQ's initial operating capability beyond 1989. The ALE-45 chaff dispenser is the third part of the F-15's tactical electronic warfare system upgrade. Manufactured by Tracor, the ALE-54 uses a solid-state microprocessor.

The F-16 will receive the ALE-47 chaff dispenser. The ALE-47 dispenses metallic chaff or flares from aircraft to foil enemy antiair defenses. Under this joint air force and navy program, Tracor Aerospace has received $16 million in development funds, although the system is supposed to be procured competitively. Current estimates indicate that a firm would need $77 million over 4.5 years from 1991 to become competitive, however, and the current budget situation may negate this possibility.

Integrated Programs

The services have been criticized in the recent past for an abundance of programs that are redundant and costly. As a result, greater stress is being placed on the development of integrated systems such as those described below.

Integrated Defensive Avionics Program (IDAP). The navy's IDAP program will combine off-the-shelf devices into an integrated ECM suite for navy tactical aircraft, beginning with the A-6E. IDAP will include the following:

- New version of ALQ-156 (IR)
- ALR-67 RWR
- Airborne Self-Protection Jammer (or ALQ-126B)
- ALE-39 expendable CM dispenser or ALE-47
- Towed decoy

Sanders was awarded $12 million in 1989 funds for the full-scale engineering development phase of the ALQ-156 (V) N, with work to be completed by September 1990. The contract includes a receiver/transmitter, a buffer box, and antennas. The receiver is a 1976 pulse Doppler radar developed by Sanders. Total funding for the ALQ-156 (V) N has been $121 million.

The Naval Weapons Center at China Lake, California, is performing systems integration, and Grumman will integrate the ECM suite in the aircraft. IDAP is expected to enter production sometime in 1993.

© 1989 Dataquest Incorporated November

AN/ALQ-178. This electronic countermeasures system, manufactured by Loral, integrates a radar warning receiver and ECM suite. It includes a central programmable computer for data analysis and system control, as well as a continuous-scan wideband radar warning receiver and a superheterodyne and crystal video receiver.

Advanced Radar Warning Receiver. The navy and air force were criticized in 1987 for failing to promote commonality in their radar warning receivers. A GAO report cited failed attempts to merge the air force AN/ALR-69 upgrade (now designated AN/ALR-74) with the navy's AN/ALR-76. The report said that the two services have acquired nine different radar warning receivers at a total cost of more than $6.6 billion.

Radar warning receiver acquisition has come under additional scrutiny with the choice of Loral's AN/ALR-56M over Litton's AN/ALR-74 for the General Dynamics F-16 aircraft. Loral was awarded the contract in December 1988, which Litton contested, claiming that information made available to Loral by officials, subsequently prosecuted as part of the Ill-Wind scandal, unfairly biased the case against them. The GAO supported Litton's contention and recommended in May that the air force terminate the Loral contract because of "improprieties" in the bidding process. In May 1989, the air force froze program funds temporarily.

The Advanced Radar Warning Receiver contract is worth $20 million for 19 production systems to be delivered by March 1991; options include production of 654 additional receivers for fiscal years 1989 through 1992 for a total value of $210 million. The first receivers will be installed in new F-16 C/Ds; they could eventually be installed in more than 1,400 tactical aircraft. The ALR-56M also will be installed in B-1B bombers to remedy gaps in the radar warning coverage of the aircraft's ALQ-161 ECM system, developed by Eaton AIL.

Electronic Countermeasure Systems

ECM Pods. The air force is currently in the process of upgrading its inventory of externally mounted electronic countermeasure pods for the F-16, the F-111, the F-4, the A-10, and the A-7. Raytheon is the prime contractor to upgrade the ALQ-119 pods, which passed qualifying tests in 1988. Westinghouse has delivered ALQ-131 Block II pods to the air force.

Raytheon is producing the AN/ALQ-184, an upgraded version of the ALQ-119 jamming pod, for use against SAMs, radar-guided guns, and airborne interceptor aircraft. The ALQ-184 is installed on the F-4, F-15, F-16, A-7, A-10, and F-111. Congress directed the DOD in 1988 to hold a competition between the AN/ALQ-131 and the AN/ALQ-184 pods, given that they address similar threats.

Decoys. The services are developing new active radio-frequency-expendable decoys. The navy awarded a contract to a Raytheon-Hughes team in July 1988 for full-scale development of the Advanced Airborne Expendable Decoy. Two versions are being explored: a rocket-propelled system fired forward of the aircraft and a towed

 © 1989 Dataquest Incorporated November

decoy. Advanced development model flight tests have been successful so far. It has been reported that Teledyne-CME has a subcontract to design and develop the on-board electronics. Other programs include the Threat Adaptive Countermeasure Dispenser System (TADS) developed by Tracor for the services. TADS is a next-generation replacement for the ALE-40 (V).

Airborne Radar Jamming System. The Airborne Radar Jamming System, a high-power standoff jammer, is based on the ALQ-99, but will be mounted on helicopters, such as the UH-60 Black Hawk. In development by Grumman, the system will be used against air defense, surveillance, and target acquisition radars. Its functions will include detection of the threat signal, location of emitter, comparison against a computerized "threat library," and transmission of the jamming signal.

TACJAM-A. The army selected a team of Sanders Associates and AEL in mid-1989 to conduct Phase II engineering development of the TACJAM-A mobile jamming system. The $4 million contract requires Sanders and AEL to design and manufacture four models; full funding of the two-year Phase II could bring as much as $70 million to the contractor.

Electronic Support Measure Systems

AN/ALR-67. In production for several years, the AN/ALR-67 is deployed on navy F-14 A/D Tomcats, F/A-18C/D Hornets, and AV-8B Harriers. The ALR-67 is a countermeasure radar warning system that will be integrated with the Airborne Self-Protection Jammer (ASPJ). Litton is the prime contractor; Dalmo Victor is a second source. Litton received two production contracts for $37 million total in early 1989 and a third contract for $49 million in March 1989 for spares procurement. Deliveries are scheduled to begin in April 1990 and last through 1991. The contract includes quadrant receivers, computers, and special receivers.

A follow-on to the ALR-67 is in its early stages. The Advanced Special Receiver program has attracted four competing teams: ESSI, Litton-ATD and Harris; Dalmo Victor and TRW; Hughes and AEL; and Loral and Texas Instruments.

AN/ALQ-156. Sanders received a contract in October 1988 for full-scale development of a tactical aircraft version of the ALQ-156 missile detection system. First developed in 1976 under the army, the ALQ-156 works with Tracor M-130 chaff/flares dispenser.

Small Platform EW System. Currently in development by Motorola, the Small Platform EW System is intended for use on remotely piloted vehicles, in particular, for the Pave Tiger RPV. The combined transmitter/receiver/processor will be coupled with a four-quadrant antenna against ground-based radars, in support of the EF-111A.

Fiber-Optic Laser Warning System. Varo, Inc., is developing this laser-sensitive warning system for air- and sea-based, as well as ground, platforms. The fiber-optic system will cover wavelengths between 400 and 100 nanometers, with an angular coverage of 90 degrees. Each sensor will be mounted flat against an outer surface of the platform; each platform will need between four and six sensors.

© 1989 Dataquest Incorporated November

Infrared Countermeasures

Infrared countermeasures have become more important as the Soviets have demonstrated both the lethality of their own heat-seeking weapons and the utility of such countermeasures against those weapons in Afghanistan.

AN/AAR-44. The AAR-44 is an infrared warning receiver, produced by Cincinnati Electronics Corp., for missile detection. Cincinnati Electronics also produces the AAR-34 aircraft self-protection system, used on the F-111 and F-15.

AN/AAR-47. Honeywell developed the AAR-47 electro-optical missile warning set for the navy and received a contract to produce 106 systems, which was modified to include an additional 150 systems in early 1989. The AAR-47 is a passive system with 360-degree coverage using four electro-optical sensors. The sensors detect missile rocket plumes. The AAR-47 also dispenses chaff or flares automatically. Honeywell is developing a version for the F-16 fighter with General Dynamics. AAR-47s will be deployed on marine corps helicopters, P-3 antisubmarine aircraft, and C-130 transports. The army also plans to procure the AAR-47.

Basic Research

Overview

Individual service electronic warfare research was consolidated under the DOD in 1987 and divided into two accounts: science and technology development, and systems development. Currently, 34 EW research projects are in progress, with most of these supporting platform upgrades. The services requested $351 million in fiscal year 1990 and $397 million in fiscal year 1991 for electronic warfare research.

A total of $554 million in DOD funding for electronic warfare R&D was approved in fiscal 1988, 75 percent of the original budget request. The importance of electronic warfare is reflected in the fact that these programs, though suffering some cutbacks, have emerged largely intact from the budget maelstrom.

Research in electronics warfare is geared toward multispectral systems. The push for integration will mean that in addition to radio frequencies, systems will have to perform in the visible and infrared portions of the spectrum, perhaps using a time-sharing method. Millimeter and microwave technologies are one important area of research. The focus of air force research is presently monopulse radar countermeasures. Other areas include communications jamming, high-power radar countermeasures, and expendable radio frequency and infrared countermeasures for aircraft.

One area in which research is likely to expand is in space countermeasures. Even in the absence of a space-based component of SDI, U.S. military forces are nevertheless increasingly dependent on satellites for communications, and electronic countermeasures to protect these systems could become critical. These satellite-defense ECM systems can be located on-board, on an escort satellite, or on a stand-off satellite, in much the

© 1989 Dataquest Incorporated November

same way that aircraft ECM systems are deployed. The types of ECMs for space are also similar to those for aircraft—noise and deception jamming, decoys, chaff, and flares—but will require performance specifications for a space environment. Jammers in space will probably rely on advances in packaging and cooling techniques, whereas signal processing will benefit from advances in artificial intelligence and neural networks for signal processing.

Closer to home, the application of low-observable technology, or stealth, in the B-2 and F-117A, will have a profound effect on electronic warfare. Although Soviet materials technology has lagged U.S. technology, Soviet laser technology is first-rate, and the Soviets will likely focus on laser target designation techniques, as well as upgrading their IR-guided missiles. This could force the United States to devote more resources into laser warning systems, for one.

In the near future, trends in EW equipment, like many other areas, point to greater integration. Some integrated systems include a radar warning receiver, a threat processor, expendable decoys, and multimode jammers. INEWS is the largest of the integrated programs.

Integrated Electronic Warfare Systems (INEWS)

The largest EW program in history, INEWS will be standard equipment aboard the next generation of combat aircraft, including the air force ATF and B-2, and the navy ATA. The DOD spent $128 million on INEWS in 1988. INEWS will be used to replace the AN/ALQ-165 (ASPJ) on existing aircraft. For combat aircraft of the next century, INEWS will fuse the capabilities of jammers, missile detection/warning, laser-radiation detection/warning, and infrared missile jammers using VHSIC technology. Each chip will contain as many as 30,000 logic gates.

In a radical departure from past designs, INEWS will share common processors and antennas among the aircraft's electronic systems, allowing savings in weight, space, and cost. INEWS will incorporate the latest microelectronic technologies, including VHSIC and MIMIC.

Two industry teams are presently working on demonstration and validation of the system: TRW/Westinghouse (with Honeywell, Perkin-Elmer, GTE, Northrop, and Tracor as subcontractors) and Sanders Associates/General Electric (HRB-Singer and Motorola as subcontractors). Contracts for this phase were valued at $48 million. Phase II of INEWS, full-scale development, will begin in 1989 and continue through 1992. The development cost of INEWS has been estimated at approximately $500 million, with production estimates of some $7 billion. The contractor teams that develop the system will compete for production, which is planned to commence in late 1993, corresponding with the schedule of the TF.

INEWS is teamed with Integrated Communications, Navigation, and Identification Avionics (ICNIA). ICNIA, like Pave Pillar, is a modular system, combining the 16 radios now used on an aircraft into a single system. If part of the system fails, ICNIA would bypass the faulty component and continue to perform the original tasks for which it was

© 1989 Dataquest Incorporated November

programmed, dropping, if necessary, the least critical function. According to calculations by TRW, ICNIA will increase the time between critical failures up to 67 times that of present discrete avionics systems. The number of different types of circuit boards required will be reduced from more than 1,000 to 28.

The INEWS program office is aiming for a unit price of $1.8 million to $2.8 million, but some observers expect the system to exceed $3 million per aircraft. In addition to air force and navy fighters, ICNIA and INEWS are intended for the army's LHX helicopter.

Survivability Augmentation for Transport Aircraft-NOW (SATIN)

The need to protect airlifters from missile attack has spurred new programs for electronic countermeasures. The air force is testing the Lockheed SATIN ECM package for the C-130 transport. Lockheed is also conducting design studies on the C-141 and C-5 transports. The SATIN system is unique because it can be temporarily installed in a single 8-hour shift, allowing kits to be prepositioned in high threat areas rather than fitted to the entire cargo fleet. Lockheed has delivered a similar prototype defensive electronic countermeasures system for the marine corps' fleet of KC-130 Hercules tanker aircraft. The marine corps version is not removable; it includes the APR-39 (V)1 radar warning receiver, the AAR-47 missile detection system, and the ALE-39 chaff and flare dispensing system.

Expendable Jammers

A classified program to develop expendable jammers is being conducted by the DOD. A second program, called GEN-X Expendable Cartridge, has been conducted since 1987. Texas Instruments was awarded a $117 million contract to develop and produce the GEN-X, which operates over a wider frequency band than its predecessor, the Primed Oscillator Expendable Transponder (POET); Raytheon was selected as a second source. The GEN-X emits radar-like signals to lure radar-guided missiles away from target aircraft.

Electro-Optic Countermeasures (EOCM)

A new niche is beginning to appear in the defense electronics market. As every military measure begets a countermeasure, the increasing use of laser guidance and optical detection will create a need for electro-optical countermeasures (EOCM).

The largest current DOD EOCM program is the advanced optical countermeasures (Coronet Prince) program, a pod-mounted system to warn aircraft crews when they are spotted with a laser. The system would respond with a laser to blind air defense personnel and disrupt optical tracking. After testing aboard an E-4 aircraft, the air force has selected the Westinghouse AN/ALQ-179 EOCM pod for production. The system will be used on high-performance tactical and special-purpose aircraft. Coronet Prince could enter full-scale development in 1991.

 © 1989 Dataquest Incorporated November

The army has a similar program for helicopters called Cameo Bluejay. Sanders has developed a system for scout and attack helicopters, with prototype delivery scheduled for August 1989. Other helicopter programs include the Perkin-Elmer AVR-2 laser warning receiver, scheduled for deployment in 1990 or 1991.

Other uses of EOCM include optical chaff to confuse laser-seeking missiles, and optical decoys.

Have Glance. At present, IR jammers are deployed on helicopters, but advances in power and decreased size are necessary before they can be used effectively on aircraft. The classified Have Glance program aims to develop potential solutions to those problems in infrared countermeasures. The Have Glance system will use an infrared or pulse Doppler warning system to detect the missile and trigger the laser. In September 1988, Loral was selected over TRW to develop a laser-based IR countermeasures system. The resulting system will be used for strategic systems until its size can be reduced for tactical systems. Loral will develop a gimballed, low-power laser to locate, identify, and track approaching missiles and confuse or disable their guidance systems. Demonstration testing is expected in 1991.

SIMULATION AND TRAINING

Overview

As weapons and combat become more complex, training requirements increase. Although live training is most desirable, it is very expensive, and hence the services are turning increasingly to simulation to meet their training needs. Although it is a significant part of readiness, which is being highlighted by the Bush administration as a priority, training probably will not be immune to prospective budget cuts, and the reductions will likely reinforce upward trends in the use of simulators.

Simulators have become attractive to the services for their potential to increase training hours while reducing costs. The navy estimated that increased use of simulators would reduce fuel consumption by 64 percent, manpower by 44 percent, and the total training cost of a navy pilot by 45 percent.

Although simulators have been commonplace in both military and civilian aviation, the changing nature of warfare makes armored and even infantry battle sufficiently complex to warrant simulations. Training and simulation is approximately a $2 billion market in the United States, with moderate growth forecast for the next five years, as shown in Table 3. Note the increase in army funds for simulation and training.

© 1989 Dataquest Incorporated November

Table 3

Estimated DOD Training Market, Fiscal 1988–1992
(Millions of Dollars)

Service	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992
Army	$ 730	$ 870	$ 735	$ 865	$ 900
Navy	1,000	950	900	935	970
Air Force	600	620	745	600	620
Total	$2,330	$2,440	$2,380	$2,400	$2,490

Source: EIA Ten Year Forecast

The current world market for simulators is about $3 billion, and has been projected to increase to $4 billion by 1994. Simulators range from strap-on computers and specialized software, to electronic combat ranges, first developed in the 1970s. Simulators are becoming more and more realistic as weapon systems become more automated.

Until the 1970s, training was accomplished mainly in classrooms and trainer vehicles (aircraft, tanks, etc.). Full mission trainers, versions of weapon systems dedicated to training, comprised the norm. As computer-generated imagery capability expands, however, full mission trainers are becoming less attractive. Even though probably no substitute exists for maneuvering an actual airplane or tank, these systems are costly, and often lag the introduction of the operational system, creating a gap between operational and trainer capabilities. For example, the B-1B trainer was introduced four years after the B-1B was deployed.

One solution to the cost and delays of full mission trainers is to employ embedded trainers—using a weapon system itself as a trainer by connecting software-driven scenarios to the system. Embedded training offers the advantage of greater realism than ground-based simulators, and ensures that the trainer is as up-to-date as the operational system. Embedded training, however, also carries drawbacks. Adding equipment required for embedded training to large numbers of systems adds costs, not only in acquisitions, but in logistical support as well. The operational effectiveness of training could be degraded, moreover, if prime contractors do not place as much emphasis on the quality of embedded trainers as specialized training manufacturers have in the past.

Simulators are used in part-task training and strap-on training. Part-task training entails simulation at the component level: using computers to train a fire control operator is an example. Another example is weapons systems trainers for training in tactics and combat mission exercises. Strap-on training includes on-board training devices increasingly and interactive videodiscs. One example is the 20B5 pierside trainer for Perry-class frigates.

© 1989 Dataquest Incorporated November

Simulators are not only useful in training operators, but play a valuable role in gathering data on systems before they are deployed. Pilot work load on various cockpit configurations can be measured and applied to the design of new aircraft, for example. Other human factors analysis can be applied in simulated combat situations in order to make the most of human reasoning and reaction time. Simulators are also becoming a valuable tool for mission rehearsals; the navy hopes to install the CV Trainer on aircraft carriers for that purpose. Simulators will be used extensively in mission planning and mission support systems. In particular, programs are being developed to give aircraft and cruise missiles preplanning, rehearsals, and in-flight updates.

One of the earliest air combat simulation efforts included the navy's Tactical Aircrew Combat Training Systems (TACTS) and the air force's Air Combat Maneuvering Instrumentation System (ACMI) programs. Cubic Corp. received a $5 million modification to a contract to upgrade, install, and test two existing display and debriefing systems for the National Guard as part of the TACTS program. Completion of the task is expected by mid-1990.

Aircraft Simulation and Training

Specialized Undergraduate Pilot Training (SUPT)

The largest training program in procurement is the Specialized Undergraduate Pilot Training Program. The air force presented a 20-year, three-plane acquisition program for training to the Congress in February 1989. The air force is hoping to create two tracks for undergraduate pilot training: bomber-fighter training and tanker-transport training. The SUPT program is estimated to cost close to $18 billion over the next 24 years, $7 billion of which would be allocated to three training systems. The air force plan calls for immediate procurement of 211 jets for the tanker-transport training portion of the program. Ten years from now, the air force would begin procuring 538 primary aircraft training system (PATS) aircraft to replace the current T-37 trainer. Finally, the air force would buy 417 new bomber-fighter training system (BFTS) aircraft to replace T-38 aircraft in the year 2005.

These plans to procure separate aircraft by the air force were rejected last fall by Congress, however; the navy has since agreed to buy up to 20 air force tanker-transport aircraft. The Congress hopes that the air force will buy the navy's T-45 Goshawk for the bomber-fighter trainer role, but the air force claims, among others, that the T-45 will be outdated by 2005. A March GAO report suggested that the air force would save $954 million over the next five years by not buying any aircraft at all, which conflicts with the air force's plan to award a tanker-transport contract by 1990.

The air force requested $151 million in fiscal year 1990 funding for initial procurement of 14 aircraft, and $181 million in fiscal year 1991 for 28 aircraft. Congress approved $10 million last year for fiscal year 1989, but funds will not be obligated until Congress reviews the master plan. A draft request for proposals for the tanker-transport system was issued at the end of March 1989; the proposal stated a

© 1989 Dataquest Incorporated November

FAA phase-II simulator with an enhanced visual system capable of day, dusk, night, and textured-image generation. Contractor teams submitting proposals included the following:

- Flight Safety International, Learjet
- General Dynamics, Cessna, CAE-Link
- Hughes, LTV
- McDonnell Douglas, Beech
- Rockwell, British Aerospace, Reflectone

Another aspect of the air force's program includes the modernization of air force simulators in the instrument flight simulator program. Night Hawk computers manufactured by Harris will be used. The potential value of contracts could be more than $3 million. Quintron was awarded $16 million in late 1988 for logistics support for undergraduate pilot training instrument flight simulators. Completion is expected in August 1990.

Full Mission Trainers. The F-15E simulator became the first trainer to be developed concurrently with a new aircraft in September 1988. The simulator is especially important to training because the air force plans to use only 12 percent of the fleet for training, instead of the usual 25 percent. This cutback was made because of budgetary constraints.

Loral Systems was awarded the production contract in 1986 and delivered the first trainer in September 1988. The remaining two trainers will be delivered in 1989 and 1990; Loral hopes to produce three additional trainers for the air force. Development and production of the three trainers will cost the air force $145 million. Subcontractor teams include the following:

- Evans & Sutherland-Computer Products
- Interactive Machines-Gould Computer Systems
- International Software Corp.-Zitel
- Telco-Ingersoll Rand

The simulator uses five mainframe computers that process over 600,000 lines of software code concurrently, as well as generate sensor data and imagery for the heads-up display and seven other multifunction displays. The system simulates moving airborne or ground targets, weapons launch, engine noise, and aircraft motion.

 © 1989 Dataquest Incorporated November

CAE-Link was awarded a contract to upgrade UH-60 Black Hawk simulators in March 1989. Part of the Aviation Synthetic Flight Training System (SFTS) program, the $7 million contract block upgrade for 18 Black Hawks includes out-the-window display improvements and night-vision goggle lighting. The visual system upgrades for the Army Tactical Digital Image Generation (ATACDIG) includes blowing sand, water, and dust created by rotor wash and capabilities for landing aboard assault carriers and frigates, as well as enabling air targets to "fire upon" simulated Black Hawks.

The AH-64 Apache simulator program awarded Link a 22-month, $16 million contract in late 1988 to upgrade seven simulators. About 30 engineering changes will be made, as well as 24 software enhancements. Other Apache upgrades included a competitive $10 million contract for Honeywell and General Electric to develop a visual system for the AH-64.

Reflectone was awarded a $9 million contract in late 1988 to upgrade the EA-6B simulator. Among the improvements will be simulation of en route flying, instrument and visual navigation, night and dusk electronic warfare operations, and shore and carrier take-off and landings.

New Starts. The development of new weapon systems increasingly depends on simulations to reduce the costs of building prototypes and to reduce the risk of flying an untested prototype. R&D simulators are also employed for subsystems such as avionics and weapons to simulate sensor inputs.

Each of the major new weapon systems in development carries with it unique simulator requirements. For example, Loral has been selected to develop an integrated aircrew instruction program for Lockheed's entry for the air force ATF.

Light Helicopter Experimental (LHX). The Light Helicopter Experimental (LHX) program will also make extensive use of simulators. The Army Crew Station R&D Facility for simulation opened in November 1988. This joint effort by Army Aviation Systems Command and NASA Ames Research Center will focus especially on simulation techniques for the LHX. The LHX will be a full mission simulator, with a two-position tandem cockpit, and will use a fiber-optic helmet-mounted display by CAE-Link. Ames research has focused on rotorcraft, human factors, and artificial intelligence.

In May 1989, CAE-Link was selected by the Boeing-Sikorsky LHX team to provide operator training systems. As part of the 23-month demonstration/validation contract begun in November 1988, Link will provide flight simulators, part-task trainers, and other equipment to train LHX pilots. Link will also provide risk-reduction efforts for Boeing-Sikorsky that focus on embedded training, visionics, and life-cycle support. Link has also developed advanced aircrew training devices for the AH-1 Cobra, AH-64 Apache, CH-47 Chinook, UH-1 Huey, UH-60 Black Hawk, and the MH-47E and MH-60K special operations helicopters, for a total of about 150 flight simulators.

© 1989 Dataquest Incorporated November

V-22 Osprey. Prior to cancellation of this program in 1989, General Electric was awarded an initial $7 million contract from Honeywell to provide an advanced Compu-Scene IV image generator for the MV-22 Osprey operational flight trainer. The system will provide seven image-generator channels for high-resolution out-of-the window displays, as well as an eighth channel for in-cockpit sensor displays. The initial system will be delivered in the fall of 1991; seven others are included as an option in the contract. Compu-Scene IV has also been chosen by both McDonnell Douglas and Sikorsky for their LHX programs, as well as by Lockheed for the ATF program.

General Electric has also recently developed the Compu-Scene V, a new visual simulator for avionics training mission rehearsal and research, which exploits the use of photographic texture. Texture maps are used to store photographic detail, which is applied to three-dimensional terrain, moving models, and airfields and buildings. The Compu-Scene V will boost texture map capacity to the point where entire visual data bases can be built using terrain elevation and photographic source data. Although any production will be delayed, the program will continue to receive development finding.

C-17 Transport. The C-17 transport aircraft Aircrew Training System is being developed by McDonnell Douglas. One of three companies that participated in the $15 million Phase I portion, McDonnell Douglas was awarded a $421 million contract in late 1988; Singer-Link and United Airlines Services also competed. Phase II will last until the year 2003. McDonnell Douglas let a subcontract to Flight Safety International at the end of 1988 for the flight crew training simulation equipment. The subcontract is worth $90 million; Flight Safety will deliver the first simulator by 1991.

McDonnell Douglas purchased Night Hawk computers from Harris for the C-17 Aircrew Training System (ATS). In early 1989, Harris was awarded a contract from McDonnell Douglas to supply a minimum of 40 Night Hawk 3000 super microcomputers to be used as weapon system trainers, flight trainers, and cockpit trainers. The award was the largest contract yet for hardware using the Ada language.

B-1B Trainer. Boeing delivered the first B-1B trainer in late 1988. The simulator program includes five weapon system trainers, which simulate all four crew positions, two mission trainers, which simulate offensive and defensive positions, and several cockpit procedure trainers.

T-45 Training System. The T-45 Training System combines both trainer aircraft and simulators. The prime contractor, McDonnell Douglas, will provide a derivative of the British Aerospace Hawk, known as the T-45 Goshawk, as well as ground-based simulators, textbooks, trained instructors, and system maintenance. Students will learn the basics in the classroom, and then graduate to the T-45 operational flight simulator produced by Honeywell. Finally, the students will practice flying in the T-45A Goshawk.

Honeywell began manufacturing two operational flight trainers early this year for the navy and will eventually provide 22 flight trainers. The trainer uses a Gould/SEL 32/8750 computer and a Rediffusion SP-X visual system that gives a wide field of view. The T-45 will provide 11 percent more simulated flight time for navy pilots. The navy also plans to acquire 10 instrument flight trainers.

© 1989 Dataquest Incorporated November

MH-47E. The MH-47E Special Operations Helicopter Program received bids in late 1988 for its aircrew training system. General Electric and Reflectone formed one team, while IBM and Link formed another team. The Aircrew Training System will provide ground-based training and real-time mission rehearsal capability.

Link subcontracted Merit Technologies in a $2 million contract in early 1989 for a radar simulator for the MH-47E Special Operations helicopter simulator. The APQ-174 device will use the same digital terrain data base as the MH-47E. Completion of the contract is expected next year.

MH-53E. Honeywell is the prime contractor for two operational flight trainers for the MH-53E Sea Dragon minesweeper. McDonnell Douglas, a subcontractor, delivered the first Vital VII MUltiview visual system to the navy in February. The eight-channel trainer will be integrated into the Honeywell flight trainer. The Vital VII MUltiview incorporates full raster technology and will simulate runways, taxiways, lightning, hangars, ground support, and traffic hazards.

Part-Task Training. Part-task training systems basically simulate components of a weapons system. Among those currently being procured are the following:

- AN/ASQ-T25. Kollsman delivered 112 AN/ASQ-T25 aircraft instrumentation subsystem pods under a $13 million contract modification in early 1989. The system acts as an aircraft-mounted downlink for aircrew combat maneuvering instrumentation system, which monitors and records weapon firing profiles.

- Electronic warfare training sets. General Dynamics received a $28 million modification to a contract in late 1988 for five electronic warfare training sets, to be completed by April 1990.

- B-1B cockpit procedures trainers. Boeing Simulation and Training Systems delivered six B-1B cockpit procedures trainers to the air force.

- LANTIRN. ECC International is presently developing and producing part-task trainers for F-15E and F-16 pilots operating the LANTIRN system.

- Special Operations Aircrew Training for C-130. In the planning stage, the Aeronautical Systems Division of the air force will be looking to develop an aircrew training system for MC-130Hs, MC-130Es, AC-130Hs, and AC-130Us.

Other part-task trainers include the Hewlett-Packard frequency-agile signal simulator for testing electronic warfare, radar, and communications systems, and Phoenix International's Non-Communication Signal Recognition Trainer (NCSRT), to simulate signal transmissions under a variety of realistic environments to train for basic ELINT proficiency.

© 1989 Dataquest Incorporated November

Naval Simulations

Overview

The navy spent approximately $88 million in fiscal year 1989 on training equipment. The largest portion ($37 million) was used to train sonar operators. An additional $31 million was used to train operators of submarine and surface combat systems.

The largest simulation systems development program funded by the navy is the Emitter Simulator System, for which Ford Aerospace was awarded a $215 million contract in early 1989. This system enables the training of ship and aircraft crews against multiple electronic threats. The system will integrate threat simulators that duplicate radar signals generated by both defensive and offensive weapons systems.

The navy is turning to simulators not only for aircraft training, but for training in antisubmarine warfare and other operations. Embedded training is more practical for ships than for aircraft due to the smaller premium placed on weight and space aboard a ship. Moreover, computer simulator equipment can be packaged in large containers to be loaded aboard or stationed at pierside during simulation exercises.

Antisubmarine Warfare Simulators. One of the larger ground-based ASW simulation efforts is the Hughes ASW Tactical Team Trainer program. At $27 million, the system will include consoles, student mock stations, a tactical command center, carrier ASW modules, and an Aegis combat information system, housed in a two-story building. The contract holds an option for a second trainer; Hughes will deliver the Device 20A66 after 1993.

CAE-Link received a $15 million contract in mid-1989 for two surface ASW team training systems, scheduled for delivery in 1991 and 1992. The systems will provide tactical and procedural training for ASW teams of up to 16 different classes of ships and their supporting aircraft. The new systems carry the designation Device 14A12, and will use microprocessors distributed on a local area network. The simulators will replicate generic combat information centers and sonar consoles.

Other ASW efforts include the acoustic operations trainer device for submarine detection; Link received $12 million at the end of 1988 when the navy exercised an option for one system.

Strap-On and Part-Task Simulators. The AAI Corporation has developed the 20B5 pierside trainer for Perry-class frigates. The system is housed in a trailer that is parked alongside one or two frigates at the pier. The simulator computer is then connected to the sensors and weapon systems of the ship itself, allowing the crew to work at their actual stations rather than in simulated facilities. Up to 100 targets can be presented in a scenario, ranging from aircraft and missiles to submarines and torpedoes. As shown in Table 4, a wide range of shipborne systems can be simulated.

 © 1989 Dataquest Incorporated November

Table 4

Perry-Class (FFG-7) Systems Modeled by the 20B5 Pierside Trainer

Radars	Weapon Systems
AN/SPS-49	Mk-13 Launcher
AN/SPS-55	Mk-75 Gun
Mk-92 CAS	Mk-15 Phalanx CIWS
Mk-92 STIR	Mk-309 Torpedo Tubes
Mk-12 IFF/SIF	Mk-46 Torpedo
	Harpoon Missile
Communications	Electronic Warfare Receiver
Link-14	AN/SLQ-32
ASW Systems	Decoy Systems
AN/SQS-56	SUBROC Chaff Launcher
AN/SQR-17	Prairie Masker
	NIXIE

Source: Armed Forces Journal

Westinghouse has developed a simulator for the launch of the Trident II strategic missile: the Simulated Underwater Partial Launch System (SUPLS II). The simulator can be used for studying effects of the launch on the submarine and for practice that would be difficult with an operational submarine.

Intellisys will develop and produce one command tactical trainer under a $7 million contract to the navy ending in 1992. The contract includes options for three additional trainers. Republic Electronics received a $3 million contract for the AN/USQ-93 (VI) radar environmental simulator system for Terrier- and Tartar-equipped ships. The system is designed for on-board training, test, and monitoring of New Threat Upgrade AntiAir Warfare equipment.

Tank Simulators. General Electric is currently developing a combat vehicle driver trainer for the M1 Abrams main battle tank under a $5 million contract. GE will apply its Compu-Scene IV system for the visual display of Defense Mapping Agency data. The driver trainer will simulate day, night, dawn, and dusk conditions, and terrains including hills, rocks, streams, lakes, ice, and mud. GE will use modular technology and incorporate networking capability. The army has an option to purchase 20 production models.

© 1989 Dataquest Incorporated November

Simulator Networking

New horizons in training are being opened by linking together a number of simulators, allowing trainees to fight with and against other humans. This is especially valuable for command and staff level tactical training. The most ambitious program of this kind is SIMNET, sponsored by DARPA since 1982. The prime contractors are Perceptronics, which builds the simulators, and BB&N, which develops the communications networks. So far, 80 tank and helicopter simulators have been linked successfully in this project, and a network of hundreds is envisioned. SIMNET reached a milestone in March 1989 when developers demonstrated a new technique called semiautomated forces that mixes in tanks and aircraft that are not connected to individual simulators. This new technique will enable the program to expand the battle to corps or army size. The network contains simulations of M1 tanks, Bradley fighting vehicles, a platoon of antiaircraft missiles, two scout-attack helicopters, two close air support helicopters, and related support elements. The Senate Armed Services Committee has endorsed the SIMNET program, authorizing $14 million in fiscal 1990 as part of the army's plan to buy 2,500 SIMNET units beginning in 1990. The army's program, called Close Combat Tactical Trainer program, is in the process of forming teams; Megatek and ECC International Corp. have announced their intention to participate. The air force has contributed a small amount of funds to SIMNET; there is the possibility that the navy and Strategic Defense Initiative Organization (SDIO) will join in.

Other initiatives are under way to connect simulators. The navy is exploring simulator networks for training in antisubmarine warfare, using both surface vessels and helicopters. CAE Link Flight Simulation Division connected the army AH-64, AH-1S, and UH-60 helicopter simulators together in 1988. Software developments enabled CAE Link to interconnect the computer processors of each system so that army pilots could practice air-to-air combat, a relatively new area of warfare for helicopters. Link developed the software as part of an internal research program begun in mid-1987.

Northrop Corporation has developed a manned flight simulator that allows up to nine pilots to fly simultaneously in a variety of scenarios. The laboratory has three cockpits with projection domes and seven simplified cockpits resembling video games. The pilots can simulate different types of aircraft and operations, such as providing air cover for ground attack aircraft. The laboratory is being used in the development of both the ATA and the B-2 bomber. It is also employed in a contract for cockpit automation technology by the Air Force Human Systems Division.

Despite the increasing number of simulator networks, an industry standard does not yet exist. The absence of standardized protocols is a stumbling block at present; SIMNET's protocols could become the standard. Standardization would require hardware connectivity and shared symbol sets. In the interim, Singer is developing a black box to connect a number of different simulator types.

© 1989 Dataquest Incorporated November

Software Improvements

Because software is central to simulation, its development has the potential for improving simulator performance even more than increases in hardware capacity. Grumman Data Systems is exploring a new approach to compressing images of natural scenery on simulators. Rather than depict every tree leaf or blade of grass, Grumman is representing objects with simple quadratic shapes such as spheres and cones. This method is 10 times faster than previous simulation techniques and reduces storage capacity by a similar amount.

Sanders Associates has delivered its Spartan I software for ASW missions. The Smart Platform Architecture for Real Time Agent software program replicates the actions of hostile submarines for ASW training. The system is based on interviews with a U.S. expert on Soviet submarine tactics.

Basic Research

The defense agencies spent approximately $60 million in fiscal year 1989 on threat simulation development. To a large extent, simulators depend on digital mapping performed by the Defense Mapping Agency, which in turn relies on satellite reconnaissance. Trends in research in simulation and training reflect trends in computer technology: miniaturization of components, diminishing complexity to get faster results, and the use of optoelectronics and artificial intelligence, to name a few. Considerable advances have been made in more realistic visual imagery and true real-time simulation because of computer research. The introduction of Gould Computer Systems' Concept 32/2000 in 1988, targeted specifically for simulation applications, may provide the fastest real-time processing yet. With a single-board central processing unit, the 32/2000 provides the computer power of 15 VAX 11/780s.

Research in simulation is likely to focus on how to make simulators more affordable and effective. As computer-based image generators become less expensive, the display portion of the system will become relatively more expensive. Research in high-definition television may contribute to greater display systems cost-effectiveness, but efforts will probably focus on reducing the number of picture elements (pixels). Two programs that seek to narrow the "area of interest" in displays, allowing for rougher (and hence, less costly) images at the periphery, are CAE Link's Esprit and fiber-optic helmet-mounted display. The Esprit incorporates both a high-resolution and a low-resolution projector, applying the high-resolution system only in those areas upon which the pilot focuses. The fiber-optic helmet-mounted display, which has been ordered for the army research simulator, uses fiber-optic links to carry imagery from high-resolution off-helmet projectors.

© 1989 Dataquest Incorporated November

MISSILE SYSTEMS

Overview

There are two discernable trends in missile technology: emphasis on fire-and-forget capability for all classes of missiles (air-to-air, air-to-surface, surface-to-air and surface-to-surface), and increased range sufficient for the missile to be fired before being detected, sometimes called beyond-visual-range or standoff range. Both developments are intended to decrease the vulnerability of the missile platform, an increasing concern given the smaller number and higher cost of modern military equipment, and the increased lethality of enemy forces. Fire-and-forget capability depends on the development of autonomous or semiautonomous guidance for the missiles. Such missile guidance allows aircraft, ships, or ground units to designate and lock on a target, launch the missile and leave the area immediately, significantly increasing its survivability. Missiles with fire-and-forget capability require independent navigation units, independent radars or other seekers, and, often, small on-board computers.

Among the most important new missiles incorporating such capabilities are the army's Fiber-Optic Guided Missile (FOG-M) and Advanced Anti-Tank Weapon System (AAWS-M), the navy's Advanced Interdiction Weapon System (AIWS) or Sea Lance, and the air force's Advanced Cruise Missile. Key manufacturers of the critical components are Northrop and Litton for navigation units, Emerson Electric, Hughes, and Westinghouse for radars, Martin Marietta and Texas Instruments for infrared seekers, and Delco and IBM for on-board computers.

All three services are seeking improved ranges for their missiles and within the Pentagon, an attempt has been made to avoid redundancy by creating an integrated plan for developing standoff weapons. A Standoff Weapons Master Plan was submitted by the services in April 1988 to the Office of the Secretary of Defense. This plan included the Modular Standoff Weapon (MSOW), the Advanced Interdiction Weapons System (AIWS), the Standoff Land Attack Missile (SLAM), and the AGM-130, a rocket-powered glide bomb. Of these programs, the AGM-130 already has been canceled, and the future could be uncertain for several other standoff weapon programs, including Have Nap, Autonomous Guided Weapon, and SLAM. The navy has favored the SLAM for its standoff range requirements, whereas the air force has preferred the Have Nap, which is a stealthy system. The SLAM appears to be an interim substitute for AIWS, but the AIWS and MSOW missions could converge, which might render the SLAM superfluous. The Pentagon's request for fiscal year 1990 for the joint standoff weapon program was $35 million; for fiscal year 1991, it was $80 million.

In the future, increasing stress is likely to be placed on incorporating stealth characteristics into many types of missiles, for example, the Advanced Cruise Missile.

© 1989 Dataquest Incorporated November

Systems Development and Procurement

Table 5 divides missile procurement into new procurement (new starts) and continuing procurement. The figures are for total program acquisition costs, including development funds.

Table 5

Estimated Missile Program Acquisition Costs for Fiscal 1989-1991
(Millions of Dollars)

	Planned	Proposed	
	FY 1989	FY 1990	FY 1991
New Procurement			
Trident D-5	$2,457	$2,045	$1,714
SRAM II	$ 197	$ 228	$ 296
Advanced Cruise Missile	------	------	------
AMRAAM	$ 849	$1,060	$1,310
AAWS-M	$ 157	$ 228	$ 149
FOG-M (NLOS-R)	$ 144	$ 172	$ 230
Penguin	$ 11	$ 43	$ 41
Sea Lance	$ 79	$ 130	$ 186
Modification Procurement			
HARM	$ 531	$ 387	$ 402
IR Maverick	$ 350	$ 190	$ 180
Sidewinder	$ 37	------	------
ATACMS	$ 147	$ 188	$ 189
Hellfire	$ 245	$ 219	$ 131
Dragon II			
TOW-2	$ 194	$ 148	$ 190
Chaparral	$ 61	$ 31	$ 26
Hawk	$ 159	$ 72	$ 61
PMS Stinger	$ 98	$ 124	$ 140
Harpoon/SLAM	$ 167	$ 214	$ 230
Continuing Procurement			
Peacekeeper (M-X)	$1,410	$2,000	$2,800
Tomahawk	$ 788	$ 630	$ 720
Have Nap	$ 18	$ 23	$ 22
Multiple Launch Rocket System (MLRS)	$ 454	$ 336	$ 326
Patriot	$ 869	$1,026	$ 890
Phoenix	$ 396	$ 471	$ 87
Stinger	$ 382	$ 188	$ 280
Rolling Airframe Missile	$ 53	$ 91	$ 87
Standard	$ 770	$ 490	$ 650

Source: Department of Defense

© 1989 Dataquest Incorporated November

New Procurement

Trident II D-5 Missile. The navy requested a total of $2 billion for development and procurement of the D-5 missile in fiscal year 1990: $222 million for development and $1.8 billion for 63 missiles. The navy expects to spend slightly less in fiscal year 1991: $71 million for development and $1.5 billion for 52 missiles. Lockheed, the prime contractor for the D-5 was awarded some additional $700 million for development and production of the missile, scheduled to be completed in March 1990. Some subcontracts include $47 million to Rockwell for production and support of inertial navigation subsystems and $9.6 million to Westinghouse for launcher system hardware, to be completed by September 1990; Atlantic Research will develop the post-boost control system for the Trident II under an $80 million contract.

Charles Stark Draper Laboratory is working on guidance; Interstate Electronics is working on instrumentation.

Short-Range Attack Missile (SRAM II). The SRAM II, a supersonic low-radar cross-section nuclear-armed missile, will upgrade existing armaments on long-range bombers deployed from the 1990s on. Boeing, the prime contractor, has emphasized the use of state-of-the-art technology, such as VHSIC, composite materials, and ring-laser gyros to increase the missile's range and accuracy, and to reduce its radar observability. Contracts let to Boeing in fiscal year 1989 totaled about $197 million to continue full-scale development, including design completion of the air vehicle, its components, and aircraft interfaces. The air force has requested $217 million in development funds for fiscal year 1990 and $213 million in fiscal year 1991; procurement funds requested by the air force for fiscal year 1990 are $11 million and $83 million in fiscal year 1991 for an initial 25 missiles. SRAM II's first live launch currently is planned for the end of 1990, after which low-rate initial production can begin. Flight testing could be completed in fiscal year 1992 with a possible initial operating capability in 1994. Boeing received a $165 million addition to its contract in September 1988 for the B-1B integration part of the SRAM II program. Boeing's subcontractors include the following:

Firm	Subsystem
Boeing Military Airplane	B-1B integration
Delco Electronics	Missile computer
Hamilton Standard	Flight actuators
Hercules-Bacchus	Rocket motor
Litton	Guidance system
Moog Missile Systems	Flight actuators
Rockwell	Prelaunch computers
Teledyne Ryan	Altitude sensors

© 1989 Dataquest Incorporated November

The SRAM II appears to be a high-priority program within the Pentagon and also in Congress, probably because of two factors: the age of the SRAM As (AGM-69A) being replaced and the reduced numbers of intermediate-range missiles available as a result of the INF treaty, a gap that the SRAM II can fill. The SRAM II should have a range of about 280 miles, just under the ceiling set by the INF agreement. The air force currently plans to procure 1633 SRAM II missiles at a cost of $2.5 billion.

AGM-129 Advanced Cruise Missile (ACM). The advanced cruise missile, a second-generation long-range air-to-ground missile, first began procurement in fiscal year 1986. Although details are still classified, some sources estimate that the program budget has reached about $7 billion. The ACM, the first cruise missile to employ stealth technology, was scheduled to be deployed this year at K.I. Sawyer Air Force Base, eventually on both B-52Gs and B-1Bs. The air force has a requirement for 1,500 advanced cruise missiles. The program itself has slipped by about two years as the result of in-flight failures, among other things. General Dynamics is the prime contractor, but McDonnell Douglas was chosen as a second-source producer after considerable quality control problems were discovered at General Dynamics in late 1987. Congress has required six successful flight tests before production can begin, after several initial failures occurred in flight testing. It is estimated that about 3,000 missiles, including a mix of ACMs and Air-Launched Cruise Missile (B versions), will be deployed.

Advanced Medium-Range Air-to-Air Missile (AMRAAM). The AMRAAM will replace the AIM-7 Sparrow as the principal medium-range radar-guided air-to-air missile in the U.S. inventory and has been selected as a standard NATO weapon. Unlike the Sparrow, AMRAAM has launch-and-leave capability by virtue of its built-in radar, as well as greater speed (Mach 4) and increased reliability. Total air force and navy contracts for the primary team of General Motors and Hughes and for the second source, Raytheon, were $849 million in fiscal year 1989. The two services have requested a total of $1.2 billion in fiscal year 1990 and $1.3 billion in fiscal year 1991.

General Motors-Hughes Aircraft, chosen for full-scale development, subcontracted with the following firms:

Firm	Subsystem
Chamberlain Manufacturing Co.	Warhead
Hercules	Rocket motor
M/A-COM	Microwave components
Northrop	Inertial navigation unit
Watkins-Johnson	RF processor, data link receiver

© 1989 Dataquest Incorporated November

Although 128 missiles already have been built by Hughes under the FSD contract, the full-rate production decision for AMRAAM will not be made until late 1989. The navy has requested procurement of 950 missiles at a cost of $511 million for fiscal year 1990. The air force and marine corps requested the remaining 650 missiles for a total of 1,600. Planned procurement in fiscal year 1991 will reach a total of 3,000 missiles at $1.3 billion. Hughes and Raytheon have shared production of the AMRAAM since March 1988; Hughes will build a total of 105 missiles and Raytheon will build 75 in the first-lot production. Second-lot production, with delivery in September 1989, will comprise 223 missiles from Hughes and 200 from Raytheon.

Even while production is beginning, an improvement program for the AMRAAM is already under way with $15 million requested for fiscal year 1990 and $25 million requested for fiscal year 1991. Both Hughes and Raytheon are working on the AMRAAM Producibility Enhancement Program, which includes 26 engineering upgrades to components in the missile. Hughes will design 10 of the upgrades, including a better transmitter, a frequency reference unit, a fuse antenna, an inertial reference unit, an RF processor, and others. Raytheon is working on 11 others, including upgrades to the fuse, the remote terminal, the RF processor, the data link processor, the inertial reference unit, and the gyro, among others. Hughes and Raytheon will collaborate on the remaining five upgrades including improvements to the mission computer, the computer input-output device, the range correlator, the filter processor, and the intermediate frequency receiver.

AMRAAM will likely be the single largest tactical missile production program in the 1990s. The U.S. military services already have requested almost $2.4 billion for AMRAAM for fiscal year 1990 and 1991. Eventual purchases by the European allies and other friendly nations add significantly to this amount and future U.S. procurement. With modifications, the program is likely to continue into the next century.

Advanced Antitank Weapon System-Medium Tankbreaker (AAWS-M). After a 27-month technology demonstration phase, the army selected the team of Martin Marietta and Texas Instruments in February 1989 for full-scale development of the AAWS, the follow-on to the shoulder-fired Dragon antitank weapon system. Fiscal year 1989 contracts for $157 million included work for the competing teams of Ford Aerospace and General Dynamics, which developed a laser-beam-riding missile, and Hughes and Honeywell, which proposed IR focal plane array guidance with optional fiber-optic data links. The winning team, Martin Marietta and Texas Instruments, chose imaging infrared guidance for their version of the AAWS. There are few publicly available details on the Martin Marietta-Texas Instruments version, but it is known that the AAWS-M will have two attack modes: top-attack against armor and direct attack against helicopters and fortifications. Requests for RDT&E funds for fiscal year 1990 were $228 million; they were $149 million for fiscal year 1991. The full-scale development phase is planned to last about 36 months; the system is expected to be fielded in 1994. Production, which may begin as early as 1993, may eventually comprise 100,000 missiles for U.S. forces as well as 70,000 for foreign buyers.

© 1989 Dataquest Incorporated November

Fiber-Optic Guided Missile (FOG-M). The FOG-M is one of three missiles incorporated in the army's Advanced Antitank Weapon System-Heavy (AAWS-H) program and also was chosen for the Non-Line-of-Sight portion of the Forward Area Air Defense System. The FOG-M is an antiarmor, antihelicopter missile and guidance system that uses fiber-optic technology to view a battlefield and attack targets from a range of roughly 10 kilometers. The Boeing Company and Hughes Aircraft Company team was selected by the army in late 1988 as codevelopers of the FOG-M. Contracts awarded to Boeing and Hughes are estimated for fiscal year 1990 as $172 million and $230 million for fiscal year 1991. Boeing will function as the systems integrator; Hughes will produce the TV and imaging infrared seekers for the system. Martin Marietta was awarded a $2 million contract in mid-1989 to provide three imaging infrared sensors, which will use platinum silicide detectors in a focal plane array.

The initial contract calls for a 43-month full-scale development phase, with deliveries of 40 missiles and eight fire units scheduled for early 1991. The projected value of the contract is $125 million. Boeing and Hughes will compete for production for a total of 403 fire units; if the army exercises its option to buy 16,000 missiles, the overall program cost could exceed $2 billion.

Penguin MK2 Mod 7. The Penguin is a Norwegian antiship short-range missile designed for operation from a LAMPS MK-III SH-60B helicopter. The Penguin MK2 Mod 7 incorporates an improved IR seeker, extended range, and foldable wings. For fiscal years 1990 and 1991, the navy requested 129 Penguins at a cost of about $92 million. The navy expects a total requirement for 272 Penguins. The prime contractor for the Penguin is Norsk Forsvarsteknogoli.

Sea Lance (ASW Standoff Weapon). In 1988, the navy decided to integrate the Vertical Launch ASROC program into the ASW Standoff Weapon program using the Sea Lance design. The prime contractor for the Sea Lance is Boeing Aerospace Company, which was awarded a $380 million contract in 1986 for full-scale engineering development through 1992. The Sea Lance began development in 1981; full-scale development is expected to begin in the early 1990s. Gould is responsible for the payload, acoustics, and signal processing, and guidance; Hercules Aerospace is responsible for the rocket motor. The first production buy of 67 units was to have taken place in fiscal year 1990, but the navy request for procurement funds for fiscal year 1990 totals only $2 million. Fiscal year 1989 planned funding was $79 million; proposed funding for fiscal year 1990 is $128 million ($126 million in R&D) and for fiscal year 1991, $186 million ($140 million in R&D).

Continuing Procurement

AGM-88 High Speed Anti-Radiation Missile (HARM). The High Speed Anti-Radiation Missile, or HARM, is designed to defend aircraft against surface-to-air missiles while they are performing strike missions. Texas Instruments is the prime contractor for the HARM and received about $531 million in contracts in fiscal year 1989. Ford Aerospace and Communications Corporation is expected to be qualified as a second source in 1989.

© 1989 Dataquest Incorporated November

Total budget requests for R&D and procurement for fiscal year 1990 by the air force and the navy amounted to $387 million, and for fiscal year 1991, $402 million. For fiscal year 1990, the air force requested 1,488 HARMs; the navy requested 1,162. For fiscal year 1991, the air force hopes to increase its procurement to 1,600 HARMs; the navy expects to procure 1,400 HARMs. Recent contracts include a $459 million contract to Texas Instruments for 2,449 HARM systems for the navy (1,319), air force (950), and the Federal Republic of Germany (180), and the provision by Texas Instruments of a new Block IV guidance section for the HARM. HARMs will be procured at least through 1994.

AGM-65 Infrared Maverick. This successful air-to-surface missile program procured by both the air force and navy may be upgraded in the future to improve its range. The prime contracting team is General Motors-Hughes, although production is currently shared with Raytheon, which currently has orders for more than 4,400 missiles, including 60 percent of the fiscal year 1988 purchase (2,483 missiles). Total contracts for Hughes and Raytheon equaled $350 million for 3,551 missiles in fiscal year 1989; for fiscal year 1990, the services have requested $261 million, and $372 million for fiscal year 1991.

Hughes began the first production of the G model of the Maverick last year. The G model combines the 300-pound warhead from the E version and the imaging infrared guidance package from the D model. The IIR guidance system extends the missile's all-weather, night, and poor visibility operating capability. The air force eventually plans to buy about 61,000 D models of the Maverick, but it is yet unclear whether G models will complement or substitute for the D models. The most recent development contract awarded in conjunction with the Maverick program was in September 1988 to Hughes for development of a millimeter wave seeker for $8 million.

Subcontractors for the Maverick program include the following:

Firm	Subsystem
Aerojet General, Morton Thiokol	Engine
Allied-Bendix, Raymond Engineering	Missile fuse
Borg-Warner, Moog	Pneumatic actuation
Chamberlain Manufacturing	Warhead
Honeywell Electro-Optics Division	Imaging infrared seeker

AIM-9 Sidewinder. In fiscal year 1989, the M version of the Sidewinder will complete production, but an improvement to the M version, the AIM-9R, has been requested for fiscal year 1990. The R version is an interim solution until the follow-on ASRAAM reaches operational capability; it will incorporate an imaging IR seeker, which will improve its ability to operate in cluttered environments and its counter-countermeasure capability.

 © 1989 Dataquest Incorporated November

Army Tactical Missile System (ATACMS). The army's Tactical Missile System is an antiarmor weapon with deep-strike capability. The ATACMS will be used against enemy second echelon forces, air defense, command and control sites, and tactical ballistic missiles. Vought Corporation, the prime contractor, began production of ATACMS in 1986 as a conventional follow-on to the Lance missile. In early 1989, Vought received a production award for $16.7 million for 66 missiles and support. The army has requested procurement funds for 276 ATACMS ($141 million) in fiscal year 1990 and hopes to almost double that number to 454 ATACMS in fiscal year 1991 at a cost of $189 million.

ATACMS will be launched from the Multiple Launch Rocket System (MLRS). A terminally guided warhead that will use millimeter wave seekers is currently in development for the MLRS, and this technology could be applied to the ATACMS. An international joint venture company consisting of Martin Marietta, Diehl GmbH (FRG), Thomson-CSF (FR), and Thorn EMI (UK) completed field tests of components for the terminally guided warhead in late 1988. The army apparently has not decided yet which seeker will be used for ATACMS and issued a request for proposals for IR seeker technology in February 1989; General Dynamics and Raytheon could be possible contenders. The army could have as much as $47 million dollars for R&D for the ATACMS in fiscal year 1990.

AGM-114A Hellfire. The Hellfire missile was developed originally as an antitank weapon system for use on helicopters. In addition to production of the heliborne version, the army has been testing a ground-based Hellfire that is mounted on a pedestal on a U.S. Army truck in much the same way as the pedestal-mounted Stinger antiaircraft missile. Although the original version of the Hellfire uses laser seekers for guidance, combined IR/RF and imaging IR seekers are being developed. Rockwell International is the prime contractor, with Martin Marietta as a second source. Contracts to Rockwell and Marietta totaled about $220 million in fiscal year 1989 for 6,000 Hellfire missiles, with the latter gaining about two-thirds of the buy. army and navy requests for procurement of the Hellfire for fiscal year 1990 and fiscal year 1991 are on the order of 4,200 missiles per year. Rockwell tested a digital autopilot successfully in late 1988, which could be incorporated into the Hellfire as early as 1990.

Dragon II. The army has decided to field the Dragon II, the result of the first phase of the Dragon Product Improvement Program, as its primary shoulder-fired antitank missile until the AAWS system is deployed in 1994. It awarded a $101 million contract to McDonnell Douglas in 1989 for 19,000 missiles. The follow-on Dragon III, developed as part of the second stage of the Product Improvement Program, will feature a new warhead claimed to have 98 percent more penetration than the Dragon I, and improved velocity and range. This has become very controversial because the Dragon tested very poorly compared to two foreign missiles, the Bofors Bill and the Milan II.

BGM-71D TOW-2. The TOW-2 missile (tube-launched, optically-tracked, wire-guided) is a heavy antitank missile used on the ground or in the air. The TOW is currently installed on jeeps, on the High Mobility Multi-purpose Wheeled Vehicle (HMMWV), as well as the AH-1S helicopter, and on armored vehicles like the M2 Infantry

© 1989 Dataquest Incorporated November

Fighting Vehicle. Hughes Aircraft Company has been the sole source for TOW missiles for many years, but a second source will be selected in fiscal year 1989. Texas Instruments is the major contractor for TOW-2 retrofit kits, which include a digital missile guidance set and the AN/TAS-4A night sight. Emerson Electric is the prime supplier of the missile guidance set, the launcher, and the optical sight. Procurement of more than 10,000 missiles has been requested in fiscal year 1990 at $125 million by the army and the marine corps; an additional $20 million has been requested by the army for R&D. For fiscal year 1991, a total of 14,184 missiles has been requested by the services at a cost of $179 million. Although a replacement for the TOW-2 is being explored as part of the AAWS-H program, the army will continue to upgrade the TOW-2. One example is the test-firing of an experimental TOW-2 with millimeter-wave RF data link by Hughes under a $3 million contract awarded in 1986. The army currently is attempting to improve speed and range with the RF data link.

MIM-72 Chaparral. A derivative of the navy Sidewinder, this self-propelled, medium-range SAM system is being improved. The current Chaparral is a supersonic missile with passive infrared guidance and fire-and-forget capability. The improved version, which began production in fiscal year 1988, will incorporate new guidance, IFF, night vision-reduced visiblity enhancement, and a smokeless motor. Ford Aerospace and Communications Corporation is the prime contractor. As an interim upgrade to air defense, the Chaparral will be transferred to the brigade level when the Forward Air Area Defense System (FAADS) is deployed. In the meantime, the army is planning continuing upgrades for the 1990s, which may include a dual-mode seeker (passive RF and passive IR) for all-weather capability.

Hawk. The Product Improvement Program Phase III version of the Hawk medium-range all-weather air defense missile is in production and scheduled to continue through 1992. Phase II improvements include, among other things, simultaneous engagement capability, new acquisition radars, and microcomputers. These changes should enhance the Hawk's electronic counter-countermeasure capability. The army requested about $20 million in R&D funds for fiscal year 1990 and 1991, and about $104 million in procurement funds for the same period. Aerojet and Raytheon are the prime contractors for the Hawk. In September 1988, Raytheon received a four-year contract from the marine corps for production of 1,708 Hawk missiles at a cost of $282 million.

PMS Stinger. The successful Stinger missile was chosen for the Line-Of-Sight-Rear (LOS-R) portion of the FAADS in a pedestal-mounted configuration, designed by Boeing and General Electric. The army plans to buy 273 FAADS systems by fiscal year 1995. The total requirement for PMS/Avenger systems is 1,200 for the army and 300 for the marine corps. The pedestal-mounted Stinger, or Avenger, features eight Stinger missiles and a Gatling gun mounted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV). Procurement of the PMS Stinger began in 1987. The most recent Stinger version features a reprogrammable microprocessor with an infrared seeker capable of rosette pattern scanning and scanning on both IR and UV channels, and provides improved countermeasure protection. Other contractors for the PMS system include CAI (optical sight). Magnavox (FLIR), and Texas Instruments (laser range finder).

 © 1989 Dataquest Incorporated November

Harpoon/Standoff Land Attack Missile (SLAM). The Harpoon is an antiship and land-attack cruise missile, able to be launched from ships, aircraft, and submarines. The navy has requested funds for procurement of 190 Harpoons in fiscal year 1990 and 184 in fiscal 1991. McDonnell Douglas is the prime contractor for the Harpoon. Listed below are the major subcontractors for the Harpoon:

Firm	Subsystem
Honeywell	Radio altimeter
IBM	Missile computer
Lear Seigler	Strap-down three-gyro navigation
Texas Instruments	Active radar seeker
Westinghouse	On-board computer

Block C improvements have been incorporated in Harpoon production; a Block II version for the 1990s could include increased computer memory, an improved seeker, and increased fuel capacity.

The Standoff Land Attack Missile (SLAM) currently in development for both navy and air force use is a derivative of the Harpoon. The navy will use SLAM on aircraft primarily against shore targets, whereas the air force hopes to arm B-52 aircraft with these conventional missiles. The air force request for fiscal year 1990 was minimal at $5 million, and for fiscal year 1991 was $10 million, presumably for B-52 launch tests tentatively scheduled for late 1990 and 1991. The navy zero-funded the SLAM program for fiscal year 1990 and fiscal year 1991, given the air force testing schedule.

The navy version of the SLAM is being developed to provide the navy with a near-term standoff attack capability. The navy SLAM uses a production version of the Maverick imaging infrared seeker, and a Walleye video data link for aircraft control of the missile's seeker; the new component is a single-channel Global Positioning Satellite receiver/processor. The SLAM began airborne launch tests beginning in March 1989. In addition to air-launched versions, the navy also hopes to test a ship-launched version at the end of this year.

Rail-Mobile MX. The initial fiscal year 1990 budget reflected the Reagan administration's effort to deploy 100 Peacekeeper missiles, in both silos and on rail garrisons. New production was planned at 12 units per year, but there was criticism that this rate is well below what has been assessed as economically optimal (48 per year). The Bush administration subsequently proposed a plan to deploy 50 existing MXs on rails while developing the Midgetman; the MX rail deployment cost has been estimated at about $5.6 billion. In 1986 dollars, the total cost of rail garrison is estimated at

© 1989 Dataquest Incorporated November

$10 billion to $12 billion over a 20-year period, including R&D, missile and train component production, construction, deployment, and operational costs. Funding in fiscal year 1989 totaled $1.4 billion; requests for fiscal year 1990 stood at $2.0 billion, and for fiscal year 1991, at $2.8 billion.

Boeing and Martin Marietta are major contractors for the rail-garrison MX. Other contractors include General Electric, which won an $18 million contract in early 1989 for 13 Mark 21 reentry vehicles and additional spare fuses, and Rocketdyne, which was awarded $107 million in June 1989 for 24 test missiles.

Sea-Launched Cruise Missile. The sea-launched cruise missile, or Tomahawk, is manufactured competitively by General Dynamics and McDonnell Douglas. The Tomahawk can be configured for both nuclear and conventional missions and can be deployed on both surface ships and submarines. In fiscal year 1989, total contracts amounted to about $788 million. In early 1989, McDonnell Douglas was awarded a $17 million contract for production of 23 Tomahawks; General Dynamics was contracted for 12 Tomahawks at $13 million. McDonnell Douglas will produce about 65 percent of the 510 SLCMs the navy plans to buy in fiscal year 1989. The navy requested slightly lower levels of production for fiscal year 1990 and 1991 at 400 SLCMs per year for about $650 million to $700 million. The navy hopes to procure a total of 2,394 missiles through 1994.

Multiple Launch Rocket System (MLRS). The Multiple Launch Rocket System, first deployed in fiscal year 1983, carries 12 conventionally armed rockets and supplements cannon artillery fire. The MLRS will be used to fire the army's ATACMs and could be configured for binary chemical weapons and the Tacit Rainbow drone. LTV is the primary contractor and received about $454 million in contracts in fiscal year 1989. The army has requested $79 million in development funds for fiscal year 1990 and $336 million to procure 24,000 MLRS systems; for fiscal year 1991, the army has requested $380 million in development and procurement for 24,000 MLRS systems. This funding level reflects a 50 percent cut in number of systems procured from fiscal year 1989 to fiscal year 1990. The program is planned to terminate, although foreign sales may keep it alive beyond that date. Major subcontractors for the MLRS include the following:

Firm	Subsystem
Atlantic Research	Rocket propulsion system
Bendix	Stabilized reference/positioning package
Norden	Fire control
Sperry-Vickers	Launcher drive system

© 1989 Dataquest Incorporated November

MIM-104 Patriot. The Patriot missile is the most advanced long-range SAM in the current inventory. Raytheon, the primary contractor for the Patriot, received more than $860 million in fiscal year 1989. Subcontractors include Hazeltine, which designed the IFF integrator, and Martin Marietta, which designed the missile airframe and launcher. The army requested funds in fiscal year 1990 and fiscal year 1991 for procurement of 1,632 Patriot missiles at $1.8 billion. It is unclear whether R&D would continue at its current level of between $20 million and $30 million in that event. This could affect R&D contracts such as that awarded in early 1989 to Brunswick Defense Division for development of an antiradiation missile decoy.

AIM-54C Phoenix. The Phoenix missile currently is being produced by Raytheon and Hughes for the U.S. Navy. Raytheon received a contract in early 1989 for 208 Phoenix missiles plus support at $140 million, whereas Hughes was awarded a contract for 195 missiles plus support at $132 million. The navy hoped to procure 420 in fiscal year 1990 at $379 million, and another 420 in fiscal year 1991 at $328 million, but Secretary Cheney canceled the program after 1990.

FIM-92A Stinger. General Dynamics is the prime contractor for the Stinger surface-to-air shoulder-fired missile. Raytheon was named a second source for production in 1987, and a $54 million contract option was awarded to Raytheon in April 1989 for 1,500 missiles. After that contract, Raytheon expects missile production to be divided between it and General Dynamics. The Stinger will remain the primary antiair defense system at the division level until FAADS is deployed. The introduction of the newest version, the RMP Stinger, named for its reprogrammable microprocessor, is being delayed by the army. Although production by General Dynamics continues, the army refused delivery as late as April 1989 because of targeting difficulties. The RMP Stinger currently is unable to shoot down helicopters that use a specific flare. While the army has two contracts totaling $900 million for 23,000 missiles through 1991, it appears that the missiles will not be accepted until the flaw is corrected.

Rolling Airframe Missile (RAM). Fiscal year 1990 will be the first full-rate production year for the Rolling Airframe Missile. The navy has requested a total of $97 million, which includes funds for procuring 580 missiles. The RAM is a type of surface-to-air missile for defense against low-flying antiship missiles. General Dynamics is the prime contractor; Hughes designed the target acquisition and systems integration for the RAM. The United States signed a memorandum of understanding with the West German government in 1987 to establish a second source in the Federal Republic. The joint company, called RAM Systems GmbH, includes AEG, Bodenseewerk, Diehl, and MBB. RAM Systems GmbH competes with General Dynamics for up to 70 percent of the U.S. and German navies' procurement contracts. The U.S. navy expects a requirement for as many as 4,900 RAMs, whereas West Germany expects to procure about 1,900 RAMs. Denmark and several other countries have expressed interest in the program.

© 1989 Dataquest Incorporated November

Standard Missile. The Standard Missile, currently in a product improvement program, is a family of supersonic, medium- and extended-range surface-to-air and surface-to-surface missiles. The navy plans to procure almost 600 Standard Missiles in fiscal year 1990 and 900 in fiscal year 1991. Raytheon received a $168 million contract in March 1989 for Block III missile production. Raytheon currently is designing the Block IV generation of missiles--the Aegis Extended Range Standard Missile-2. Full-scale production of the Block IV version is planned for the early 1990s. General Dynamics, the prime contractor, will act as codeveloper of the Block-IV guidance and control system. The new missile will be deployed on Aegis cruisers equipped with the Mk 41 vertical launch system and on Arleigh Burke destroyers.

Research and Development

Overview

In the near term, R&D in missiles will probably focus on improved guidance, including fiber-optic data links and millimeter wave guidance. Some feasibility studies have been conducted on fiber-optic applications, specifically by the Hughes Missile Systems Group on controlling long-range, air-launched missiles with fiber-optic data links. Hughes will conduct a flight concept demonstration program (18 months) to study the dynamics and kinematics of fiber-optic data links as they interact with the turbulent air flow field around an aircraft. Other near-term trends include research on target acquisition to allow weapons operators to adjust targeting manually.

In the longer term, missile R&D will move in the direction of "brilliant guidance," which will include techniques such as laser radar sensors and improvements in infrared and millimeter wave signature recognition, and on autonomously guided weapons. For example, Texas Instruments received $24 million from the air force to develop autonomous guidance for conventional weapons, in particular, autonomous imaging infrared seeker technology. The 34-month contract includes two separation test vehicles, one ballistic unit to verify aerodynamic characteristics of the weapon and five units for free-flight test as well as development and demonstration of the prototype mission planning system.

Work should continue on new algorithms to enable microprocessors to recognize targets.

ICBM Modernization (Midgetman). The fiscal year 1990 budget submission initially did not include any funds for the Small ICBM, but funds from fiscal year 1989 ($243 million) could keep R&D alive. Secretary Cheney canceled ICBM modernization but was overruled by President Bush. Support has grown in the Senate but is still weak within the DOD. Contractors for the Midgetman include Aerojet, Boeing, Hercules, Martin Marietta, Rockwell, and Thiokol. A force of 300 Midgetmen has been estimated to cost $17 billion.

© 1989 Dataquest Incorporated November

Follow-On to Lance. The army requested $33 million in the fiscal year 1990 and $129 million in the fiscal year 1991 budget for research into a follow-on to the Lance short-range nuclear-armed missile, which could enter engineering development in fiscal year 1990. The system is extremely controversial, however, and the West German government, on whose territory three-fourths of the Lances are deployed, has refused to endorse a modernization decision until after their elections in late 1990. It is not yet clear whether Congress will appropriate the requested funds without such an endorsement. If the program goes ahead, total development and production costs could reach $1 billion. The army issued a request for proposals in June 1989; Boeing, LTV, Martin Marietta, McDonnell Douglas, and Raytheon are expected to respond.

Air Defense Anti-Tank System (ADATS)

ADATS is designed to shoot down assault helicopters that threaten front-line troops. In early 1989, Martin Marietta delivered the first preproduction ADATS mobile air defense units for tests in New Mexico, including live-fire and vulnerability testing. About 562 ADATS units and 10,078 missiles are expected to be procured at a cost of $5.7 billion. The ADATS program schedule has been delayed by about six months because of a 30 percent reduction in the budget from 1990 to 1994. The budget request for fiscal years 1990 and 1991 was $540 million.

Advanced Air-to-Air Missile (AAAM)

The Advanced Air-to-Air Missile is expected to provide fleet air defense against antiship missile launching aircraft and jamming aircraft at ranges of about 150 miles. The AAAM will replace the Phoenix, but should be a smaller, Sparrow-sized missile. Initial demonstration/validation contracts were awarded by the navy in late 1988 to the teams of General Dynamics-Westinghouse and Hughes Aircraft-Raytheon. Worth more than $42 million, the contracts cover a four-year period. The navy has requested $73 million in R&D funds for fiscal year 1990 and $83 million for fiscal year 1991. The Hughes-Raytheon team is developing a rocket ramjet missile with an active radar guidance system and semiactive guidance at midcourse flight. The General Dynamics-Westinghouse team has proposed a tube-fired rocket with semiactive guidance throughout the flight. General Dynamics claims that the lack of an active seeker will save the navy about $100,000 per missile. Full-scale engineering development is planned to begin in October 1991, with full-scale development scheduled for 1997.

Hypervelocity Missile (HVM)

The Hypervelocity Missile, a rocket-powered air-to-surface guided missile, has been experiencing difficulties with its fire control system. The air force and army have halted ground-launched testing of the HVM until flaws can be corrected. LTV is the prime contractor and has solicited Texas Instruments to help correct the guidance system. HVM is a joint air force, army, and marine corps program. Until the ground-launched version is approved, the air-launched version program probably will not proceed. The air force planned to spend approximately $5 million in fiscal year 1989 on research.

© 1989 Dataquest Incorporated November

Advanced Interdiction Weapon System (AIWS)

Design work continued on the Advanced Interdiction Weapon System when the navy chose three contractor teams in early January 1989 for the engineering study phase. The AIWS is an air-to-surface standoff glide bomb and probably will be deployed on the F/A-18, the A-16, and the new A-12 Advanced Tactical Aircraft, possibly by 1994. The $50,000 demonstration/validation contracts were awarded to Boeing Aerospace, Honeywell, a McDonnell Douglas-Hughes team, and to Texas Instruments-LTV team. Two teams will receive an 18-month engineering contract; one team will proceed to a full-scale engineering development (FSED) phase of about 36 months' duration. With the FSED contract, the navy plans to award a low-rate production option (about 300 missiles). The navy requested $13 million in fiscal year 1990 and $25 million in fiscal year 1991 for R&D.

Long-Range Conventional Cruise Missile (LRCCM)

The navy has requested concept definition studies of the LRCCM after the Defense Acquisition Board designated the navy as lead service in December 1988. Congress appropriated $18 million in fiscal year 1989. The concept exploration phase is planned to last two years. The services will choose from Boeing, General Dynamics, Lockheed, Martin Marietta, McDonnell Douglas, Northrop, Rockwell, and TRW. The Defense Advanced Research Projects Agency will continue to work on propulsion, guidance, and manufacturing techniques for the LRCCM in a parallel effort that would attempt to insert technologies prior to full-scale development.

Medium Surface-To-Air Missile (MSAM)

The MSAM was approved as a major system in 1986, and eventually will replace the Hawk and Chaparral systems for air defense. No contractors have yet been named, although Hughes and Raytheon have suggested types of systems. Hughes appears to have suggested a version of its AMRAAM. Raytheon has suggested using a truck-mounted, vertically launched, multimode missile with the Agile CW Acquisition Radar for division defense and for area defense, the same system supplemented by the Hawk. The MSAM is a candidate for cooperative development under the Nunn Amendment.

MILITARY SPACE

Overview

Until components of the Strategic Defense Initiative (SDI) reach full-scale development, military space procurement will continue to be shaped predominantly by requirements for space launchers and satellites. New programs are emphasizing reductions in weight requirements and enhanced power supplies for space vehicles. At the same time, there is a push toward expendable launchers and cheap, disposable satellites. Currently, a backlog of about two-dozen spacecraft is waiting for launch, the result of the Space Shuttle's problems and the failure of several military launches. This backlog may take up to five years to eliminate. As a result, the DOD is focusing on procuring satellites and launchers that can be boosted into space more quickly and cost-effectively; by the mid-1990s, all DOD payloads will be launched by expendable boosters.

The creation of the U.S. Space Command, coordinating the Army, Navy, and Air Force Space Commands, could eliminate some of the redundancy in U.S. space programs, and could also create new opportunities, given its broad mandate. Future plans include new satellite programs, launch methods, support of operational satellite constellations, and processing and distributing space-based information. In the near term, NAVSTAR, Milstar, and Defense Support Program Block 14 satellites will be deployed, offering significant improvements in navigation, command, control, communications, and surveillance capabilities.

A study sponsored by the Space Command, "Assured Mission Support Space Architecture Study," completed in the summer of 1989, examined all aspects of U.S. launch responsiveness and will guide U.S. launch planning for the next 30 years. Among other things, options to improve launch responsiveness examined by the study include more rapid satellite launch processes and faster on-orbit checkout of spacecraft, launching replacement satellites before the end of useful life of their predecessors, procurement of less costly satellites with reduced capability for launch-on-demand, procurement of a mix of high- and low-capability satellites, and improvement of the survivability of orbiting satellites. The services want greater flexibility and a greater degree of reliability in space launches, needs that they perceive as the most pressing problems in military space today. The army has a special requirement, seeking autonomous control of the battlefield systems deployed in space, such as intelligence and communications. One solution may be the proliferation of single-purpose, relatively inexpensive satellites.

Systems Development and Procurement

Table 6 below shows the funding proposed for military space satellites and launchers in the Cheney budget.

© 1989 Dataquest Incorporated November

Table 6

Estimated Military Space Program Acquisition Costs
(Millions of Dollars)

System	Planned FY 1989	Proposed FY 1990	FY 1991
Fleet Satellite Communications (UHF)	$194	$329	$215
Defense Support Program Satellites	---	$124	$ 61
Defense Meteorological Satellite Program	$210	$190	$200
NAVSTAR GPS	$122	$104	$232
Milstar	$350	$410	$230
Defense Satellite Communications System	$ 88	$ 74	$ 77
Medium Launch Vehicle	$256	$137	$207
Space Boosters (Titans)	$815	$759	$557
Advanced Launch System	--	$99	$ 99

Source: U.S. Department of Defense

All of the procurement programs for space satellites and launchers in the Reagan budget were maintained in the Bush-amended budget, although funding for the Defense Support Program Satellites was cut $10 million in fiscal year 1990 and $1 million in fiscal year 1991. In addition, $3 million was cut from the Defense Satellite Communications System in both fiscal years 1990 and 1991.

UHF Follow-On Satellite Program

The navy currently uses a constellation of five Fleet Satellite Communications satellites and three leased satellite spacecraft for worldwide ultrahigh frequency communications. In summer 1988, the Defense Acquisition Board approved the construction of one HS 601 advanced satellite for $120 million by Hughes; the contract included an option to build the other nine. In August 1989, the Board decided to procure nine additional satellites as part of a program to upgrade this UHF constellation. The total program will cost about $1.5 billion and will be completed in fiscal 1993. The navy hopes to procure two satellites in fiscal year 1990 at a cost of $313 million and three in fiscal year 1991 at a cost of $201 million.

Defense Support Program (DSP)

Third-generation satellites currently are being procured for the Defense Support Program, which provides early warning of missile launches in foreign nations and at sea. The first DSP spacecraft were launched in 1971; the first of the current Block 14 upgraded spacecraft were launched in March 1989. The new DSP satellites have greater survivability, sensitivity, higher power,and a longer lifetime than their predecessors.

 © 1989 Dataquest Incorporated November

Built by TRW, nine of these $180 million satellites are expected to be put in orbit in the next few years. Aerojet ElectroSystems developed and builds the infrared telescope and sensor subsystem; IBM developed the software for the DSP. Total cost of the program is estimated to be more than $2 billion.

Defense Meteorological Satellite Program

Funded at a level close to $200 million annually, the Defense Meteorological Satellite Program maintains two satellites in polar orbit continually to record visual and infrared imagery for strategic and tactical missions. RCA is the prime contractor for this program. Second-phase studies are currently being conducted for the program's Block VI satellites, scheduled for launch beginning in November 1990, and to continue through 1993 or 1994. Potential upgrades include active sensing techniques, increased survivability and autonomy, satellite internetting for relaying data, and integration into the Air Force Satellite Control Network.

NAVSTAR Global Positioning Satellite

The NAVSTAR Global Positioning Satellite (GPS) program will provide aircraft, artillery, ships, tanks, and other weapons systems with information on their position, velocity, and time. The prime contractors are General Dynamics and Rockwell International. The air force requested $104 million for fiscal year 1990 and $32 million for fiscal year 1991. Although Block II NAVSTAR satellites, first launched in February 1989, were four years behind schedule, the outlook for the GPS program is good, since the technology is established and is being used on many types of military systems.

NAVSTAR GPS will be launched using McDonnell Douglas Delta II rockets. The DOD hopes for two-dimensional coverage by 1991 and three-dimensional coverage using 21 satellites by 1992 or 1993. A total of 60 GPS satellites are planned to be launched over the next few years. Block II satellites differ from their predecessors in greater size and weight, and longer mission life; they are expected to orbit for about seven years. Principle electronic subcontractors for this program include: ARINC Research, Datum, Frequency Electronics, General Dynamics Electronics, Hughes Aircraft, Interstate Electronics, ITT, Logicon, Magnavox, Canchan Marconi Stanford Telecommunications, Texas Instruments, and Unisys.

MILSTAR

The Military Strategic/Tactical and Relay constellation of satellites will provide extremely high-frequency communications transmissions for U.S. nuclear and other military forces. Most details of the program are classified, but the air force expects to begin deployment in the mid-1990s, using Titan IV/Centaur boosters. The final integration of MILSTAR payloads will be tested by Lockheed, the prime contractor, in 1990. Total cost of the MILSTAR program may reach $10 billion, with each satellite and booster combination costing $1 billion.

© 1989 Dataquest Incorporated November

MILSTAR satellites are geosynchronous and provide direct communications links in a 10-satellite constellation. Each service will have receiver terminals, but the air force is managing research, development, and production of the satellites. Raytheon, with Rockwell and Textron-Bell Aerospace, developed MILSTAR terminals for the air force and navy. Magnavox is providing small mobile terminals for the army (AN-TSC-124).

MILSTAR will be the first defense communications satellite to use frequency-hopping on the up-link to deter enemy listening and jamming, as well as phased-array antennas. The satellites are designed to resist attacks against communications signals by radio jamming, lasers, antisatellite interceptors equipped with explosive charges, and electromagnetic pulses. TRW has responsibility for the communications payload under Lockheed, the prime contractor. Hughes Aircraft will provide the superhigh frequency down-link subsystem, and TRW will provide the extremely high frequency up-link; E-Systems is developing the UHF communications subsystem. Other subcontractors include the following:

- Arinc
- Booz-Allen, Hamilton
- Computer Sciences Corp.
- Electromagnetic Sciences
- Electrospace
- Ford Aerospace
- General Electric
- GTE
- Linkabit Inc.
- M/A-COM
- Martin Marietta
- Motorola
- Raytheon
- Tracor
- Ultrasystems
- Yardney

The MILSTAR program has been beset by technical delays and cost overruns since it began in 1983; it is now two years behind schedule. The Cheney amendments to the budget cut funds for MILSTAR beyond 1992, but the DOD requested an additional $200 million each in the fiscal year 1990 and 1991 budgets to maintain the launch schedule. The first satellite was to begin construction in the summer of 1989, with the first launch now set for 1991.

Defense Satellite Communications System (DSCS)

The current Defense Satellite Communications System consists of seven satellites, including two dormant spare satellites, orbiting at an altitude of 37,000 kilometers. The primary function of the DSCS is to relay information by and for the White House Communications Agency, State Department, and the DOD's worldwide military command

 © 1989 Dataquest Incorporated November

and control system. Although the DOD is moving toward using super and extremely high-frequency radios in other satellite programs, such as MILSTAR, DSCS replacement satellites would use ultrahigh frequency. The prime contractor for the DSCS is General Electric; other contractors include the Aerospace Corporation (a federally funded R&D center), Hughes, and TRW.

The follow-on program for the DSCS will require funding in 1992 to put new satellites aloft by 1998 with Atlas II rockets. Although 11 replacement satellites have already been built, the air force contracted with Aerospace, Hughes, and TRW last year for studies on options for the replacement satellites. The DSCS-3 upgrade will require launching four geosynchronous satellites with one spare; two were launched in May 1989 on Titan 34D rockets.

Funding requests by the air force for fiscal year 1990 are approximately $77 million; for fiscal year 1991, approximately $79 million. The total requirement is for 10 DSCS-3 satellites through fiscal year 1997, at a cost of $200 million.

Intelligence Systems

The DOD spends approximately $5 billion annually to establish a network of satellites and computers to collect information about economic and military developments in foreign nations, and to monitor world events. In addition, the Tactical Exploitation of National Capabilities Program (TENCAP) uses intelligence satellites such as White Cloud, Magnum, Vortex, and Chalet satellites to acquire information on troop movements and potential targets to battlefield commanders. During the 1990s, the DOD plans to launch at least four Lacrosse radar imaging and four KH-12 photographic satellites that could be used for TENCAP. Contractors include Geodynamics, Lockheed, and TRW.

TOPEX Satellite

The Earth observation satellite, TOPEX, is scheduled for launch in June 1992. A joint venture with the French Space Agency (CNES), TOPEX will be launched by Ariane 4 boosters. Fairchild Space Co. is the prime contractor for the TOPEX; TRW was selected to build electrical, electronic, and electromechanical elements of the TOPEX by Fairchild under a $7 million contract early this year. The life expectancy of the satellite is limited to three to five years.

TOPEX will be used for observation of ocean topography to determine the circulation of the ocean and its variability, the role of the ocean in the climate, and wind effects on currents, among other things. Previous Earth observation satellites such as NROSS or GEOSAT had a 50-centimeter accuracy, whereas TOPEX will have a 14-centimeter accuracy. TOPEX began production in May 1989 after the critical design review in April. Integration of the modules is planned for April 1990, and the instruments will be installed in November. Integration of the bus and payload will begin in February 1991.

© 1989 Dataquest Incorporated November

Medium Launch Vehicles

Procurement of the Delta II and Atlas II space boosters are funded under the Medium Launch Vehicle program. McDonnell Douglas is the prime contractor for the Delta II; General Dynamics is the prime contractor for the Atlas II. The Delta II will be used to launch the NAVSTAR GPS, whereas the Atlas II will launch the Defense Satellite Communications Systems satellites. First flown in December 1988, Delta II carries an 8,400-pound payload into low-Earth orbit (or 2,500 pounds to a 22,300-mile height) and costs about $50 million each. The first seven launch vehicles will be produced under a $316 million contract to McDonnell Douglas. Production of and launch support for all 20 MLVs has an estimated value of $750 million.

The air force selected General Dynamics to provide a high-performance medium launch vehicle (MLV-II) to launch 10 General Electric DSCS-3 geosynchronous defense communications satellites and one P87-B NAVSTAR technology development satellite. The air force is not buying the launchers, but rather the launch services of General Dynamics, resulting in a cost savings of at least $100 million per flight compared to the Space Shuttle. The launch schedule calls for four satellite launches in 1991, followed by one per year through 1997.

Heavy Launch Vehicles

Martin Marietta produces the Titan IV and Titan II Space Launch Vehicles that are funded by the air force. The air force requested three boosters in fiscal year 1990 at a cost of about $250 million and two in fiscal year 1991 at about $240 million. The Titan IV, which flew for the first time in early 1989, can carry payloads as heavy as 65,000 pounds (comparable to the Space Shuttle), but at a cost of about $3,000 per pound.

Forty-one rockets are expected to be procured at a cost of $12.2 billion. Loral Instrumentation was awarded a $2 million contract in March 1989 to provide telemetry data processors for the Titan IV.

Basic Research

Overview

Basic research in military space systems is dominated largely by the Strategic Defense Initiative (SDI), which covers a wide range of research programs from artificial intelligence to propulsion systems. Still, DARPA and the military services are also funding research separately into inexpensive satellites, new launch systems, antisatellite weapons, and the National Aerospace Plane, as well as basic technologies. These programs may benefit from advances made by SDI research, such as those related to miniaturization, power plants, and high-data-rate communications systems, although the SDI Organization (SDIO) has typically focused on technologies near maturity rather than on the space technology base. Some enabling technologies for SDI include high-power microwaves, precision pointing and tracking systems, noncooperative target recognition, and brilliant guidance. There also has been some research into ways of controlling large space structures and methods to improve survivability of up- and down-communications, and control links between the earth and satellites. In rocket propulsion, research will likely focus on the application of composite materials, very large-scale integrated circuits, software development, advanced sensors, optical information processing, and artificial intelligence.

Special-Purpose Inexpensive Satellite (Spinsat)

The navy's program to develop small, inexpensive satellites cost about $8 million last year. Defense Systems Inc. was awarded a two-year, $6 million contract in August 1987 for three Maestro (multiple autonomous spacecraft for telecommunications, recording, and observation) satellites. Ardak Inc. was contracted to develop a fourth Spinsat for $2 million, which is called Profile, or passive radio frequency interference location experiment. Although funding for light satellites is not consolidated under one program, the Office of Naval Research, which manages the Spinsat program, expects to undertake future technology demonstrations and issued a request for proposals to that effect in September 1988. Spinsats potentially could be used for communications, oceanography research, and possibly antisatellite, surveillance, and naval-targeting missions. Given the growing emphasis on satellite survivability, redundancy, and autonomy, this program can be expected to grow in the future.

Advanced Satellite Technology Program

DARPA's five-year program to develop inexpensive, small satellites has been cut back from a $35 million to $40 million a year effort to $10 million in fiscal year 1990. Congress may restore some funding since this program addresses the requirement for reducing weight in space systems. DARPA accepted proposals in March 1989 for complete, inexpensive satellite systems. Similar to the navy's program, the goal of the Advanced Space Technology Program is to develop and demonstrate advanced technology space systems that will enable the DOD to acquire lightweight, cost-effective military satellites for use by theater commanders, to ensure the availability and reconstitutability of communications, intelligence, and targeting systems after an attack.

DARPA hopes to launch four Lightsat research spacecraft in 1989. The primary designers of Lightsats are Defense Systems Inc. and Ardak. A DOD study recently completed, "The Alternative MILSATCOM Architectures Study," looked at Lightsats as possible replacements for existing communications satellites in the early 2000s.

Another innovative program is the Pegasus project, developed by Hercules Aerospace Corporation and Orbital Sciences Corporation. Pegasus is intended to provide a low-cost and flexible method of boosting satellites; this three-stage solid fuel rocket will be launched from bomber aircraft. DARPA awarded a total of $12 million contract to Orbital and Hercules in 1988 to fund the first flight of a booster launched from a B-52, scheduled in August 1989; a full flight test will be conducted in the fall.

© 1989 Dataquest Incorporated November

Space Concentrator Solar Cells

Key to advanced space systems is the development of more efficient power sources. Varian was awarded a $3 million contract by the Air Force Aeropropulsion Laboratory in March 1989 to develop solar cells for use in terrestrial power plants and orbiting satellites. The cells will be capable of converting sunlight to electricity with about 30 percent efficiency under operating conditions, whereas existing silicon solar cells are only about 15 percent efficient at the outset. These new cells are expected to operate at temperatures of about 75 to 100 degrees Celsius, using a layer of gallium arsenide between aluminum gallium arsenide and indium gallium arsenide or germanium. Varian expects to complete the project in three years. Other contractors include Spire Corp., with a contract for $2 million, and the Triangle Research Institute, with a contract for $500,000.

Advanced Launch System (ALS)

The Advanced Launch System is a new family of space vehicles that will provide relatively low-cost and high launch rates across a wide range of payload sizes. The goal of the ALS program, in place since 1986, has been to reduce the cost of space launches from the current roughly $3,000 per pound to $300 per pound by using simpler booster and engine designs, composite materials, and advanced production processes. Some progress has been made. Current cost estimates for the hydrogen engine for the ALS, for example, are about $5 million, compared to $40 million for a Space Shuttle engine. One factor in keeping prospective costs low, however, would be a high rate of production. The total cost of an ALS fleet could run as much as $80 billion through 2010, but this would depend critically on U.S. launch requirements, especially those of SDI.

In December 1988, three Phase II ALS contracts were awarded for studies and technology demonstrations as part of the Space Transportation Main Engine and Space Transportation Booster Engine programs: Boeing, General Dynamics, and Martin Marietta were awarded a total of $264 million by the air force. Boeing received an $83 million contract for work on expendable structures, including cryogenic tanks, composites, and low-cost heat shields, as well as automated operations. General Dynamics received $83 million for demonstrations of multipath redundant avionics, adaptive guidance, navigation and control, expert systems, and electromechanical actuators. Martin Marietta received $98 million to study cryogenic tanks, composite materials, automated launch vehicle integration, ground operations flow management, and mission analysis simplification. The completion of the studies is scheduled for late 1990.

Other contracting activity includes five awards totaling $83 million to Aerojet TechSystems in March 1989 for engine components for the ALS. Aerojet will develop a liquid hydrogen turbopump, an engine propellant control effector system, an engine controller, a methane/oxygen gas generator, and a methane/oxygen thrust change assembly. Pratt-Whitney and Rocketdyne were also awarded contracts for engine development: Pratt received a 40-month $23 million contract to develop a liquid oxygen turbopump, whereas Rocketdyne will develop a liquid methane turbopump, also for $23 million. NASA spent $81 million in fiscal year 1989 on guidance system development, but will contribute only $5 million to the ALS effort in fiscal year 1990.

 © 1989 Dataquest Incorporated November

The ALS is scheduled for initial operating capability in the year 2000, with full-scale development expected to begin in fiscal year 1993. The program will cost between $150 million and $169 million in fiscal year 1989, with funding requests for fiscal years 1990 and 1991 at $200 million.

Standard Small Launch Vehicle

Funding for the Standard Small Launch Vehicle in fiscal year 1989 totaled $13 million. DARPA's requirement is for a vehicle that can boost a 1,000-pound payload into a 440-mile polar orbit. DARPA hopes for a launch two years after the contract award, expected this year. Among others, Lockheed, Space Services Inc., and TRW bid for the contract.

Anti-Satellite Weapon Systems (ASATs)

The DOD's ASAT program has had a difficult past, stemming both from political controversies and technical hurdles. Congress passed legislation for the past three years prohibiting the testing of ASATs in space, and the DOD terminated LTV's aircraft-launched ASAT program when it ran into repeated technical problems and huge cost increases.

The Reagan 1990 and 1991 budget brought the ASAT program back to life, providing about $431 million in ASAT-related funding, funding which survived Secretary Cheney's initial budget cuts. The Defense Acquisition Board approved Milestone 0 development of ASAT in mid-1989, while recommending that the army take the lead in development, based on research conducted for the ERIS interceptor program. A decision on a directed-energy ASAT system is planned for fiscal year 1991. A joint program office for ASAT technology was created by the DOD for surface-based kinetic energy weapons effort, with the army as leader of an army-navy team; approximately $200 million in navy funds for ASAT was transferred to the army by Secretary Cheney. The air force will be responsible for single comprehensive space surveillance and battle management system for controlling all ASAT capabilities.

Under the proposed ASAT program, the first system to be developed would be a land-based kinetic kill missile. Later systems would incorporate directed energy weapons such as the free electron and chemical lasers. The army is working on the free electron laser through 1991, whereas the air force will conduct parallel research leading to a decision in 1991 on ASAT directed-energy system selection. The Air Force Space Division awarded eight study contracts in December 1988 at a cost of $7 million. These studies will report on current and future kinetic energy technologies for the ASAT mission, including those applied to sensors, boosters, command and control, and surveillance. The contractors include Advanced Technology, Boeing, General Dynamics, Lockheed, Logicon, LTV, Rockwell, and Science Applications International Corp. The air force is also continuing research into technology, cost, and alternative concepts for directed energy weapons. Finally, the navy is experimenting with the Medium Infrared Chemical Laser (MIRACL) as an ASAT weapon at the White Sands Proving Ground.

Even so, as long as the USSR maintains its own moratorium on ASAT tests, the future of these programs must be considered problematic.

© 1989 Dataquest Incorporated November

National Aerospace Plane (NASP)

The National Aerospace Plane is a hypersonic plane (+Mach 5) designed to take off horizontally from conventional airfields and achieve an orbital speed of 18,000 miles per hour. NASP is intended to deliver both military and civilian payloads into space. Some defense applications might include strategic reconnaissance, high-velocity strategic bombardment, and rapid surgical strike missions. NASP is envisioned as an airbreathing, hydrogen fueled, single-stage-to-orbit vehicle. The NASP (X-30) is planned to fly in late 1994 or early 1995 after an investment of $4 billion. Approximately $1.5 billion has already been spent, with 70 percent of that figure swallowed by relevant contractors. By June 1989, the NASP program was one year behind schedule and $700 million over budget.

The air force requested $300 million for the NASP for fiscal year 1990; NASA requested $127 million in fiscal year 1990. The Defense Resources Board recommended cutting DOD funding completely, but Secretary Cheney appeared to have been swayed somewhat by Vice President Quayle and the Space Council's recommendation to continue funding. The DOD's request was left at $100 million for fiscal year 1990 and nothing in fiscal year 1991.

Teams of contractors are led by General Dynamics, McDonnell Douglas, and Rockwell for the airframe, and Pratt-Whitney and Rocketdyne for the engine. In May 1989, the air force chose to continue development of both Pratt-Whitney and Rocketdyne propulsion concepts through 1990; both firms received close to $65 million each. A consortium to research materials technology was formed in March 1988 and includes General Dynamcis, McDonnell Douglas, Pratt-Whitney, Rocketdyne, and Rockwell. Total funding for the consortium is $150 million through October 1990. Members will work on the following technologies:

Firm	Technology
General Dynamics	Refractory composites
McDonnell Douglas	Titanium matrix composites
Pratt-Whitney	High specific creep strength materials
Rocketdyne	High-conductivity composites
Rockwell	Titanium aluminides

A second consortium will develop vehicle subsystems for the aircraft. Accelerated development of the following subsystems is sought by the air force: rocket propulsion systems, crew escape systems, turbopumps, slush hydrogen production, instrumentation, air data systems, and high-temperature antennas. The air force spent approximately $107 million in 1988 on engine research related to the NASP. The NASP will use scramjet (supersonic combustion ramjet) technology; officials predict technology spinoffs in propulsion and composite materials, and computational and fluid dynamics, among

© 1989 Dataquest Incorporated November

other things. NASP will be aided by related research efforts in space technology. One example is the Light Detection and Ranging System (LIDAR), developed by the air force and Georgia Institute of Technology, which will collect information on atmospheric density as high as 50 miles.

NASP's future has to be considered problematical given current budgetary constraints, although the development of component technologies no doubt will continue under one guise or another.

Strategic Defense Initiative (SDI)

Overview

Several changes are in store for the Strategic Defense Initiative, which is cautiously emerging from basic research into demonstration and validation of systems that could be deployed in the mid- to late-1990s. With the departure of Lieutenant General James Abrahamson as the Strategic Defense Initiative's lead proponent and the change in administrations, however, to say nothing of the defense budget squeeze, the SDI program is losing a great deal of political and financial momentum. The new director of the SDI Organization, Air Force Lieutenant General George Monahan, has stated that he intends to act as a program manager rather than an advocate for SDI.

The SDI research program is divided into five key technology areas: directed energy weapons; kinetic energy weapons; surveillance, acquisition, tracking, and kill assessment systems (SATKA); systems analysis/battle management; and survivability, lethality, and key technologies for space logistics and power.

President Bush proposed cutting $7 billion from former President Reagan's SDI plan over the next four years, including a cut of $1 billion for fiscal year 1990. Funding requests now stand at $4.6 billion in fiscal year 1990 and $5.4 billion in fiscal year 1991. SDI will not be funded at these levels, given Congress' past decisions on the program. Of the $1 billion in cuts, about one-third came from the directed energy weapon program (DEW). Funding for the surveillance, acquisition, tracking, and kill assessment program element actually increased by $60 million from the Reagan projections. Finally, the Cheney amendments do not allow for deployment funds in fiscal year 1990.

Some SDI technologies entered the demonstration and validation phase in 1987, including the Boost Surveillance Tracking System, the Space Surveillance Tracking System, the Space-Based Interceptor, the Ground-Based Interceptor, the Ground-based Surveillance and Tracking System (GSTS) sensor satellite, the Ground-Based Radar, and battle management/command, control, and communications. These technologies have been grouped together in a Phase I SDI system, approved for Milestone I development by the Defense Acquisition Board (DAB) in 1988. SDI's official cost estimate for Phase I was $69 billion in March 1989, a little more than half of the previous estimates. Half of all SDI resources are devoted to this Phase I system, with the other half allocated to more fundamental research. SDI Phase I will be reviewed formally in 1989; in spring 1990, a Systems Requirement review for Phase I will be conducted. General Electric is the systems engineering contractor for SDI Phase I.

© 1989 Dataquest Incorporated November

SDI tested the Beam Experiment Aboard Rocket in April, which demonstrated the first neutral particle beam in space, and launched the Delta Star in March 1989. Delta Star, a satellite carrying eight sensors, will observe U.S. launches of rockets and missiles for six months to collect information about rocket plumes and Earth background. The Space Power Experiment Aboard Rocket II investigated how high-voltage equipment operates in space in August 1989. Four key tests are scheduled for 1990, including a flight test of Lockheed's ERIS interceptor; the launch of two laser relay test satellites; a ground test of the main boost-phase sensor satellite; and Starlab, an acquisition, tracking, and pointing system based on the Space Shuttle.

The emergence of the "Brilliant Pebbles" concept from Livermore Laboratory may sidetrack early deployment of the Phase I SDI system. Under the concept, thousands of 3-foot long sensor-guided independent projectiles would be dispersed in a low-Earth orbit, and in the event of a ballistic missile launch, directed to target and collide with attacking missiles in the boost phase of their trajectory. Proponents maintain that Brilliant Pebbles would cost less than $10 billion, with each projectile costing only a few hundred thousand dollars. Brilliant Pebbles would be linked to Phase I sensors, including the Boost Surveillance and Tracking System, and the Space-Based Surveillance and Tracking System. Combined with an orbiting surveillance satellite system and C2 ground complex for $15 billion, the total cost could be as low as $25 billion, according to its sponsors. Brilliant Pebbles technology was demonstrated in ground tests in 1988 and a comparably sized vehicle was flown in a laboratory in April 1989. Although the program would use off-the-shelf electronics technology, the projectiles will still require the computing power of a Cray-1 in the size of a deck of cards. Brilliant Pebbles is not yet linked to Phase I but will be evaluated in that context this year; the program will receive $46 million in fiscal year 1989 and if successful, would receive a lion's share of the $200 million planned for kinetic energy weapons in FY 91.

One disadvantage of the system is the lack of sensors for midcourse discrimination. Another is the political difficulty of justifying the placement of thousands of weapons in orbit. A third, and most important, is the unproven character of the technologies involved. A fourth is the incredibility of current cost estimates.

In effect, the DOD will have to choose next year among three options: continuing with the relatively proven, if limited, technologies of the current Phase I system; shifting to the Brilliant Pebbles concept, meaning a several-year delay at least in deployment; and moving away from any definite deployment plan toward a more diverse technology development program.

Phase I Strategic Defense Initiative

The components of the current Phase I system are described in the following sections.

Boost Surveillance Tracking System (BSTS). The Boost Surveillance Tracking System is the key early warning component of the SDI Phase I architecture. Utilizing infrared technology to detect exhaust plumes of ballistic missiles during the boost phase of flight, the BSTS also would upgrade U.S. national attack warning and assessment capabilities. BSTS was planned to start full-scale development in 1990, but with funding cuts, the schedule will be pushed back to fiscal year 1991. SDIO and air force requests for fiscal year 1990 totaled $329 million, and for fiscal year 1991, $427 million.

Grumman and Lockheed are developing and testing BSTS sensor technology; one company will be selected to carry forward full-scale development in 1991. Both Grumman and Lockheed received $304 million contracts in 1987, which were extended by $100 million to accommodate the schedule slippage. Grumman's design has been noted as a more sophisticated focal plane array, Lockheed's design is simpler and less costly. Grumman collaborates with Ford and Rockwell, whereas Lockheed works with Hughes and IBM. Other subcontractors include the following:

Grumman	Lockheed
General Electric-RCA	GTE
Honeywell	Litton-Itek
McDonnell Douglas	Raytheon
SAIC	Sparta
TRW	

Critical technologies for the BSTS program pertinent to defense electronics include high-density, radiation-hardened integrated circuits, high-speed analog-to-digital converters, and low-cost infrared detectors for focal plane arrays. SDIO developed a VHSIC space borne computer to meet its requirements for high availability and low time-between-maintenance, choosing a local area network approach supporting fault-tolerant, loosely coupled distributed microprocessors. BSTS will use a total of 23 sensors.

Production of six satellites and three spares is expected to begin in 1995. Although the original concept for the BSTS included battle management and command, control, and communications capabilities, the versions now in development do not include BM/C3I capability. Estimated to cost $8 billion, the BSTS is being touted as a possible tool for arms control verification and tactical warning, as well as a substitute for Defense Support Program satellites, given its ability to track high-altitude cruise missiles and short-range ballistic missiles. This is one element of the SDI Phase I system almost certain to be deployed regardless of decisions on the architecture overall.

Space Surveillance and Tracking System (SSTS). The Space Surveillance and Tracking System would be a constellation of six satellites used to monitor the midcourse phase of enemy missiles' trajectories. SSTS sensors are able to resolve smaller objects

© 1989 Dataquest Incorporated November

than the BSTS, using small, passive, long-wave infrared sensors, and must be capable of discriminating between warheads and decoys. Some of the technologies developed have been long-wave infrared focal plane arrays, cryotechnology, background noise measurement, and space mirrors.

Lockheed and TRW are the prime contractors for the SSTS; Lockheed was awarded $139 million additional funding in January 1989, TRW was awarded $102 million in additional funds. Subcontractors include Aerojet, GM-Hughes, Honeywell, Raytheon, and Sparta. The demonstration/validation phase is expected to last through 1991; a ground demonstration of the technology is scheduled for 1992, after which a single contractor will be selected. Full-scale development is scheduled for 1992 through 1997, with production slated for 1995 to 2000. These dates will probably slip further as SDI seeks to accommodate funding cuts, and deployment of the system is far from assured.

Space-Based Interceptor (SBI)

The Space-Based Interceptor would be a constellation of killer satellites intended to destroy attacking missiles in their boost and post-boost phases. Operationally, 10 interceptors would be grouped in each satellite. The interceptors would be conventionally armed. SBI satellites presumably also would require short-range optical sensors.

The SBI program is being revised in preparation for a full-scale development decision in 1994. Cost estimates for the SBI were halved in late 1988, allegedly because improvements were made in accuracy that allowed fewer interceptors to be deployed; skepticism has been expressed about this claim. The demonstration and validation phase is expected to last through 1993; full-scale development from 1994 to 1997; production is scheduled for 1996 through 2000. With funding cuts, however, deployment will slip by at least two years, and neither FSD nor deployment are assured. Martin Marietta and Rockwell are the prime contractors for the SBI. Subcontractors include the following:

Martin Marietta	Rockwell
Acurex	Aerodyne
Aerojet	Calspan
Ford	General Electric
Kaman	Litton
LTV	McDonnell Douglas
Mission Research	Photon Research
Teledyne	Rockwell Space Vector

© 1989 Dataquest Incorporated November

Battle Management. This program focuses on ways of relaying information from surveillance satellites, sensors, and radars to battle managers, as well as assigning targets to spaceborne and ground-launched weapons systems. Much of the research has focused on developing dependable, fault-tolerant, high-performance computer systems, and advanced computer architecture. Radiation-hardened microelectronics programs also have received considerable attention.

The prime contractor for the battle management/command, control, and communications portion of SDI is TRW. Among others, TRW won a three-year, $12 million contract in 1989 from the army to provide systems engineering and integration in a program to develop a prototype battle manager for SDI using advanced parallel computers. TRW has subcontracted with Alphatech and Advanced Decisions Systems to provide algorithm research and hardware development. The resultant computers will be used in the Algorithmic Architecture Program under the direction of DARPA.

General Electric won a $236 million contract in 1988 for systems engineering and integration for the command and control system for Phase I.

SDI National Test Bed. The SDI National Test Bed is the primary tool for integration, test, and evaluation of SDI battle management systems. The primary contractor for the National Test Bed program is Martin Marietta. The National Test Bed was funded at $100 million in fiscal year 1989; funding requests for fiscal year 1990 and 1991 stood at $116 million and $122 million.

Subcontractors include CAE-Link, Carnegie-Mellon, Computer Tech Associates, Ferranti (United Kingdom), Geodynamics, Hughes, IBM, Logicon, Nichols Research, and Ralph M. Parson Co. Logicon won an award in March 1989 to assist Martin Marietta in integrating the National Test Bed program for $25 million. The contract will allow Logicon to continue to provide Martin Marietta with threat scenarios, object data, and engagement simulations through 1993.

Phase II Strategic Defense Initiative

Among the SDI programs still in basic research are midcourse and terminal sensors, free electron lasers, the medium infrared chemical laser (MIRACL), the neutral particle beam, and HEDI and ERIS ground-based interceptors. Technology base programs within SDI will have to be cut back, however, if the DOD decides to go ahead with development of the Phase I system. Some of the research relevant to defense electronics sponsored by SDIO Office of Innovative Science and Technology include optical computers, atomic layer epitaxy manufacturing methods for integrated circuits, and the use of thin-film diamond technology in electronic circuits.

One critical area of research is in infrared detection; Westinghouse was awarded $3 million to lead a two-year program that will develop infrared sensors using high-temperature superconducting materials for SDIO. The sensors will provide

© 1989 Dataquest Incorporated November

surveillance spacecraft with IR detection capabilities and will be applied to an IR focal plane array. Westinghouse is working with Hypres Inc. and the National Institute of Standards on this program.

Exoatmospheric Reentry Interceptor System (ERIS). The army has been selected by the Defense Acquisition Board as the lead service for the ERIS system. ERIS is a ground-launched interceptor designed to destroy enemy missiles in late midcourse. Improvements already have been made in miniature kill vehicle technology, advanced propellants, guidance, control, and electronics. The prime contractor for ERIS is Lockheed; GM/Hughes, Hercules, Honeywell, Singer-Kearfott, Texas Instruments, and TRW are subcontractors. ERIS functional test validation flight series are scheduled for fiscal year 1990. The program has undergone considerable changes in the last few years, and the army is already considering follow-ons. The army asked for innovative proposals to improve ERIS in April 1989. It seeks to lower costs for the interceptor and improve its ability in on-board discrimination, maneuverability, operation in a nuclear environment, and response to countermeasures. The army hopes to make concept and technology integration contract awards for an ERIS follow-on in March 1990.

High Endoatmospheric Defense Interceptor (HEDI). The High Endoatmospheric Defense Interceptor would be SDI's primary weapon against incoming missiles in their final stage of flight. First flight of the HEDI took place in mid-July 1989, and other flight tests are scheduled at the rate of one per year. The HEDI kill vehicle includes an optical window, an active cooling system for its infrared seeker, a propulsion system, a protective shroud, and an explosive warhead. McDonnell Douglas is the prime contractor. Fiscal 1989 funds were $113 million.

Directed Energy Weapons. All directed energy weapons are categorized as Phase II technologies in the SDI architecture, but their development has been extremely expensive and slow. One major experiment, costing $1.8 billion, is called Zenith Star, tentatively planned to be launched in mid-1990s. Martin Marietta is the prime contractor. The Zenith Star would link the Alpha laser to a beam director. Launched by two Titan IVs, the Zenith Star would carry Itek's LAMP large advanced mirror and Lockheed's hardware for beam control, pointing, and tracking.

The Alpha hydrogen-fluoride laser, part of the Zenith Star experiment, was tested in early April 1989, marking the first time a laser close to SDI-scale in terms of power has been demonstrated. Alpha is the result of 10 years of work by TRW, the prime contractor; already 15 months behind schedule, its cost has risen to $200 million. Tests should be completed in mid-1990.

The air force also has established a Space-Based Laser Integration Technology (SBLIT) Program to conduct applied research into chemical laser technology. The air force is seeking proposals for the design and initial fabrication of components of an advanced optical resonator assembly, and the design of a high-power-beam clean-up experiment.

A second major directed energy weapon experiment is for more advanced ground-based lasers, both chemical and free electron. A major demonstration of the free electron laser is scheduled for the mid-1990s. The Medium Infrared Chemical Laser

 © 1989 Dataquest Incorporated November

(MIRACL) is a deuterium-fluoride laser that operates at 3.8 microns. MIRACL successfully shot down a supersonic target drone in March 1989. The ground-based laser program was scaled back to $170 million annually for the next three to four years; the program had been funded at $453 million from fiscal year 1987 through 1989. Contractors include Boeing and Los Alamos Laboratory, which are developing a radio frequency linear accelerator, and Lawrence Livermore and TRW, which are developing an induction linear accelerator.

The third directed energy weapons system is the neutral particle beam. SDI is funding three neutral particle beam programs at $110 million annually: a continuous-wave deuterium demonstrator, a ground test accelerator, and a power system demonstrator. The Army Strategic Defense command awarded a $46 million contract to Grumman Space Systems to build a continuous-wave deuterium demonstrator to prove the technical feasibility of neutral particle beams. Grumman has subcontracted work to Los Alamos National Laboratory and Culham Laboratories (United Kingdom).

SHIPBOARD ELECTRONICS SYSTEMS

Overview

Procurement of naval ships may take a dramatic turn if the navy's new warfare plan is implemented, but it will not likely diminish the importance of shipboard electronics. Outlined in the Surface Combat Force Requirements Study, the plan calls for a fleet of 120 "battle force combatants" (BFC) and 104 "protection of shipping ships" (POS). Approved in December 1988 by acting Secretary of Defense William Taft, the plan allows for the BFC to replace several classes of cruisers and destroyers: The BFC is envisioned with a phased array radar, vertical launching system, advanced surface-to-air missiles, improved sonars, and two LAMPS III helicopters. The existing DDG-51 with improved electronics would be a prime candidate for the BFC function. The POS would probably include improved antiair warfare systems, improved sonar, two LAMPS III helicopters, and shipboard standoff ASW weapons. The Surface Combat Force Requirements Study calls for building five or six BFCs beginning in 1990, with total force levels achieved by 2025.

As in avionics, greater commonality and integration will probably be the focus of future electronics procurement for naval systems. Emphasis will be placed on two areas: antisubmarine warfare sensors and air defense.

Systems Development and Procurement

The navy's amended procurement request for shipbuilding in fiscal years 1990 and 1991 includes 28 conventional force ships: 3 nuclear attack submarines, 10 guided missile destroyers, 3 amphibious ships, and mine countermeasure and coastal minehunters. Table 7 shows procurement acquisition costs, including R&D, as projected in January 1989.

© 1989 Dataquest Incorporated November

Table 7

Estimated Program Acquisition Costs and Quantity of Navy Ships (Millions of Dollars)

		Proposed			
System	Planned FY 1989	FY 1990 Number	Cost	FY 1991 Number	Cost
DDG-51 Arleigh Burke Destroyer	$2,862	5	$3,672	5	$3,698
SSN-688 Los Angeles	$1,427	1	$ 806	1	$ 96
SSN-21 Seawolf	$1,721	-	$1,010	2	$3,510
Carrier Service Life Extension	$ 84	-	$ 683	--	$ 134
MHC-1 Mine Countermeasure Ship	$ 201	1	$ 120	3	$ 256
LSD Cargo Variant	------	1	$ 229	1	$ 237
Landing Craft	$ 308	9	$ 223	12	$ 302
TAGOS SURTASS Ship	$ 167		$ 169	--	$ 27
AO Auxiliary Ship	$ 75	-	$ 36	--	$ 6
LHD-1 Amphibious Assault	$ 760	-	$ 11	1	$ 960

Source: U.S. Department of Defense

Submarines and Related Systems

SSN-21 Seawolf. General Dynamics was selected early in 1989 to build the first of the new Seawolf-class of nuclear attack submarines, with a contract valued at about $726 million. Construction began at the end of 1989, with delivery expected in 1995. Newport News is expected to compete for the contract for the second submarine, which could be funded in 1991. A total of 29 vessels is expected to be built from 1989 to 2000. The navy has requested two SSN-21s in fiscal year 1991 and three per year thereafter. Total procurement is expected to cost about $36 billion, with the first SSN-21 costing as much as $2 billion and additional copies costing about $1.2 billion each. The DOD projects that it will spend $2.8 billion just for the C2 computer system on board the Seawolf.

The SSN-21 will use Harpoon and Tomahawk missiles as well as Sea Lance and Mk 48 torpedoes. Other components include surface search radar, BSY-2 sonar with bow-mounted transducers, wide-aperture array, and the TB 16 and TB 23 towed array sonars. Martin Marietta received a $14 million contract in March 1989 from General Electric for full-scale engineering development of the Wide Aperture Array listening device, a key element of the AN/BSY-2 combat system. The device consists of hydrophones mounted on the outside of the submarine's hull, and will collect, process, and display acoustic sensor data. The contract could be worth between $300 million and $500 million over the next 10 years.

IBM has an initial contract of $75 million for the towed sonars. SPD Technologies also was awarded a contract in March for electric plant control panels for the SSN-21, to be delivered by June 1991. Based on a distributed architecture with a fiber-optics bus, the BSY-2 will use 6 AT&T EMSP signal processors and 200 Motorola 68030, 32-bit MPUs, for assorted processing and control functions.

The SSN-21 has been criticized as being too expensive, with few improvements over the Los Angeles class of attack submarines now being procured. Given recent Soviet advances in quieting their submarines and in ASW research, as well as heated criticism in Congress of the navy's ASW program, pressure may be exerted on the navy to design a less expensive follow-on submarine, or at least to keep the cost of the Seawolf down.

SSN-688 Los Angeles. Procurement of Los Angeles-class submarines, which entered service in 1976, has been terminated. The navy had requested funds to procure two SSN-688s each in fiscal years 1990 and 1991, and one in fiscal year 1992, but these requests were canceled as part of the Bush cuts in defense spending. The Los Angeles-class uses the BSY-1 combat system (SUBACS), in contrast to the SSN-21 Seawolf submarines, which will use the BSY-2 combat system. IBM is the prime contractor for the BSY-1; General Electric is the prime contractor for the BSY-2. The SSN-688 uses Mk 48 torpedoes manufactured by Gould and Emerson Electric Mk2 decoys, as well as the Unisys (Sperry) UYK-7 computer. Other components include the BPS-15A Sperry radar for surface search, navigation, and fire control, IBM's BQQ-5 IBM passive/active search and attack sonar, and the OK-276 thin-line array sonar. Through 1989, 61 SSN-688s had been authorized, 40 delivered and 20 yet to be delivered by 1995.

Unmanned Undersea Vehicles. Unmanned undersea vehicles may play a larger role in navy operations given their lower cost relative to submarines. The navy is in the process of developing a Master Plan for these vehicles. Martin Marietta was awarded a $15 million contract in December 1988 for an acoustic sensor for an unmanned undersea vehicle as part of a DARPA prototype development program. The vehicle is supplied by the Charles Draper Lab, and the entire system will be delivered in late 1989. The DOD expects to award one unmanned undersea vehicle payload contract annually.

Submarine Combat Systems. U.S. submarines are being fitted with the AN/BSY-1 combat system. IBM is the prime contractor for the BSY-1, which is the first submarine system to combine the functions of sonar and fire control. Formerly called SUBACS, the BSY-1 includes active sonar, passive flank array sonar, passive towed array, and combat control system, featuring an advanced distributed processing architecture. The principal subsystem is the Wide Aperture Array sonar, manufactured by Martin Marietta. The navy procured one BSY-1 in fiscal year 1987 and one in fiscal year 1988, both at a cost close to $45 million. IBM delivered the first full-function BSY-1 in February 1989, scheduled for installation on the USS Miami (SSN-775). IBM, which holds a $2 billion contract for 21 systems, already has delivered four other systems for the SSN-751 through -754. Major subcontractors for the BSY-1 include Hughes, Raytheon, and Rockwell.

© 1989 Dataquest Incorporated November

Future submarines, including the SSN-21, will incorporate the BSY-2 system under development by General Electric. The BSY-2 should include upgraded sonars, fire control systems, and displays. General Electric received a $225 million addition to its contract in January 1989.

Surface Ships and Related Systems

DDG-51 Arleigh Burke class. The Arleigh Burke guided missile destroyer is expected to be operational by October 1989. Manufactured by the Bath Iron Works and Ingalls Shipbuilding, the DDG-51 class of ships is planned to be procured at a rate of three per year from fiscal year 1987 to fiscal year 1990, and five per year thereafter. The DDG-51 uses the following subsystems: two Mk 41 Mod 0 vertical launchers for Standard Missiles, ASROC, and Tomahawk missiles; one SPS-64, one SPS-67, one SPY-1D phased array radars and three SPG-62 radars; and the SQS-53C and SQR-19 towed array sonars. A total of 29 ships is expected to be procured through 1993. Principle electronic subsystem suppliers include the following:

Firm	Subsystem
Martin Marretta-FMC	Mk 41 launcher
GE-RCA	AEGIS air defense system
	SQS-53C towed sonar
	SPY-1D SPG-62 radars
Unisys	UYK-43, 44 computers
Raytheon	SPQ-62 radar
	Mk 99 launcher
Gould-Raytheon	SQQ-89
Gould-GE	SQR-19

Future DDG-51 class ships will contain sprinkler systems in accommodation compartments and steel ladders in place of aluminum ladders as a result of the May 1987 Blue Ribbon Panel report on the USS Stark incident. Although a nine-month delay from the original procurement schedule and rising costs point to problems with the DDG-51 program, the destroyer's future looks bright as the most likely candidate for the Battle Force Combatant role.

 © 1989 Dataquest Incorporated November

LHD–1. The LHD–1 Wasp–class Amphibious Assault Ship will be used to establish Marine Expeditionary Forces and Brigades. The navy did not request procurement funds for the LHD–1 for fiscal years 1990 and 1991 because of a one–year delay in procurement. The overall goal of 83 amphibious ships, moreover, including the LHD–1, LSD–41, and others, has been pushed back from 1994 to 1999. However, the navy has stated a current requirement for five LHD–1 ships by the mid–1990s and five more by 1999. The LHD–1 uses Sea Sparrow missiles, SYS 2(V)3 weapon control system, Mk 91 fire control system, and three radars: the Hughes air search SPS–52, the ITT SPS–48, and the Raytheon SPS–49. Ingalls Shipbuilding, the prime contractor, delivered the fourth LHD–1 in April 1989; three more have been authorized by Congress. Total cost for the 10–ship LHD–1 program will be more than $10 billion.

AEGIS. With the end of the CG–47 Ticonderoga (Aegis cruiser) procurement program in fiscal year 1988, the Aegis advanced surface missile system will continue to be procured for DDG–51 Arleigh Burke destroyers, but no new hulls will be built. The Aegis system reached initial operating capability in 1983. Although it has been criticized by Congress and the GAO as expensive and not completely reliable, the final report on the USS Vincennes incident, which pointed to human error, has diverted attention away from technical shortcomings of the hardware.

AEGIS uses SM–2 medium–range missiles, three clusters of four Unisys UYK–7 computers and Mk 41 launchers manufactured by Martin Marietta. The navy plans to buy more than 50 AEGIS systems, 29 of which would be installed on the DDG–51s. The AEGIS is projected to cost about $1 billion per ship. RCA, the prime contractor for the AEGIS system, received a $376 million contract in 1988 for five AEGIS Mk 7 systems for three cruisers and two destroyers to be delivered in 1990. Subcontractors to RCA include the following:

Firm	Subsystem
Aerojet General	Mk 32 torpedoes
Computer Sciences	CMS-2 software
FMC	Mk 26 launchers
GD, Raytheon	SM-2 missile
General Dynamics	Mk 15 CIWS Phalanx gun; RIM-66/67 surface-to-air missile
General Electric	SQS-53 bow-mounted sonar
Gould	SQR-19 tactical towed array sonar

(Continued)

© 1989 Dataquest Incorporated November

(Continued)

Firm	Subsystem
IBM	LAMPS Mk III helicopter ASW, AAW
Hughes Aircraft	AN/UYA-4, -21 Weapon Control displays
Martin Marietta, FMC	Mk 41 vertical launching system
McDonnell Douglas	Tomahawk cruise missiles, Harpoon missile
Raytheon	Mk 99 fire control; AN/SPS-49 air search radar; SLQ-32(V) electronic warfare suite
RCA	Mk 131 command and control
RCA, Raytheon	AN/SPY-1 phased array radar
Lockheed	AN/SPQ-9 weapons radar
Unisys	AN/UYK-7 computers

The Mk 26 launcher uses a digital interface with the Mk 1 weapons control system, one of three computerized subsystems of the Aegis. The Mk 1 accepts weapon assignment commands and threat criteria from the Mk 1 command and control system, as well as data from the radar. The Mk 1 also generates commands for the Mk 26 launcher and the Mk 99 fire control, using the UYK-7 computer and the UYA-4 display. Future Aegis systems will replace the AN/SPY-1A multifunction phased array radar with the AN/SPY-1 D radar, and the AN/UYK-7 computer with the AN/UYK-43 computer.

ASROC. The ASROC, an all-weather, missile system, is manufactured by Honeywell. The ASROC incorporates Mk 46 acoustic homing torpedoes, Mk 112 launchers, and a computer linked to SQS-23, SQS-26, or SQS-53 sonar for fire control. Ships utilizing ASROC are equipped with Mk 114 fire control systems. Honeywell remains the prime contractor for the conventionally launched ASROC; Loral Systems was chosen as the prime contractor for the vertically launched ASROC with Martin Marietta as a second-source supplier. This program has been integrated with Sea Lance to constitute the Antisubmarine Warfare Standoff Weapon program. The navy has requested $9 million in fiscal year 1990 and $10 million in fiscal year 1991 for further development of the system.

SQQ-89 Integrated Combat System. The SQQ-89 is one of three integrated navy weapons systems programs incorporating computer-controlled surveillance and detection equipment as well as communications facilities and weaponry. Currently in production, the SQQ-89 is a sonar system for surface ships that integrates detection, location,

© 1989 Dataquest Incorporated November

tracking, and fire control functions, installed on the CG-47 Ticonderoga-class AEGIS cruiser and DDG-51 Arleigh Burke-class Aegis destroyers. Components include the AN/SQS-53B (a hull-mounted low-frequency sonar), the SQR-19 tactical sonar towed array, the SQQ-28 LAMPS Mk III acoustic processing system, the Mk 116 Mod 5-7 ASW control system, and the Sonar In Situ Mode Assessment System. The navy plans to install one of four variants of the SQQ-89 on up to 130 ships by 1995. The navy procured 10 SQQ-89 systems in fiscal year 1989 at a total cost of $216 million. For fiscal year 1990, the navy has requested $193 million for seven SQQ-89 systems, and for fiscal year 1991, $254 million for nine additional systems. Contractors include General Electric for the AN/SQS-53C, a new version of the hull-mounted sonar now in production.

Information Processing and Display

Improved information processing systems and displays are critical to the highly integrated systems that the navy will be procuring into the next century. Some of the key programs are described below.

Naval Tactical Data System (NTDS). The Naval Tactical Data system, deployed on all major naval combatants, combines digital computers with displays and data links for the automated organization and display of information for command and control of threat assessments and weapons allocation. Although early systems employed AN/UYK 20 or AN/UYK-7 computers, these are scheduled to be upgraded to the AN/UYK-43 and AN/UYK-44 computers. Hughes is the prime contractor for the Tactical Data System, and has already delivered 2,500 UYA-4 and UYQ-21 displays. The navy plans to spend $93 million in fiscal year 1989, $69 million in fiscal year 1990, and $81 million in fiscal year 1991.

Advanced Combat Direction System. The Advanced Combat Direction System is the next-generation follow-on to the navy Tactical Data System, which beginning in 1992, will be installed on all carriers. One advanced feature over the NTDS is an automated electronic surveillance/emitter identification, association, triangulation, and tracking capability. The Advanced Combat Direction System will facilitate integration of antijam data links with new tracking algorithms; the navy hopes that this will lead to higher track data accuracy, more identification detail, and greater track processing capacity. The Advanced Combat System will be installed in two Blocks: Block 0 will consist of new hardware, and Block I will add new software and hardware. The system will be deployed eventually on all surface ships except those equipped with the AEGIS air defense system.

AN/SPA-25G Radar Display. ISC Cardion Electronics manufactures AN/SPA-25G radar displays. The AN/SPA-25 G uses digital scan converter to overlay sensor data with graphic symbols on ships' tactical displays. Production is presently under way; the development contract was valued at about $13 million. Key features of the AN/SPA-25G include VME-based digital architecture and use of 68000 processors.

© 1989 Dataquest Incorporated November

Shipboard Computers. The navy currently uses two standard shipboard computers: the UYK-43 and the UYK-44. The UYK-43 is a large-scale computer installed on surface ships and submarines for radar processing, weapons fire control, carrier air traffic control, communications, and navigation. The UYK-44 is a medium-size computer used for much the same purposes. The latest AEGIS cruisers are equipped with 6 UYK-43s and 23 UYK-44s; SSN 688s are equipped with 2 UYK-43s and 5 or 6 UYK-44s. Unisys produces UYK-43s, and Control Data was chosen in 1988 as a second source; Unisys and Control Data will compete for production in 1990. At present, General Electric, Microlithics, and Raytheon are being qualified as additional UYK-44 suppliers.

While the navy is researching its next-generation computing requirements, upgrades are planned for the UYK-43 and -44. The navy approved the upgrade program in December 1988. The navy expects to spend about $29 million for UYK-43 improvements from fiscal year 1989 to fiscal year 1994, and about $19 million for improvements to the UYK-44 in the same time period. Both the UYK-43 and -44 will benefit from enhanced central processing units that will be four to six times faster than the existing units and additional memory. In addition, the UYK-43 will receive a coprocessor. The navy expects to install its next-generation computer, outlined in the Next Generation Computer Resources study, in 1996. The advanced computers are expected to incorporate modular design and use international computer standards.

Signal Processors. The navy will receive a new signal processor in the mid-1990s. Developed by AT&T, the Enhanced Modular Signal Processor (EMSP), or UYS-2, will replace IBM's UYS-1 as a key element in all platforms used for antisubmarine warfare. Using VHSIC chips developed by Honeywell, the EMSP will be able to process data from acoustic detection systems, synthetic aperture radars, adaptive beam forming, and electronic warfare systems. The navy projects software development costs to total about $60 million for the EMSP, in contrast to $150 million for its predecessor, the UYS-1. In addition to lower development costs, the EMSP's open architecture, designed for flexibility and adaptability, may offer further advantages. The EMSP will be installed on the LAMPS III helicopter and on platforms using the SQQ-89 integrated combat system. The navy also expects to install the EMSP in the SSN-21's BSY-2 system, SURTASS, and the Advanced Low Frequency Sonar System. Original estimates of the total cost were $2 billion, but budget cuts have reduced that figure.

Production approval was planned for August 1989 with prototypes to be delivered in April 1990. However, a report released in February 1989 by the Naval Audit Service recommended that the navy drop AT&T's processor in favor of a more powerful, lighter, and less costly alternative. The navy has already spent approximately $300 million on AT&T's research and development. IBM has proposed a system that costs roughly half of AT&T's, with potential savings estimated at more than $1.2 billion over the next 10 years. As a result of the audit, the navy reorganized the program, including plans for competitive procurement and the shifting of procurement schedules for different versions of the EMSP. Delivery of the most sophisticated E version is expected in mid-1990.

 © 1989 Dataquest Incorporated November

Antisubmarine Warfare Systems. In addition to ASW systems designed for specific platforms, the navy also procures many systems that are interoperable among platforms. Among these are sonobuoys, sensor nets, and towed array sonars. The navy canceled procurement funds for the Low Cost Sonobuoy Program for fiscal year 1990 because of technical deficiencies, but has provided research funds to improve the system's accuracy. Contractors involved in research include Hermes Electronics, Magnavox, Sippican, and Spartan. Production is planned for 1994 for the enhanced system. Procurement of other sonobuoys continues. Magnavox was awarded $7 million for 42,552 AN/SSQ-57B sonobuoys and 42,552 LAU-126/A launcher containers in early 1989. In addition, the SQQ-62 Directional Command-Activated Sonobuoy (DICASS) is undergoing an upgrade program to improve its detection range. The navy bought 15,026 DICASS systems in fiscal year 1989 for a total cost of $23 million.

The Sound Surveillance System (SOSUS), a fixed network of sensors on the ocean floor, has been deployed since the 1950s. The navy will spend $30 million in fiscal year 1989 to improve the system, and has requested $21 million in fiscal year 1990 and $39 million in fiscal year 1991 for the same purpose. The upgrade program, the Fixed Distribution System, could cost as much as $7 billion. It will use the latest signal processing techniques and fiber-optic technology. The navy expects to award two contracts, each worth $10 million, this year. Four teams have lined up to bid, led by AT&T, General Electric, Hughes, and IBM. One team will be chosen to pursue full-scale engineering development.

Procurement of towed-array sonars ranges from simple to sophisticated systems. Martin Marietta won a contract in February 1989 for 20 towed-array sonars; the $12 million contract specified deliveries from October 1990 through 1993 with an option for an additional 49 sonars at a price of $20 million. Sachse introduced the Sea Search Mk 5 towed underwater search and locate system in March 1989. The Sea Search Mk 5 includes the vehicle, topside control and display consoles, integrated navigation system, and deployment unit.

Sonars and Radars

The navy purchases a wide variety of sonars and radars, including multifunction systems like the SPY-1, and mission-specific systems like fire-control radars and mine-warfare sonars. Key programs are discussed below.

SPY-1 Multifunction Radars. Used in the Aegis air defense system, the SPY-1 is an electronically scanned fixed array radar that operates in the E-F band and is controlled by the UYK-7 computer. The SPY-1B version is deployed on AEGIS cruisers beginning with the CG-59 Princeton; the SPY-1 D will be deployed on the DDG-51 Arleigh Burke class destroyer. RCA manufactures the antenna, Raytheon manufactures the transmitter, and Computer Sciences Corporation provides the software.

Mine Warfare Sonars. Two sonar systems are presently being procured for navy mine warfare ships: the SQQ-30 and SQQ-32. The SQQ-30, comprising a search sonar and a classification sonar, is produced by General Electric and is fitted to

© 1989 Dataquest Incorporated November

MSM-1 Avenger class minehunting ships. The SQQ-32 began initial production in March 1989 when Raytheon won a $47 million contract. Raytheon will produce the detection sonar, and Thomson Sintra of France will produce the classification sonar. The SQQ-32 is designed to provide simultaneous search and classification data, as well as independent display, and is scheduled to be installed on Avenger class (MSM-1) and Osprey class (MCM-1) mine countermeasure vessels.

Towed Array Sonars. Towed array sonar systems include the Surveillance Towed Array Sensor System (SURTASS) and the Tactical Towed Array Sonar (TACTAS). SURTASS was deployed in 1984 as a successor to the AN/BQR-15 Towed Array Surveillance System, and towed by slow, small surface ships. For fiscal years 1990 and 1991, the navy requested about $160 million to procure the specialized T-AGOS ships that tow SURTASS. TACTAS is also for surface ship use. TACTAS is used for passive detection and classification of submarines. The SQR-19 is currently in full-scale production and has been installed on Spruance destroyers since 1987. This sonar is slated for use on all major ships built since 1970.

Air and Surface Search Radars. The navy procures at least 10 different air and surface search and surveillance radars at present. Among these, the Hughes SPS-52C three-dimensional radar, which provides target position in range, bearing, and elevation, is currently operational on LHA-1 ships and some guided missile destroyers. The SPS-52C is also scheduled to be deployed on the LHD-1 amphibious assault ship. The SPS-55 radar is currently in production and installed on DD-963, CGN-41, and CGN-47 ships. Manufactured by ISC Cardion, the SPS-55 will replace the older SPS-10 on destroyers and larger ships. The SPS-67, which operates in the C-band, will complement the SPS-55, which operates in the X-band. The SPS-67 is manufactured by Norden and United Technologies. The navy would like 220 systems in total, approximately half of which have already been delivered. In fiscal year 1989, the navy has bought 28 SPS-67 radars, at a total cost of $7 million. Another new system is the SPS-65 (V), which is a pulse Doppler air search and target acquisition radar operating in the D-band. The SPS-65 (V), manufactured by Westinghouse, is intended for use on ships that are not fitted with the navy Tactical Data System; the SPS-65 (V) includes an advanced radar/weapons interface system.

Fire Control Radars. As in search and surveillance radars, the navy procures a number of fire control radars, which differ in range, bandwidth use, and sophistication. Westinghouse produces the W-120 and W-160 Fire Control Radars: the W-120 operates in the I/J band and is used for small ship gunfire control, and the W-160 is a multimode, pulse Doppler, X-band radar for ranges between 45 and 90 kilometers. The W-160 includes the antenna, the microwave assembly (transmitting and receiving units), and electronic equipment that includes a computer and digital signal processor, among other things.

Hughes produces the FLEXAR Weapon Control. FLEXAR is a next-generation shore and ship weapons control system for short- and medium-range missiles or guns for use against ships, aircraft, or other missiles. The FLEXAR is presently in the test and evaluation stage, although technology developed for the FLEXAR is now being used in the multifunction radar for the Hawk air defense system.

© 1989 Dataquest Incorporated November

The R-76, manufactured by RCA, is presently in production. The R-76 is the principal sensor of the H-930 series of fire-control systems. Operating in the I-band, the R-76 includes a director, transmitter, receiver/signal processor, computer, and servocontroller.

Target Acquisition Radars. Currently, the navy is upgrading the Mk 23 target acquisition radar to improve response time, expand radar coverage, and increase flexibility. The Mk 23 is produced by Hughes and used with Sea Sparrow missiles against a variety of targets. Upgrades include a new computer and a phased array antenna with phase shifters. The Litton AN/UPX-24 (V) Shipborne identification, friend or foe (IFF) system is also in production. The UPX-24 (V) accepts commands from, and provides target reports to, the AEGIS computer. Nineteen systems have been installed on CG-47 Ticonderoga-class cruisers, DDG-51 Arleigh Burke-class destroyers, and the LHD-1. About 10 systems are currently under contract with additional systems proposed. In fiscal year 1989, three Mk 23 systems were procured at a cost of $23 million.

Missile-Launching Systems

The navy uses a variety of missile launching systems, including the Mk 13, Mk 41, and Mk 48. In January 1989, FMC was awarded $87 million for the Mk 13 Mod 4 Guided Missile Launching Systems for FFG 7 class ships; Martin Marietta received an addition of $61 million to its contract for the Mk 41 vertical launching systems for DDG 58, DD 997, and DD 972 ships.

The Mk 41 vertical launching system, first operational in 1986, is a modular design with AN/UYK-20 digital processors used as launch control units. The navy expects to upgrade the Mk 41 with a AN/UYK-44 processor. The Mk 41 is interoperable with the AEGIS, Tomahawk, and Vertical Launch ASROC systems. At present, research is continuing on developing an underwater variant. Martin Marietta is the prime contractor, with FMC chosen as the second source.

Raytheon completed the Comparative Test Program for Mk 48 Guided Missile Vertical Launching System for the NATO Sea Sparrow in March 1989. Raytheon could propose the Mk 48 as a launching system for the LHD-5 Amphibious Assault ship; the contract award for the LHD-5 is expected for fiscal year 1992.

Research and Development

Overview

In general, the navy, like the other services, sees a requirement for increasingly reliable and higher-speed computing power, particularly for air defense and antisubmarine warfare applications. The most important advances in the navy's

 © 1989 Dataquest Incorporated November

R&D program, as cited by navy officials, include software for communications architecture and information processing systems, low-loss fiber-optic cables, improved materials for superconductors, composite materials for structures, and GaAs for integrated circuits. The navy conducted an Advanced Technology Demonstration Program and reported on its areas of research in March 1989. Technologies included advanced fiber-optics, a fiber-optic tethered air weapon, all-optical towed array, fiber-optic tethered torpedo, underseas weapons, unified networks, airborne transient processors, surveillance IRSTS, magnetic and acoustic detection of mines, quiet weapon launch, adaptive monopause countermeasures, and advanced assault amphibian demonstrator technology.

The navy expects future research to include intelligent welding systems, air-surface data fusion, air weapon neural computers, underseas weapons guidance and control, and high-power microwave technology.

Antisubmarine Warfare

The navy spends approximately 25 percent of its R&D budget on antisubmarine warfare, about $2.1 billion annually. Some of the navy's requirements in ASW include self-noise monitoring, synthetic aperture arrays, over-the-horizon targeting, advanced capability torpedo optimization, analysis of oceanographic data, and fire control. Research on underwater surveillance is concentrating on developing integrated acoustic display and wideband acoustic recall software packages.

Specific programs to detect Soviet submarines include the Fixed Distributed System, a new underseas sensor system that will listen at specific locations, or chokepoints, and will supplement the Sound Surveillance System (SOSUS). Four industrial teams made proposals for design of the shore signal information and processing segment of the program: AT&T, General Electric, Hughes, and IBM. The navy plans to award two $10 million contracts for a 20-month design phase, after which one team will be selected for full-scale engineering development. Design of the entire system may cost more than $980 million. The DOD is also funding prototype designs for hydrophones, based on mathematical modeling.

Other programs for detection of Soviet submarines include research into nonacoustic techniques, including magnetic anomaly detectors, wake detection analysis, the use of fiber optics, and the use of blue-green lasers to probe ocean depths. Antisubmarine warfare conducted by surface ships is depending increasingly on small ships (less than 1,500 tons). This trend may imply that research funds could be diverted toward ASW methods better suited for smaller ships closer to shore, than for larger, blue-water ships. In that event, one might expect more research into depressed tow arrays and possibly, variable depth sonars.

The navy has come under fire in the first half of this year with respect to its ASW R&D program. At the urging of a Defense Science Board task force, the navy created a "czar" for ASW research and development efforts in March 1989. In that same month, Congress released its assessment of the navy's antisubmarine warfare program, stating that the navy ought to transfer money from air and ship programs to develop new

 © 1989 Dataquest Incorporated November

antisubmarine technologies. Congress also faulted the navy for failing to take into account significant advances by the Soviets in quieting their submarines. These advances call for other than passive sonar detectors, which have been a mainstay of the navy's ASW program. The Advisory Panel on Submarine and Antisubmarine Warfare, composed of former Pentagon research directors, retired naval intelligence directors, and former DARPA directors, also recommended that the navy explore means of submarine propulsion other than nuclear as a way of quieting its own subs. The panel was cautious about recommending budget growth, and repeatedly emphasized that spending money wisely was, in their estimation, most important. The panel did urge predictable funding, however.

A new research effort for an ASW sonobuoy was launched in May 1989; the Advanced Active Sonobuoy will replace the AN/SSQ-62 DICASS in about 10 years' time. Using a lower frequency than DICASS, AAS will have a longer operating life (about three days). Companies that bid for the proposal are: Hermes Electronics, Magnavox, Sippican, and Spartan.

Other Submarine Research

DARPA's submarine research program includes a project on advanced computer systems for command and control for submarines. Four industrial teams participated in the demonstration of prototypes in May 1989. These were led by Dupont and Martin Marietta, General Electric, Lockheed, and McDonnell Douglas. General Electric's proposal, called the Submarine Operational Automation System, included artificial intelligence and neural networking techniques. DARPA will select one or two contractors to continue the program in the summer.

The navy and DARPA also are funding programs in submarine defense. Technologies are explored in the areas of countermeasures, target acquisition, pointing and tracking, sensors, signal processing, submarine design, and quieting techniques. Some of the contractors include Martin Marietta, whose previous contract may be extended by about $10 million.

Kollmorgen won a $4 million contract from DARPA in early 1989 to develop a prototype of the photonic mast. This nonhull-penetrating mast will enable the command center to be positioned forward and integrated with the sonar room, averting potential water damage. In conjunction with the photonic mast, Kollmorgen also is working on an advanced submarine imaging system, with Dowty Maritime Systems (United Kingdom) and Riva Calzoni of Italy. Some of the sensor types under consideration are high-resolution color and monochrome television, infrared and millimeter wave imagers, and microwave sensors. The sensors will be housed in a rotating module mounted on a nonhull-penetrating mast and in off-board devices such as tethered platforms, airborne platforms, and fixed underwater sensors. Integration of sensor data will require signal processing techniques, image enhancement, artificial intelligence, automatic target recognition, and overlaying multiple images. Prototype will take between 15 and 18 months to build, followed by full-scale engineering development, and then production by fiscal year 1992 or 1993. Each system will cost approximately $3 million. Deployment could be as early as 1995 on the SSN 688 Los Angeles and SSN 21 Seawolf.

© 1989 Dataquest Incorporated November

Electro-Optical Systems. Kollmorgen currently is producing the Model 975 Optronic Director, an electro-optical system designed to acquire and track surface or air targets for surveillance and/or direct the ship's defensive systems. The Optronic Director can automatically track and detect the range of targets using a television system or infrared target pointer. Kollmorgen is also producing the Model 985 Optical Director, similar to the Model 975 with respect to its functions, but different in technology.

Vehicles and Weapons

Overview

Systems included in this category are powered and motorized vehicles, torpedoes, artillery, and crew-served weapons. These types of equipment, of course, tend to have relatively small electronic content. Increasingly, the services are attempting to integrate different weapons to make a combined arms approach on the tactical battlefield feasible. A key element of successful combined arms is the coordination and integration of fire control, which requires that diverse types of weapons be made compatible. One example of this trend in current procurement is the army's effort to coordinate several gun and missile development programs as part of the Forward Area Air Defense System. Another trend in vehicle and weapon procurement is toward greater commonality, apparent in the army's plan to procure a common chassis for families of vehicles. The army's artillery procurement all will probably reflect greater commonality, as it is guided by the Fire Support Master Plan, approved in September 1988 by Army Chief of Staff, General Carl Vuono. The plan calls for an increase of $7 billion in the army's spending for artillery, including the accelerated deployment of a new self-propelled Howitzer, the Multiple Launch Rocket System, Sense and Destroy Armor Munition, and the development of the Advanced Field Artillery System, among other things.

Table 8 shows total program acquisition costs, including R&D spending and procurement, for key vehicles and weapons.

Forward Area Air Defense

The army could spend as much as $8.8 billion on research, development, and procurement of systems in the Forward Area Air Defense (FAAD) program over the next five years. Some of the elements of the FAAD include fiber-optic guided missiles, the air defense antitank system, the pedestal-mounted Stinger air defense missile, a new command, control, communications, and intelligence system, and a program to upgrade guns and ammunition of M-1 tanks and Bradley Fighting Vehicles. This last program, called the FAAD Ground-Based System, is scheduled to begin in fiscal year 1990 with an army request for $48 million for both fiscal years 1990 and 1991.

© 1989 Dataquest Incorporated November

Table 8

Estimated Program Acquisition Costs for Vehicles and Weapons
(Millions of Dollars)

System	Planned FY 1989	Proposed FY 1990	FY 1991
New Procurement			
Forward Area Air Defense	------	$ 954	$1,033
Medium Tactical Vehicles	$ 25	$ 18	$ 86
Palletized Load System	$ 29	$ 52	$ 253
Mk 50 Barracuda Torpedo	$ 338	$ 336	$ 345
Continuing Procurement			
M-1A1 Tank	$1,758	$1,964	$2,000
M-88A2 Recovery Vehicle	$ 109	------	------
Mk 48 ADCAP Torpedo	$ 517	$ 545	$ 474
Bradley Fighting Vehicle	$ 705	$ 659	$ 699
High Mobility MWV	$ 162	$ 223	$ 253
Bushmaster Gun	$ 30	$ 19	$ 23
Mk 15 Phalanx Air Defense Gun	$ 24	$ 65	$ 74
Mobile Armed Reconnaisance Vehicle	$ 18	------	$ 26

Source: U.S. Department of Defense

Family of Medium Tactical Vehicles

The army awarded $62 million in October 1988 for prototype development of this family of 2.5- and 5-ton trucks to Stewart and Stevenson Services, Tactical Truck Corp. (a joint venture of GM and BMY) and Teledyne; prototypes will be delivered at the end of 1989. The army plans to procure 644 trucks in fiscal year 1991 at a cost of $78 million. The army's total requirement for the family of medium tactical vehicles is about 150,000; under current plans, about 18,000 trucks would be procured between 1991 and 1995 at a cost of $2 billion.

Palletized Load System

The Palletized Load System, or the Family of Heavy Tactical Vehicles, comprises 16.5-ton tactical trucks with trailers. A key component for the transportation and distribution of supplies and equipment, the army's stated requirement is for 4,334 heavy trucks overall. The army requested 112 units at $43 million for fiscal year 1990 and 789 units at $237 million for fiscal year 1991. Three contractors received contracts for Phase I development of the Palletized Load System: General Motors was awarded a

© 1989 Dataquest Incorporated November

$12 million contract, Oshkosh Truck Co. received $11 million, and PACCAR received $5 million. The winner of the development competition will receive a five-year contract for 3,800 vehicles, 1,600 trailers, and 16,000 flatbeds, to be awarded in April 1990.

Mk 50 Barracuda Advanced Lightweight Torpedo

Initial operational tests were completed early this year, but due to design problems, the Mk 50 is not slated for introduction into the inventory until early 1991. A successor to the Mk 46 Mod 5 lightweight torpedo, the Mk 50 is designed to be launched from either ships or aircraft against submarines. The prime contractor is Honeywell; Westinghouse won an $8 million contract in 1987 for second-source production. The Westinghouse team includes Martin Marietta and Argo Tech Corporation (formerly TRW). The navy plans to procure 140 Mk 50 torpedos in fiscal year 1989, 200 in fiscal year 1990, and 270 in fiscal year 1991, at a total cost of $795 million. U.S. procurement of the Mk 50 can be expected to continue well into the next century. Sales overseas also are likely to be extensive.

M1 Abrams Tanks

The M1 program is one of the largest weapon procurement programs at almost $1.5 billion per year. Block 1 tanks, or M1A1s, are in production, and Block II upgrades, the M1A2, are in the development stage. The Abrams, which replaces the M60 series of tanks, is manufactured by General Dynamics. The M1A2 will feature an improved 120mm cannon, a nuclear-biological-chemical overpressure system, a Texas Instruments' Commander's Independent Thermal Viewer, an improved carbon dioxide laser rangefinder, and an internal databus to connect electronic sensors and control systems. Upgrades have been subject to a $300,000 per tank cost limit, but it appears unlikely that this goal will be met. M1A2s could cost as much as $3 million each when they are procured beginning in 1992; General Dynamics expects to manufacture between 2,000 and 3,000 tanks.

General Dynamics awarded a 31-month, $12 million contract in early 1989 to Texas Instruments to develop the commander's thermal viewer for the M1. Competitors included Hughes, Kollmorgen, and Kollsman. The new viewer should allow a 360-degree field of view and the capability to search for targets at night and in poor visibility conditions. The thermal viewer could bring as much as $500 million to Texas Instruments if options for all 4,200 systems are exercised.

The army requested 448 M1A1s for fiscal year 1990 and 261 in fiscal year 1991. The marine corps requested 155 Abrams tanks in fiscal year 1990 at $527 million and 255 in fiscal year 1991 at $655 million. This level of 500 to 600 tanks represents a significant stretchout of the M1 program from the mid-1980s, when the army procured about 840 tanks per year. A decision on whether to proceed with the Block III upgrade is expected to be made in 1991. The Abrams program will extend well into the next century and will find buyers in many foreign nations.

 © 1989 Dataquest Incorporated November

M-88A2 Recovery Vehicle

M-88s are used to recover tracked vehicles from the battlefield and perform minor repairs. Fiscal year 1990 and 1991 production of the M-88A2, an improved version of the M-88A1 armored combat support vehicle, was canceled by the army in the Cheney budget cuts. BMY was awarded a $4 million contract in December 1988 for prototype construction of the next-generation tank recovery vehicle. The total program could be worth as much as $1 billion. The army hoped to procure 78 M-88A2s for fiscal year 1991 at a cost of $90 million, but the program encountered technical problems, causing the army to announce in April 1989 that it would not release fiscal year 1988 funds for long-lead items (about $24 million) to BMY, the prime contractor. The program's five-year history of technical problems may defeat BMY's attempts to reinstate it.

Mk 48 Mod 5 ADCAP Torpedo

The Mk 48 ADCAP torpedo completed its operational tests and evaluation in 1988 and entered full production in 1989. The Mk 48 is a submarine-launched, conventionally armed, wire-guided acoustic homing torpedo, designed to attack submarines or surface ships. The Advanced Capability program's objective was to increase speed, depth, and range of the torpedo. ADCAP incorporates upgraded acoustics and electronics, increased fuel delivery rate, and improved surface target capabilities. The prime contractor for the Mk 48 ADCAP is Hughes Aircraft; Gould was named as a second source in 1986. Research and development are expected to continue into fiscal year 1990 and 1991 at an annual rate of about $45 million to $60 million. Procurement of the Mk 48 Mod 5 torpedo could total several hundred. Future upgrades may include antiship homing features and greater diving depth.

M-2 Bradley Fighting Vehicles

Bradley Fighting Vehicles are fully tracked, lightly armored vehicles used to accomplish reconnaissance and security missions. The Bradley uses a 25mm automatic gun as its primary armament and a 7.62mm machine gun and TOW missile as its secondary armament. FMC Corporation is the prime contractor. The army request for fiscal year 1990 and fiscal year 1991 was 600 each year, at a total cost of about $1.4 billion.

High Mobility Multipurpose Wheeled Vehicle (HMMWV)

This contemporary version of the army's jeep can be used as a TOW and Stinger weapons carrier, as a command and control vehicle, as a forward observer, forward air controller, or to protect rear areas. The army has requested funds to procure more than 8,500 HMMWVs in fiscal year 1990 and more than 9,400 in fiscal year 1991, and awarded $1.6 billion to LTV's AM General for 69,077 Hummers in January 1989.

The HMMWV can be equipped with the Lightweight LTACFIRE fire control system, provided by Litton, and with Mobile Subscriber Equipement, built by GTE.

© 1989 Dataquest Incorporated November

Bushmaster

The Bushmaster is a 25mm rapid-fire weapon system for use on vehicles. As the primary weapon for the Bradley Fighting Vehicle, the Bushmaster's task is to defeat enemy reconnaissance and mechanized combat vehicles, personnel, and unarmored targets. The army requested funds to procure 560 systems in fiscal year 1990, and 480 systems in fiscal year 1991. Hughes Helicopter Corporation is the prime contractor for the Bushmaster.

Mk 15 Phalanx

The navy's Mk 15 Phalanx Close-in Weapon System is a lightweight, ship-mounted, rapid-fire gun system. The Mk 15 carries out search detection, threat evaluation, tracking, firing, and kill assessment, and is expected to be used as a last-ditch defense against cruise missiles and other antiship missiles. The Mk 15 Phalanx comprises six parts: the radar-servo assembly, the gun assembly, the mount and train drive platform, the barbette equipment assembly, the electronics enclosure, and the control panel; these are supported by a digital computer. Currently in full production, total orders for the Mk 15 number about 1,000. Prime contractors are General Dynamics and General Electric.

Mobile Armed Reconnaissance Vehicle

General Motors produces the Light Armored Vehicle chosen for the Mobile Armed Reconnaissance Vehicle. The system will be used by the air force to survey runway damage after enemy attack. The air force did not request procurement funds for fiscal year 1990 but hopes to procure 40 vehicles at a cost of $26 million for fiscal year 1991.

Basic Research

Research in vehicles and weapons includes a marine corps request of $58 million for research on new technologies for assault vehicles for fiscal year 1990, and an army request of $157 million in fiscal year 1990 and 1991 funds for concept exploration and initiation of a program to demonstrate a common heavy protection-level chassis for multiple combat vehicle system applications. This research program is expected to lead to development of a Block III Abrams tank, the combat mobility vehicle, a new self-propelled howitzer, and an improved Bradley fighting vehicle.

COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE

Overview

Although the Reagan Administration greatly elevated command, control, communications, and intelligence (C3I) as a national security priority, budget growth has been relatively modest in these categories during the Reagan years. Spending on C3I will grow even more slowly over the next few years, but no major C3I programs were cut during Mr. Cheney's review of the fiscal year 1990 and 1991 budget requests. Despite the limits on growth, C3I programs offer significant opportunities for defense electronics firms.

Defense-wide command, control, and communications support systems will grow over the next few years, as tactical C3 diminishes in importance. Defense-wide programs cut across all services and include the Joint Tactical Communications Program (TRI-TAC) and the World Wide Military Command and Control Information System, among other things. Strategic programs include systems like the Over-the-Horizon radar, and modernization of the North American Air Defense command center; tactical C3I programs include Mobile Subscriber Equipment, and a variety of air- and ground-based radio systems.

Part of the explanation for this trend lies in the increasing use of satellites for C3I. Indeed, an overlap exists between space and C3I programs, such as the MILSTAR satellite program (see the earlier section, "Military Space," for a description). Increasingly, efforts will be made to link existing ground-based and air-based communications systems with satellites. Other areas of technological emphasis are survivability, greater integration, and interoperability.

Programs can be divided into three major categories: warning and attack assessment, command and decision, and strategic communications. Under warning and attack assessment, the DOD is funding programs to increase the survivability of early warning satellites, mobile ground terminals, advanced warning concepts (particularly in space), and modification of the Ballistic Missile Early Warning System (BMEWS). In command and decision, funding covers hardened airborne command and control posts, mobile command centers, and improved survivability of fixed command centers. In strategic communications, the following programs are being funded: GWEN, New ECX aircraft for TACAMO, MILSTAR, LF/VLF receivers on bombers, DSCS-III satellites, ELF communication with submarines and FLTSATCOM (see the earlier section entitled "Space").

Systems Development and Procurement

The major command, control, communications, and intelligence programs currently in systems development and procurement are described below.

Tactical Systems

Congress requested three reports last year from the army on the progress of tactical communications programs because the fielding of the Mobile Subscriber Equipment, Single Channel Ground and Airborne Radio Systems, and the Army Data Distribution System radios were not coordinated with the army's Tactical Command and Control System (ATCCS) program. These three systems are critical to information flow in the ATCCS. Delays in tactical programs are likely as budget cuts are implemented.

© 1989 Dataquest Incorporated November

Mobile Subscriber Equipment (MSE). The Mobile Subscriber Equipment System will provide the army with mobile voice, high-volume data, and facsimile communications capabilities. MSE must be compatible with a wide range of communications equipment, including SINCGARS, JTIDS, and TRI-TAC. It will be used in conjunction with army and NATO satellites.

The "backbone" of the MSE is message switching and relay equipment; subscriber equipment includes the Digital Subscriber Voice Terminal and Digital Non-Secure Voice Terminal field telephones, the Line-Of-Sight AN/TRC-190 radio, and the AN/UXC-7 facsimile machine. The prime contractor is GTE. In December 1988, the army awarded GTE a high-volume production option contract worth $948 million, covering the fourth year of a six-year program. Subcontractors include the following:

- AM General
- ATACS Corp.
- British Marconi
- Ericsson Radar
- Honeywell
- Magnavox
- Raytheon
- Thomson-CSF
- A.R.E. Manufacturing
- Bendix
- Cubic Communications
- Genisco
- Litton
- Motorola
- RCA
- Unisys

Total U.S. content of the MSE is about 75 percent; French companies are building the system control center, the AN/VRC-97 mobile subscriber radio telephone terminal, and the radio access unit. In addition, French companies are collaborating with U.S. companies on the node center switch and the large extension node switch. British, Swedish, and Canadian companies are also participating.

The army has spent more than $2 billion on MSE thus far; estimates of the total cost of the program range as high as $4.7 billion through 1993. A total of 50 division systems was planned, but a recent cut of $277 million in planned fiscal year 1991 appropriations will likely reduce that number to 48.

Army Data Distribution System (ADDS). The ADDS is a control station that performs data management functions. The ADDS will provide secure, jam-resistant data communications, as well as position/location, navigation, and identification capabilities to support the army automated battlefield. Fiscal year 1990 funds were requested for low-rate initial production equipment; fiscal year 1991 and fiscal year 1992 funds are scheduled for full-scale production. The army spent about $75 million on the system in fiscal year 1989. Total cost of the program is expected to run about $3.4 billion for 140 systems.

© 1989 Dataquest Incorporated November

Single Channel Ground and Airborne Radio Systems (SINCGARS). SINCGARS are frequency-hopping VHF-FM radios planned to replace the AN/VRC-12, AN/PRC-77, and the AN/ARC-54-131 family of radios. SINCGARS will be the army's main combat radio and the primary means of communicating with infantry, armor, airborne, and artillery units. ITT, the prime contractor, has received a contract estimated at about $316 million, including funds for production and introduction of the system into operational use. A team of General Dynamics and Tadiran (Israel) was chosen in mid-1988 as a second source for the radios. The General Dynamics team will build a different, but interoperable, radio that will match the "form, fit, and function" of the original model.

SINCGARS are available in six versions for ground operations and three for airborne systems. By 1990, the second generation of SINCGARS with an internal communications security subsystem will be available. In the meanwhile, first-generation radios remain in production. The program was expected to cost as much as $5.2 billion for approximately 250,000 SINCGARS radios for the army and marines, and $500 million for second-source procurement of close to 30,000 radios. Cuts in the SINCGARS program of $75 million in fiscal years 1990 and 1991 will delay completion of the program.

Army Tactical Command and Control System (ATCCS). ATCCS has experienced considerable delays throughout the 1980s but its major components are now being prepared to enter production in the 1990s. The system is composed of five elements: the Maneuver Control System (MCS); the Forward Area Air Defense Command, Control, and Intelligence System (FAADC2I); the Advanced Field Artillery Tactical Data System (AFATDS); the All-Source Analysis System (ASAS); and the Combat Service Support Control System (CSSCS). The total budget for these elements is slightly more than $7 billion. The army requested a total of $333 million in fiscal year 1990, and $395 million in fiscal year 1991. Funding for the ground-based sensor for FAAD command and control was cut by $46 million in the fiscal year 1990 request. This will result in a delay of one year; other delays can be expected.

Research and development funds for integration of the ATCCS total $27 million. Although these funds were cut from the fiscal year 1990 and fiscal year 1991 requests, they were restored in Mr. Cheney's amended budget. Competing contractors included Contel Federal Systems and RDA; General Electric and Lockheed; McDonnell Douglas and SAIC; Hughes, Electronic Data Systems, and Systems Research and Applications Corp.; Singer/Librascope, Syscon, and Engineering and Professional Services; and Planning Research Corporation. Planning Research Corporation's subcontractors include Advanced Systems Technology, Booz-Allen Hamilton, BTG, Essex, and IBM. The $100 million systems engineering and integration contract was to be awarded in April 1989, but was delayed until the fall. Block A of the contract will continue through 1991, during which the contractor will run the Initial Force Level Control Capability software with the AFATDS, FAADC2I, and CSSCS. Block B of the contract will last from 1992 to 1996, during which the remainder of the components of ATCCS will be integrated, with the exception of the Common Hardware System computers being developed by Miltope.

© 1989 Dataquest Incorporated November

ATCCS will connect the five components in a number of ways: using interoperable, off-the-shelf microcomputers; and information channels such as the Mobile Subscriber Equipment, SINCGARS, and JTIDS. Miltope Corporation received an initial $38 million contract last year to deliver equipment for evaluation under the Command Hardware and Software Program for ATCCS. The total program value could be as high as $600 million; the army wants to purchase approximately 27,000 microcomputers. A total of $50 million was requested in the fiscal year 1990 and fiscal year 1991 budgets. Miltope teamed with the following subcontractors:

Firm	Subsystem
Analytics	Support services, training
Ford Aerospace	Software engineering
GTE	Adaptive Programmable Interface Unit
Hewlett-Packard	HP 9000 Series 300 computer
Tadiran	Hand-held terminal

The Bobcat, a ruggedized, 32-bit computer, will be based on the HP 9000 Series 300, which uses a Motorola 68020 microprocessor and 68881 floating-point coprocessors.

The Maneuver Control System (MCS) is the first component of ATCCS expected to be fielded, in fiscal year 1992. It will be followed by AFATDS at the end of 1992, and by FAADC2I in 1993 and CSSCS in 1994. The MCS will provide automated collection, coordination, and dissemination of information at the corps, division, brigade, and battalion levels. Procurement of common computer hardware for the Maneuver Control system will be delayed by two years due to funding cuts of about $20 million in fiscal year 1991. Lockheed Missiles and Space Company demonstrated the first phase of the maneuver planning systems under a three-year, $19 million contract for the army and DARPA. The program is aimed at demonstrating the capability of an expert system to speed mission planning.

The Advanced Field Artillery Tactical Data System (AFATDS), a computerized decision aid, is among the more interesting components of the army's tactical command system. It will provide field artillery units with fire control, target analysis, and intelligence. A successor to the tactical Fire Direction System (TACFIRE), the system will be used by fire support teams, maneuver commanders, operations, logistic staff, and intelligence officers. Funding was cut for fiscal year 1989 by the Congress, after delays of almost three years and serious problems in software development. While the prognosis is not as bright for AFATDS as for other components of the ATCCS, the army plans to award Magnavox, the prime contractor, a new contract in December 1989 after a Defense Acquisition Board review.

© 1989 Dataquest Incorporated November

FAADC2I will track aircraft and provide data to air defense units. The army requested fewer dollars for C2I engineering development for the Forward Area Air Defense in fiscal year 1990: $72 million, down from $93 million planned for fiscal year 1989. The Joint Tactical Fusion program involves coordination of the army All-Source Analysis System (ASAS) and the air force Enemy Situation Correlation Element (ENSCE) to analyze target data from all sources on the battlefield and air. Prime contractor is the Jet Propulsion Lab, with Martin Marietta serving as systems integrator. Principal subcontractors include the following:

- American Development Corporation
- BDM International
- Cyberchron Corp.
- Emerson Electric
- GE
- Informatics General
- Mitre Corp.
- United Technologies
- Analytic Inc.
- Boeing Aerospace
- Electrospace Systems Inc.
- Ford Aerospace
- HRB Singer
- McDonnell Douglas
- TRW

The budget for ASAS is $840 million for development and $1.63 billion for procurement of the system. Major army and air force operational tests are scheduled for 1989 and 1990, after which a final procurement decision will be made. A production decision may be made in late 1991 or 1992. Procurement will include a number of nondevelopmental items, including computers, disk drives, video displays, power supplies, and communications equipment.

Information Processing System. The air force is developing a new command and control system for the Military Airlift Command to automate tracking of airlift aircraft and crews worldwide. The air force selected Computer Sciences Corp. in January 1989 to develop the software for the Information Processing System, scheduled to replace the existing manual tracking system for the Military Airlift Command. The current system is composed of a 158-node network, including 42 systems at fixed sites and 116 deployable systems. Competitors for the project included Contel Federal Systems, GTE, and TRW. Computer Sciences will spend two years and $31 million developing software. GTE was awarded a $14 million contract in May 1989 to integrate air force systems with World Wide Military Command and Control Information System, as well as to modernize air force C2 systems and acquire hardware and software.

The air force hopes to deploy the entire Information Processing System by 1994. Computer Sciences has recommended using Digital Equipment Corporation MicroVAX 3 processors to manage data bases and Zenith 248 terminals, although the Electronic Systems Division has not made a final decision. Total value of the contract including hardware is estimated at approximately $111 million.

© 1989 Dataquest Incorporated November

The Information Processing System terminals will be linked to the the Global Decision Support System, which is a series of seven local area networks at the Military Airlift Command's headquarter locations. Digital Equipment Corporation is presently developing a MultiLevel Security system to be used with the Global Decision Support System for $4 million, to be completed in 1991.

HAVE QUICK. The HAVE QUICK is a frequency-hopping, ultrahigh-frequency communications system. Magnavox Electronics Systems was selected as the initial producer of the airborne radio, and already has produced between 12,000 and 15,000 units. Boeing received $68 million to produce an improved version of the HAVE QUICK A-NET system, following a four-year development program. The contract includes 11 shipsets for AWACS aircraft. McDonnell Douglas received $6 million in addition funds to integrate HAVE QUICK and SINCGARS EECM communications systems into F/A-18 aircraft in March 1989.

Tactical Intelligence Information Exchange Subsystem (TACINTEL). The navy issued a request for proposals in the summer of 1989 to upgrade TACINTEL, a system that receives and transmits special intelligence messages. TACINTEL II will be interoperable with the Communications Support System and FltSatCom programs. Full-scale engineering development is expected to begin in fiscal year 1991. TACINTEL II will be installed on ships as well as shore and mobile platforms; the system will use as many as five different radio frequencies for increased flexibility.

Defense-Wide Programs

Defense-wide programs are conducted by the Defense Communications Agency. Two key programs are TRI-TAC and WIS/WAM.

Joint Tactical Communications Program (TRI-TAC). The DOD has been pursuing TRI-TAC for almost 15 years. TRI-TAC provides common, ground-based, tactical digital communications for all the services. These include mobile and transportable systems for voice and data communications. Contractors include General Atronics Corporation, Martin Marietta, and Raytheon. The total program cost is estimated at approximately $2 billion for 555 systems. Fielding of the systems will continue through 1995. As part of the TRI-TAC program, AT&T was awarded a two-year, $23 million contract to supply new fiber-optic cables to connect TRI-TAC and the PATRIOT air defense system. Fibercom supplied modules to convert electronic signals into light, which will pass through the cables, under a $15 million contract with the DOD.

Equipment included in the TRI-TAC system are:

Item	Quantity
AN/TTC-39A nodal control switch	77
AN/TYC-39 message switch	25
AN/TTC-46 large extension switch	7

(Continued)

© 1989 Dataquest Incorporated November

(Continued)

Item	Quantity
AN/TTC-48 small extension switch	243
AN/TRC-138A radio repeater set	206
AN/TRC-173 radio terminal set	256
AN/TRC-174 radio repeater set	242
AN/TRC-175 radio terminal set	70
AN/TRC-170 V2/V3 troposcatter radio	162
AN/TYQ-30 (V) I communications system control element	44
AN/TYQ-31 (V) I communications system control element	70

Worldwide Military Command and Control Information System (WIS). The WIS will provide crisis planning and execution aids to the National Command Authorities and specified and unified commands. When it is completed after 1993, it will replace the World Wide Military Command and Control System hardware and modernize its software. WIS includes local area networks, automated message handling, intelligent workstations, modern processors, data base management, and multilevel security systems. The prime contractor is GTE Government Systems Corporation. The total program cost is estimated at about $2 billion for 35 systems. Program management was transferred from the air force to the Defense Communications Agency (DCA) in 1988. The DCA restructured and renamed the program to accommodate technical and financial difficulties. The new program, called World Wide Military Command and Control System Automatic Data Processing Modernization (WAM), will use about 80 percent of the $115 million requested for both fiscal years 1990 and 1991 to run software on existing computer hardware.

Strategic Programs

Strategic C3I programs are expected to grow through fiscal year 1991 as the Ground Wave Emergency Network begins production and costs grow for NORAD Modernization. Several key programs follow are described below.

Ground Wave Emergency Network (GWEN). The Ground Wave Emergency Network will provide U.S. strategic forces with critical communications despite high-altitude nuclear bursts, by proliferated radio relays using ground wave radio equipment. GWEN, which reached full-scale development in 1988, consists of unmanned low-frequency radio sites hardened against electromagnetic pulses. The system comprises 8 input/output stations, 30 receive-only stations, and 56 tower relay nodes. The prime contractor is RCA, which was awarded $5 million in early 1989 for interim support and data, to be completed in December 1989.

© 1989 Dataquest Incorporated November

Over-the-Horizon Backscatter Radar (OTH-B). The Over-the-Horizon Backscatter Radar will provide wide-area, long-range, all-altitude surveillance of U.S. coasts, bouncing high-frequency waves off the ionosphere to achieve over-the-horizon coverage between 500 and 2,000 miles. The air force successfully demonstrated 180-degree coverage of the OTH-B in Maine in early 1989. The radar previously covered only 120 degrees, in two 60-degree sectors. The Maine receiver uses 28 VAX computers for data and signal processing.

The air force requested $210 million for fiscal year 1990 to procure a second sector of the radar in Alaska, which would offer 120-degree coverage. For fiscal year 1991, the installment of an OTH-B in the central United States is planned. General Electric is the prime contractor.

The navy also began installing the first operational relocatable OTH radar on Amchitka Island in the Aleutians. The radar is scheduled for deployment in the summer of 1989. The relocatable OTH radar, manufactured by Raytheon, is designed to track both ships and aircraft at a range of 1,800 nautical miles, with 60-degree coverage. The navy requested $87 million in fiscal year 1990 and $80 million in fiscal year 1991 funds to purchase two radars.

NORAD Modernization. The NORAD modernization program, already in its sixth year of development, has encountered similar software obstacles faced by other C3I modernization programs. The program to upgrade the Cheyenne Mountain Complex's software and hardware is several years behind schedule and several hundred million dollars over budget. Prime contractors include Ford Aerospace, Logicon, and MITRE.

Among others, the NORAD program includes modernization of the Space Defense Operations Center (SPADOC), which reportedly can monitor up to 10,000 manmade objects in space. Ford Aerospace is the prime contractor for the upgrade, IBM will supply computer hardware, and MITRE will provide engineering support. SPADOC will be eight years overdue by the time it is deployed; estimates of the cost of development have increased from $290 million to $347 million. Another program included in the NORAD modernization is the Communications System Segment Replacement (CSSR). GTE is the prime contractor for this program, which is running six years behind schedule and already $60 million over budget.

The GAO has recommended halting Block B of the NORAD modernization. Block A, in operation but not up to speed, automated the space warning and assessment center. Blocks B and C were to upgrade the space surveillance capability. Block B of the $200 million upgrade program was expected to be completed by the end of 1989, but the air force is still in the process of negotiating with Ford Aerospace on IBM computers; an evaluation is expected late in the summer.

Intelligence Data Handling System. Planning Research Corporation was awarded a two-year, $9 million contract to continue development of the Intelligence Data Handling System for the air force's Strategic Air Command. Planning Research will develop applications, a data base, and a network interface, as well as system software. The Intelligence Data Handling System will provide SAC commanders with critical intelligence data.

 © 1989 Dataquest Incorporated November

COBRA DANE. Early this year, the air force awarded two concept-definition phase contracts for modernizing the COBRA DANE radar system. COBRA DANE collects intelligence data on Soviet ballistic missile tests and supplements the Defense Support Program satellites. The modernization program will replace computers and signal processing equipment. General Electric and Raytheon won $4 million and $3 million contracts, respectively. The concept-definition phase is scheduled to end in September 1989.

Basic Research

Overview

The DOD spends about a third of its C3I funds on research and development—about $7 billion annually. Research funds for C3I are being channelled increasingly toward developing mobile ground units and advanced communication satellites like MILSTAR.

Funding for research in C3I systems is declining as mature systems enter production. The air force's research budget for command, control, communications, and intelligence was cut in half from fiscal year 1989 to fiscal year 1990, from $19 million to $9 million; $9 million was requested for fiscal year 1991. The navy cut $21 million in fiscal year 1990 from its C3I program and $20 million in fiscal year 1991.

Research efforts will focus likely on adaptive systems, advanced test beds and techniques, and expanded simulation using ARPANET and SIMNET. VHSIC technology is key to the speed of communications as are fiber optics, which also enhance survivability in extreme environments. It is likely that funds will be allocated increasingly in the direction of software writing and debugging. Because systems typically have three or four million lines of software code, greater effort will be placed on artificial intelligence and modular software. In addition, the use of natural computer languages and expert systems may aid in overcoming some of the significant software barriers facing C3I.

Wide Area Surveillance, Tracking, and Targeting System (WAST2). The WAST2 global surveillance system is the subject of a two-year study to be completed in 1990. In the preliminary stage, no dates or dollar figures are available. The WAST2 will use computers and sensors to connect existing surveillance systems. DOD officials expect to use fiber-optic links and satellites to connect AWACS, JSTARS, Over-the-Horizon radars, surveillance satellites, and the North Warning System radar for global surveillance purposes. One possible candidate is the Boost Surveillance and Tracking System under the SDI program. The difficulties inherent in such a program, for example, setting protocols for receiving information, have not been ironed out yet.

© 1989 Dataquest Incorporated November

MILITARY COMPUTING TECHNOLOGY

Overview

The Department of Defense played a key role in developing the U.S. computer and semiconductor industries. Although that role has diminished greatly, the DOD remains dependent on information systems for its technological edge. DOD requirements for information systems often lag those in the civilian sector, with exceptions for military-specific qualifications like radiation hardness. DOD procurement of electronics systems and microelectronics devices follow the civilian lead in areas such as general-purpose computers, and advance the state-of-the-art in areas such as optoelectronics and neural networking.

The DOD procures computers for a wide assortment of tasks from specialized battlefield uses to more normal office and laboratory applications. Management information systems have become ubiquitous in all service arms. Computer-aided design, modeling, and other automated tools are used to oversee development of new systems, and for testing and evaluation. Particular emphasis is being placed on programs to develop advanced semiconductors because of their centrality to nearly every modern major weapon system.

The DOD spent $8.3 billion in fiscal years 1988 and 1989 each on automated information systems. Acquisition of such systems is managed by the Major Information Systems Review Council in the Pentagon, which reviews every program of more than $100 million. The DOD is expected to purchase off-the-shelf computer hardware and software costing $1.3 billion in fiscal year 1989, and an additional $4.3 billion on commercial services, including time-sharing on computer systems, leased communications equipment, and operations and maintenance.

Systems Development and Procurement

Overview

The armed forces are turning increasingly to modified versions of civilian computers to fulfill military requirements rather than designing new systems. These nondevelopmental items (NDI) represent the state-of-the art, which is driven more by commercial than military needs, and are less expensive to acquire and operate. Gould Computer Systems estimates that commercial equipment is suitable for 80 to 90 percent of defense applications and costs only 10 to 20 percent as much as a computer developed to military specifications.

Data Processing and Training Systems

In addition to microprocessors in weapon systems and dedicated processors for target acquisition, tracking, and battle management, the U.S. military purchases a substantial number of general-purpose computers. The Air Force Computer Acquisition Center (AFCAC) at Hanscom AFB, Massachusetts, presently manages some $1.7 billion

 © 1989 Dataquest Incorporated November

in computer contracts. Zenith has won four major contracts from the air force to supply microcomputers at a total value of more than $500 million; eventual sales are likely to exceed the face value of the contracts. A 1986 air force contract to buy Zenith Z-248 microcomputers over a three-year period resulted in the sale of all 90,000 computers specified for the full period in the first year of the contract.

Harris also provides general-purpose computers to the air force. Harris Night Hawk computers are a new generation of multiprocessing computers with real-time performance, compatible with industry standards, and Ada programming language. All three models (1200, 3000, 7000) use the Motorola MC 68030 processor, which operates at 25 MHz. More than 100 Night Hawk 1200 super microcomputers were supplied to the air force in early 1989 as part of a Quintron Corp. contract. The Night Hawks will be used to modernize air force simulators in the undergraduate pilot training instrument flight simulator program. The potential value of contracts could be more than $3 million. Night Hawk computers also will be used in aircrew training systems for the C-17 transport aircraft, as part of a $421 million contract from the air force. In early 1989, Harris was awarded a contract from McDonnell Douglas to supply a minimum of 40 Night Hawk 3000 super-microcomputers to be used as weapon system trainers, flight trainers, and cockpit trainers. This is the largest contract yet for hardware using the Ada language.

The armed services also represent a large market for superminicomputers and minisupercomputers. Militarized versions of commercial minicomputers are being developed to cater to the government market. Raytheon has introduced a new line of militarized VAX computers matching the commercial VAX 6200 series produced by Digital Equipment Corporation. A request for proposals was issued in late 1987 for purchases of minicomputers that will be worth some $4.5 billion in the 1990s. Digital Equipment Corporation and Wang chose to forgo bidding, claiming that system specifications favor AT&T and its UNIX operating system.

DARPA contracted NYSER-Net, Inc., in early 1989 to construct a National Networking Testbed, to tie together aerospace, defense, and government research computers. The $7 million fiber-optic network will supplement the current Arpanet. In the area of secure computers, Mesa Technology was awarded a three-year contract in May 1989 to supply Tempest microcomputers to the DOD. The $16 million contract includes a first delivery of 54 systems and 26 spare parts kits. The microcomputers use Intel processors.

Computer Sciences Corp. was chosen by the air force to provide the Military Airlift Command with a command and control information processing system. Computer Sciences, under a $31 million contract, will install both hardware and software worldwide. The potential value of the contract is $111 million over seven years if the air force exercises all options. The system will use the DOD's standard Ada programming language. Electrospace Systems will provide the communications subsystem.

Each service has a number of programs that entail large computer upgrades, as shown in Table 9. Most funding for ADP improvements comes from operations and maintenance accounts or industrial funds.

© 1989 Dataquest Incorporated November

Table 9

ADP Modernization Programs

	Contract Value (Millions of Dollars)
Army	
Standard Depot System	$545
Reserve Component Automation System	$500
CALS/TIMS	$250
Corps of Engineers Automation Plan	$178
Integrated Procurement System	$163
Dept of the army Information Network	N/A
Supercomputers	N/A
Commodity Command Standard System	$ 76
Trans Coordinator Auto C2 Information System	N/A
Theater Auto C2 Information Management System	$ 50
EUCOM Intel Support System	$ 25
Navy	
Engineering Data Management Information and Control System	$200
Personnel and Pay Systems Follow-on	$ 93
DON Office Automation and Communication System	$ 40
Basis and Stations Information System	$300
Shipyard Upgrades--Numerous Programs	N/A
Paperless Ship Programs	N/A
Consolidated Communications System Replacement	N/A
Information Engineering Automated Support Tools	$ 45
Hardware/Software Material Planning Depots	$ 62
ADP Support AIR-41	$ 49
SW Support NALCOMIS	$ 30
Hardware/Software Replacement Casis II	$ 20
Air Force	
AF Command and Control System	$437
AF Capability Assessment Program	$250
SAC Ware Planning System	$242
HQ Replacement Program	$200
Logistics Information Management Support System	$170
Intelligence Data Handling System	$ 80
AF Logistics Modernization Programs	$ 40
Depot Maintenance MIS	$150
Contract Data Management System	$ 30
Pacific Distribution System	$ 30

N/A = Not Available

Source: EIA Ten Year Forecast

© 1989 Dataquest Incorporated November

Embedded Computers

New weapons systems introduced into the force posture create commensurate increases in data processing requirements. The air force Strategic Air Command will need to increase computing capability some 300 percent over the next few years, for instance, as new weapons such as the B-2 bomber and rail-based M-X missile are deployed. The Joint Surveillance and Target Radar System will require advanced airborne computers: Raytheon was awarded a $17 million contract from Grumman in early 1989 to supply 12 militarized DEC VAX Model 860 superminicomputers for the first six Boeing E-6A JSTARS aircraft. If plans for an additional 20 aircraft are carried out, Raytheon could fill orders for $70 million worth of computer equipment.

The introduction of new weapons systems also generates requirements for writing software. General Dynamics and McDonnell Douglas chose Telesoft's VAX/VMS host to develop avionics software for both the Advanced Tactical Aircraft and the Advanced Tactical Fighter—the navy's and air force's primary aircraft development programs.

Software Upgrades

The DOD spends between 6 and 7 percent of its budget on software. The Defense Science Board Task Force on Military Software predicted in 1987 that software costs could climb to $30 billion annually by 1990. To combat the rising costs of software, the Department of Defense has taken several actions. The DOD created the Software Engineering Institute in 1985, which attempts to create less labor-intensive methods of developing software by pressing for industry-wide standards, and encouraging automation and greater interoperability. The DOD also established Ada as the DOD standard programming language, and consolidated three of the five major software programs in 1988. At present, the Defense Acquisition Board Science and Technology Committee is writing a Software Technology Master Plan. The Air Force Communications Command awarded a contract in the fall of 1988 for the development, integration, and support of standard command and control software and specialized software for all major air force commands. The contract value could exceed $100 million. TRW teamed with Harris Corp., Systems Research and Applications Corp., and Input Output Computer Services Inc. to bid on the program.

Electronic Components

The procurement of integrated circuits by the DOD will be streamlined when the services adopt a new method of generic qualification known as the qualified manufacturer's list (QML). The generic military specification Mil-I-38535 will certify manufacturing process and lines instead of individual chips. This will have a critical impact on the certification of application-specific integrated circuits (ASICs).

Very High-Speed Integrated Circuits (VHSIC). The goal of the Very High-Speed Integrated Circuits Program was to develop very large-scale integrated circuits and cause them to be used in military systems. The $1 billion, 10-year program has resulted in faster chips that will be used for real-time processing of images and signals, automatic target recognition, infrared focal plane staring and scanning arrays, and fusion of sensor data.

© 1989 Dataquest Incorporated November

The VHSIC program was conducted in three phases. Phase I resulted in 1.25-micron chips with functional throughput 100 times greater than commercially available integrated circuits, and with operating speeds of about 25 MHz. Phase I contractors included Honeywell, Hughes Aircraft, IBM, Texas Instruments, TRW (teamed with Motorola), and Westinghouse (with National Semiconductor).

The first operational installation of VHSIC was in the F-111D signal transfer unit, replacing 102 integrated circuits with one VHSIC chip. Reliability of the unit increased by a factor of 125; the cost dropped from $24,000 to $2,000. In congressional testimony, acting Deputy Undersecretary of Defense for Research and Advanced Technology George Millburn noted that by 1989, the VHSIC program will complete development of a chip containing components as small as 0.5 microns, yielding an additional 50 to 100 fold increase in signal processing capability over present VHSIC devices. air force VHSIC funding is $44.1 million for fiscal 1989.

Approximately 40 efforts are under way to utilize VHSIC chips in military systems at present, including the Mil-Std-1750A on-board computer, built by Texas Instruments; the AN/APG-70 radar built by Hughes for the F-15; and the AN/UYS-1 Advanced Signal Processor, built by IBM for the navy. The UYS-1 reportedly doubled its sonobouy processing capability with the VHSIC insertion. IBM also delivered the first all-VHSIC common signal processor in July 1988 to the air force. The common signal processor uses Phase I technology, capable of 1.8 billion floating-point operations per second (flops) and adaptable for radar, electronic warfare, commmunications, and many other applications. IBM also received a $14 million full-scale development contract from McDonnell Douglas in early 1989 for VHSIC computers for the F-15. The contract included a $7 million option for initial low-rate production of 20 computers.

In May 1989, Westinghouse delivered the first of six VHSIC Avionics Modular Processors. The Avionics Modular Processors, part of the Pave Pillar advanced modular architecture studies, consist of a Mil Std 1750A processor and external input-ouput modules. One processor weighing 1.2 pounds will replace seven similarly sized components, each weighing 1 pound. The system has four central processing modules that operate at 2 million instructions per second (mips) and two fiber-optic high-speed data bus modules, which transfer data at a rate of 50 mips.

Phase II has produced 0.5-micron chips that increase processing power 1,000 percent. IBM claimed to be the first to produce a functional Phase II chip in May 1988, containing 37,000 logic gates and operating at 100 MHz, four times faster than Phase I chips. Other Phase II contractors include Honeywell and TRW, (Motorola, Westinghouse).

TRW and Motorola demonstrated their Phase II "superchip," the CPUAX, in late 1988. The VHSIC team demonstrated the first of eight macrocells for digital signal processing; the superchip will contain 142 of these macrocells on a 1.5 by 1.7-inch space. Incorporating 4 million devices, the superchip will operate at 200 million flops, the speed of a Cray supercomputer. Other features of the superchip include self-contained spare parts (almost half of the 4 million devices are spares), built-in testing, and the ability to be reconfigured using software.

 © 1989 Dataquest Incorporated November

Honeywell also demonstrated its Phase II chip in early 1989, the PI-Bus interface, which will link avionics modules together. IBM demonstrated its Phase II acoustic beam forming module in March 1989; the module will be used to process sonar signals.

Microelectronics Manufacturing Science and Technology (MMST). Increasing manufacturing yields in microelectronics has been a goal of the semiconductor industry for some time. Yields are most important in the ASIC market, where ICs are customized. This implies a requirement for flexible manufacturing techniques. The MMST program focuses on flexible manufacturing of high-yield and low-volume integrated circuits, including very large scale integrated circuits (VLSI), millimeter-wave monolithic IC (MIMIC), and infrared focal plane arrays. The effort, undertaken by Texas Instruments for the air force and DARPA, will include developing processing equipment for a single wafer at a time, in contrast to the batch processing used today. This requires a significant improvement in yield to be cost-effective. With higher yields, the production of ASIC chips may become more cost-effective for the DOD.

MMST will fund the development of advanced process sensors, process-control expert systems, and an integrated factory-control approach applicable to other fabrication facilities. Production goals include less than 0.5-micron feature sizes, more than 1,000 designs per year, with 800 wafers per month. Cost goals are 10 times less expensive than conventional facilities. Texas Instruments will receive $113 million in the course of five years, sharing the total cost with the government. Funding in fiscal year 1989 was $40 million.

Basic Research

Overview

Defense requirements in military computing technology focus on speed, weight and size, and invulnerability to effects like radiation, and extreme heat and cold. Research conducted by the Department of Defense in military computing spans computer architecture, integrated circuits, optoelectronics, and software. Solutions to defense requirements may lie in one or more of these research areas. For example, increased speed may be achieved through computer architectures like parallel processing, or optoelectronics, or new semiconductor or even superconductor materials.

In computer architecture, research has focused on three areas: parallel processing, neural networks, and artificial intelligence. According to the DOD's Critical Technologies report released in spring 1989, the DOD could spend as much as $90 million on parallel processing, with half that amount from DARPA's budget. In integrated circuits, DOD research will likely move away from exotic materials and applications and place greater emphasis on manufacturing. Optoelectronics will become a key technology for making the most of current IC designs like VHSIC and MIMIC, and could pave the way for all-optical computation in the late 1990s. Software remains a stumbling block in applications and hence is an area of considerable interest to the DOD. Trends indicate increasing use of artificial intelligence to write software and the use of neural networks to circumvent the software problem.

© 1989 Dataquest Incorporated November

In addition to its own research projects, the DOD will continue to build on commercial developments. The most prominent of these is the introduction by Intel of its 80860 "supercomputer on a chip," based on reduced-instruction-set computing (RISC).

The management of some of the Pentagon's biggest electronics projects has been shifted from the DOD to DARPA. In April 1988, five programs were moved to DARPA: Sematech, MIMIC, infrared focal plane array, and two software programs—the Software Engineering Institute and Joint Software Technology for Adaptive, Reliable Systems. At present, the most visible research program in military computing is DARPA's High-Definition TV, although it is certainly not the largest. The VHSIC program, begun in 1980, is in its final year; the Sematech program, in its second year, is generating less publicity since it has settled down to business.

Computer Architecture

Artificial Intelligence. Artificial intelligence is being employed increasingly for surveillance and target acquisition systems. Radars, optical, and infrared systems must be able to distinguish their targets from ground clutter and other signals, even in the midst of a complex, rapidly changing battlefield environment. The Strategic Computing Program, begun in 1983, is aimed at developing machine intelligence and parallel processing architecture. Using advanced VLSI chips in a multiprocessor system, the program intends to demonstrate performance 1,000 times faster than existing computers, about 10 billion instructions per second. Research has included innovative parallel architecture for symbolic computing applications, advanced microelectronics, and new hardware. Other initiatives are aimed at exploring artificial intelligence for military systems, such as the development of the Martin Marietta autonomous unmanned vehicle. The pilot associate program applies artificial intelligence, advanced sensors and a voice interface to the cockpit, creating an artificial "copilot." Artificial intelligence will also be used increasingly for battle management as a decision tool.

TeraOps Program. In May 1989, DARPA began to sort through proposals for the next phase of the program, which aims to achieve a computer operating speed of one trillion operations per second. Approximately $300 million has been spent already, but the program could run as high as $1 billion if it extends through the mid-1990s. Among other areas, research will target advanced microprocessor technology, three-dimensional chip-packaging techniques, gallium arsenide chips, and optical interconnects.

The Touchstone project, run by the TeraOps project office in DARPA, seeks to develop a processing system capable of 100 billion operations per second, or 2,000 times faster than the Cray 1 supercomputer. Intel received an $8 million contract as part of the program in spring 1989. The Touchstone supercomputer will use Intel's i860 microprocessors. DARPA intends to use up to 2,000 of these microprocessors in a network. Development funds will be used for system software, a high-speed communications network, and advanced packaging technology that will allow the computer to operate in an air-cooled environment, in contrast to the liquid-cooled environments most advanced supercomputers operate in today. Intel expects to spend $20 million of its own on the computer, scheduled to complete the protyping phase in 1991.

 © 1989 Dataquest Incorporated November

Parallel Processing Research. Military systems require extremely fast processing for advanced sensors, avionics, electronic warfare, and fire control systems. Parallel processing methods have been explored as a way of achieving optimal speeds. In addition to high-speed performance, parallel computer architectures also offer a high price-to-performance ratio, modular expandability, and fault tolerance. DARPA has funded research into parallel processing techniques for some time. Among these are five alternative approaches to parallel processing by the following firms: Butterfly-BBN Systems and Technology Corp., Connection Machine-Thinking Machines, Warp-Carnegie-Mellon University, 2D Interconnected Network-California Institute for Technology, and Myrias Computer. DOD-wide funding for parallel processing is approximately $90 million per year.

A parallel processing technique that is neither new nor associated with hardware is the residual number math. Residual number math originated with the Chinese, and although research into applications has been ongoing since the early 1970s, residual number math is being considered only recently as a possible breakthough in computing techniques. Current Boolean (0-1) logic requires carrying numbers in computations. Residual number math, because it represents numbers only in terms of their residue from prime numbers of 2, 3, and 5, does not require the computer to hold a place for remainders. Therefore, numbers can be processed in a parallel fashion, independent of each other. This method could be used to simplify circuit designs without losing speed, or gain speed with existing designs. The most likely applications would be where real-time digital signal processing systems are required, for example, in radar filters or communications receivers, or in space-restricted fault-tolerant systems. MITRE, among others, performs research on residual number math applications for the DOD.

Neural Network Research. Neural networks are a kind of knowledge representation and processing scheme. Based on the biological paradigm for computing, neural networks consist of many processing units (nodes or neurons) that are connected to each other and operate simultaneously, in contrast to the central processing units used in typical digital processors today that calculate in a serial fashion. Neural networks, in contrast to pure parallel processors or expert systems, do not use algorithms or rules for calculating, but rather compare inputs and outputs, developing their own mechanisms for transforming inputs into correct solutions. This process may succeed where digital processing and algorithmic processing have failed, particularly in the fields of pattern and character recognition, speech recognition and synthesis, and robot control. The neural network is able to screen out unnecessary or poor input based on what it has learned from human experts.

This "automatic learning" frees human programmers from many of the fine details that make software development so labor-intensive. In addition, neural networks exhibit noise tolerance and automatic generalization properties, both of which make neural networks ideal for intelligence monitoring. Other applications for neural networks include radar, sonar, and electronic warfare signal identification, image compression, adaptive systems such as flight and manufacturing control, and speech recognition, among others.

© 1989 Dataquest Incorporated November

At present, existing neural networks consist of a software neural net transposed onto a conventional parallel processor. However, hardware neural nets are the focus of DARPA research. In November 1988, DARPA began a $33 million, 17-month initiative to "advance neural network theory, determine its advantages, and develop advanced hardware technology." Four types of neural networks currently are being researched. These are spatial situation recognizer, missing parts reconstruction model, time-line recognition model, and a combination of the previous three. Rome Air Development Center has funded the first type of neural network, and the navy has awarded funding to AT&T for the Aspen project to develop a neural network for speech recognition. Lincoln Laboratory has been working on a DARPA-funded project in automatic target recognition. In spring 1989, the air force selected Martin Marietta to develop two robotic testbeds over the next three years for neural networking.

Other ongoing neural network projects include research at the Jet Propulsion Lab into an analog-digital hybrid neurocomputer, and TRW's Mark III Neural Network. The Jet Propulsion Lab project uses high-density random access memory (RAM) to store information, and analog "neurons," or processors. TRW has designed the Mark III as a coprocessor for the VAX/VMS. The Mark III will implement networks of up to 65,000 neurons, with 1.1 million interconnects, and speeds 25 times greater than that of a MicroVAX II. The Naval Research Lab is currently working on a sixth-generation computer, which will incorporate 100,000 neural network nodes, optical computing, and superconducters. The goal of the program is a processing speed of 10 billion flops.

Integrated Circuits

DOD research in integrated circuits ranges from developing advanced compound semiconductor materials to manufacturing processes such as X-ray lithography. Projected funding levels for electronic devices are shown in Table 10. As the table indicates, the DOD funding is heavily weighted toward advanced development of integrated circuits rather than research or exploratory development. This is explained partly by the new Semiconductor Manufacturing Technology program, which is devoted solely to manufacturing techniques.

The DOD breaks down semiconductor-related funding into five basic areas: materials, manufacturing, test and assembly, design, and applications. In 1988, the DOD spent about $440 million in semiconductor-related research. About half that amount was spent in the applications area of semiconductor research.

© 1989 Dataquest Incorporated November

Table 10

Estimated Projected Electronic Device Funding by Budget Category
(Millions of Dollars)

Budget Category	Planned FY 1989	Projected FY 1990	FY 1991	FY 1992	FY 1993	FY 1994
Research (6.1)	$ 85	$ 89	$ 96	$104	$104	$104
Exploratory Development (6.2)	$ 77	$ 90	$110	$121	$121	$121
Advanced Development (6.3)*	$247	$230	$228	$238	$142	$146
Other (7.2, 7.8)**	$ 44	$ 96	$101	$105	$110	$115

Notes: *Includes $100 million for Sematech, ending in fiscal year 1992
**Includes Infra Red Focal Plane Array program.
FY 1989 was funded at $9 million

Source: Computer and Electronics Technology Office, OSD

In the basic research category, about 40 percent of the funds are channelled into applications and 25 percent in test and assembly; the remainder of the funds are divided almost equally among design, manufacturing, and materials subcategories. The same breakdown of funding is true for exploratory development. Some of the projects funded in exploratory development include night vision, systems support technology, avionics, command, control, and communications, and materials and electronics technology. In the advanced development category, the breakdown of funding varies somewhat. Half of all funding is devoted to applications, and half to design and manufacturing within the following program elements: advanced electron devices, advanced avionics, and advanced command, control, and communications. The VHSIC program allocated funds about equally to applications, test and assembly, and manufacturing. The MIMIC program uses approximately 50 percent of its funds for applications, 20 percent for test and assembly, and the remainder split between design and manufacturing.

Microprocessors. RISC processors are making headway in the commercial market, and the DOD appears to be taking advantage of this. Texas Instruments demonstrated a 32-bit single chip RISC microprocessor in January 1989, capable of 100-MHz operating speed, and incorporating 12,900 gate circuits in GaAs. TI's goal was 200 MHz by April 1989 and 200 mips by 1991. TI also demonstrated a 32-bit CMOS microprocessor with 40-MHz operating speed with a graphic system processor. The air force will use this chip in ATF radar displays, and IR seekers in the AGM-130 missile.

© 1989 Dataquest Incorporated November

McDonnell Douglas demonstrated a 32-bit RISC processor in summer 1988, operating at 60 MHz with 21,606 transistors. McDonnell Douglas is currently working on a single chip that operates at a rate of one million mips.

The DOD also has awarded contracts for high-performance, radiation-hardened 32-bit data and signal processors for space and airborne applications. Phase I contracts were awarded to Honeywell, IBM, TRW, and Unisys. TRW is teamed with McDonnell Douglas for development of the RH32 under a 14-month, $2 million contract. Phase II contractors will be chosen in October 1989 to manufacture and test the microprocessor as well as produce an advanced development model. The RH32 will be based on RISC technology, with emphasis on fault tolerance and reliability. Phase II of the program will last 22 months.

Millimeter Wave and Microwave Monolithic Integrated Circuits (MIMIC). A growing number of military systems depend on sophisticated sensors for their operation, but analog circuitry for such sensors continues to be very expensive. The MIMIC program, launched in 1986, is aimed at reducing the cost of these components, making advanced sensor technology more widely available and affordable than ever before. The means for this improvement is monolithic solid-state technology, using exotic materials such as gallium arsenide. In addition to operating at higher frequencies (1 to 300 GHz), gallium arsenide offers the advantages of greater radiation hardness than silicon, extremely low-noise signal amplification, and wide temperature operating ranges.

Commercial demonstrations of MIMIC technology already have been made on a small scale, beginning in 1974 with Plessey's demonstration of the first GaAs MIMIC chip. The Microwave/Millimeter Wave Integrated Circuit (MIMIC) Program could mobilize the U.S. electronics industry behind this effort. Industry observers predict that individual defense programs could require as many as 200,000 GaAs chips per month; the entire U.S. industry produced only 300,000 GaAs chips in 1987.

An integral part of the MIMIC program is to create faster, less expensive tools for RF circuit design. The TRW MIMIC team is developing expert-based software to cut the design and layout time by as much as 97 percent—from four weeks to two hours. Libraries of circuit designs will be stored to guide engineers in developing new chips.

The program has been divided into four phases. Phase 0, the initial study phase, was completed in 1988, and involved 16 teams exploring a wide range of fabrication technologies for gallium arsenide. Teams that have received major ($750K to $1 million) phase 0 contracts are as follows:

Army	Navy	Air Force
Eaton	Allied Bendix	Harris
ITT	Ford	Hughes
Martin Marietta	Raytheon	Sperry
TRW	Sanders (Lockheed)	Westinghouse

© 1989 Dataquest Incorporated November

Like VHSIC, MIMIC will have broad application in a number of military systems, as shown in Table 11. Electronic warfare systems engineers are looking at GaAs monolithic microwave integrated circuits particularly for their wider bandwidth capability, higher frequencies, and multifunction capability. Additionally, GaAs MIMICs offer better performance, functional integration, reduced system size and weight, and cost-effective production. Part of the success of the MIMIC program has been its active pursuit of applications for MIMIC technology.

Phase 1, with a three-year planned duration, will culminate in demonstrations of MIMIC hardware in an operational environment. Phase I tasks include material and technology development; design, fabrication, and demonstration of modules; development of computer-aided design tools; identification of affordability barriers; and system brass-board demonstrations. Second sources will be selected for all components in this phase.

Another three-year phase (Phase 2) will continue technological improvements in MIMIC, perhaps using more exotic materials, with additional technology demonstrations. Phase 3 will run concurrently with Phases 1 and 2 of the program. Its activities will center on ancillary research, including computer-aided circuit design and new testing approaches.

Table 11

MIMIC Applications

Contractor	System Type	Army	Navy	Air Force
Allied-Bendix	Communication Radar	Mark XV Fuse Patriot	Mark XV	Mark XV
Ball	Communication Radar	MILSTAR	MILSTAR Airborne Multimode	MILSTAR
Eaton	EW	MEDFLI	ALR-77	ALQ-161
E-Systems	Communication	GPS	GPS	GPS
Ford	Smart Weapons	HARM, low-cost seeker	AMRAAM	
	EW	APR-39	Expendable decoys APR-39	ALR-46, -62, -74 APR-39
	Radar	Phased array	Phased array	Phased Array
Harris	Communication	MILSTAR, GPS, Anti-Jam Data-Links, JTIDS	MILSTAR, GPS, Anti-Jam Data-Links, JTIDS	MILSTAR, GPS, Anti-Jam Data-Links, JTIDS

(Continued)

© 1989 Dataquest Incorporated November

Table 11 (Continued)

MIMIC Applications

Contractor	System Type	Army	Navy	Air Force
Hittite	Smart Weapons	MOFA		
Hughes	Smart Weapons	TOW	OABM	AMMW
	EW		ASAP, expendable decoy	
	Radar	Firefinder	SBR	ATF, ATSR, SBR
ITT	EW	ALQ-136, LHX	ALQ-136, 165, INEWS	ALQ-165, INEWS
	Radar	ETAS Firefinder		ATSR, SBR
Loral	EW	-----------RWR, expendables-----------		
Martin Marietta	Smart Weapons	SADARM, MLRS TGW	Low-Cost Seeker	Terminal Guidance
Raytheon/TI	Smart Weapons	SADARM, MOFA	HARM	Terminal Guidance
	EW			Active Arrays
	Communication	MILSTAR, GPS	MILSTAR, GPS ICNIA	MILSTAR, GPS ICNIA
	Radar	ETAS, Patriot	SBR, Shared Aperture	ATSR, SBR
Sanders	Smart Weapons	MOFA	EX-60	INEWS
	EW	!INEWS	INEWS, AAED, expendable decoys, ASAP, AlQ-126	
	Communication	MILSTAR	MILSTAR	MILSTAR
TRW	Smart Weapons	SADARM, MLRS-TGW	Std. Missile	AMRAAM
	EW	MEDFLI	INEWS	INEWS
	Communication	MILSTAR, GPS	MILSTAR, GPS ICNIA	MILSTAR, GPS ICNIA

(Continued)

© 1989 Dataquest Incorporated November

Table 11 (Continued)

MIMIC Applications

Contractor	System Type	Army	Navy	Air Force
Unisys	Smart Weapons	MLRS-TGW SADARM, STAFF		AMMWS
	Communication	Tactical Radio	Tactical Radio MMW Spacelinks	Tactical Radio MMW Spacelinks
Westinghouse	EW	INEWS	ASPJ, INEWS	ASPJ, ALQ-131 INEWS
	Communication	GPS, JTIDS	GPS, JTIDS ICNIA	GPS, JTIDS ICNIA
	Radar		ATA, ASAP	ATF

Source: Defense Electronics

The DOD narrowed the number of contractors for Phase 1 of the program to four teams. These are led by Martin Marietta-ITT, TRW, Raytheon-Texas Instruments, and Hughes-General Electric. The Martin Marietta-ITT and TRW teams will develop MIMIC for the army. The navy contractor is Raytheon-Texas Instruments; Hughes-General Electric will work on air force applications. Raytheon and Texas Instruments inserted monolithic amplifiers in the High-Speed Anti-radiation Missile in May 1989, marking the first application of MIMIC technology. The gallium arsenide amplifiers have replaced hybrid devices, which are typically complex, and have low manufacturing yields.

TRW completed the first three GaAs chips for the MIMIC program in February 1989, using heterojunction bipolar transistor technology. TRW was awarded a 36-month, $58 million Phase-1 contract in May 1988. Subcontractors include Honeywell, General Dynamics, and Hittite Microwave Corporation. TRW's $25 million pilot production fabrication line is scheduled to open at the end of this year.

Sanders Associates developed a GaAs MIMIC phase shifter chip for the air force. The chip will be used in phased array radar and electronic countermeasures technology for aircraft, as well as in expendable electronic countermeasures devices. Other applications for MIMIC chips are likely to be the air force's AMRAAM and the navy's GPS programs.

Funding for the MIMIC program has ramped up from about $50 million a year to almost $70 million per year in 1989. The MIMIC program will cost a total of $500 million; the Pentagon plans to spend $80 million in fiscal year 1990 and $84 million in fiscal year 1991.

© 1989 Dataquest Incorporated November

Semiconductor Manufacturing Technology Program. Last year, the DOD launched a new initiative aimed at redressing the erosion of the U.S. defense industrial base semiconductor manufacturing capability and reduce dependence on imported semiconductors. According to congressional testimony, the Semiconductor Manufacturing Technology program's purpose was to establish a facility in which a wide range of manufacturers can jointly pioneer advanced semiconductor manufacturing techniques.

Research is being carried out by the earlier-mentioned industry consortium known as Sematech, established in late 1987. The DOD funding for Semiconductor Manufacturing Technology was $98 million in fiscal 1988. Congress raised the DOD funding request of $44.8 million in fiscal 1989 to $100 million. The total annual operating budget of the consortium is estimated at $250 million, to be shared evenly between government and industry. After five years of DOD funding, Sematech plans to become autonomous.

Sematech completed construction of a research facility and manufacturing line in Austin, Texas, in late 1988 and began to process integrated circuits in the spring of 1989. The Sematech program switched managerial hands both in DOD and within Sematech; the chief operations officer left in March 1989 after disagreements with Robert Noyce, the chief executive officer. Although off to a rocky start, Sematech appears to have spurred other consortia efforts in related areas, like HDTV and machine tools.

Defense Strategic and Tactical Array Reproducibility Program (DSTAR). The DSTAR program was created to produce affordable infrared focal plane arrays. IR focal plane arrays convert natural thermal radiation from objects into signals that can be processed by computers. The program will integrate processes, equipment, and tests into manufacturing lines and demonstrate flexible manufacturing. The materials under research include mercury cadmium telluride, platinum silicide, and indium antimonide. IR focal plane arrays will be incorporated in target acquisition, infrared search and track systems, man-portable sights, missile seeker-threat warning, and missile launch surveillance.

The IR focal plane array program has had a mixed funding history. Originally planned on a scale of approximately $50 million/year, the program was cut back in fiscal year 1988 to $2 million and then increased to $9 million in fiscal year 1989. DOD officials have stated that the funding reflected poor scheduling. Along with MIMIC and Sematech, program responsibility was shifted to DARPA in 1988. DARPA requested $20 million in fiscal years 1990 and 1991 each.

Signal Processing Applications. Oryx demonstrated its Super Signal Processor in May 1989. This high-performance 32-bit coarse-grain parallel processor SIMD/MIMD was funded by Kodak and Grumman, among others, and is presently being tested by Grumman for military applications. The Super Signal Processor uses AMD's 29325C floating-point chips.

 © 1989 Dataquest Incorporated November

Gallium Arsenide Research. Spurred by the success of MIMIC, DARPA is pushing for speedy introduction of GaAs circuits in current military systems. The DOD expects to spend $100 million on gallium arsenide and other compound semiconductor materials in fiscal year 1989 in addition to the MIMIC program. In spring 1988, DARPA solicited proposals for a program to design, demonstrate, and test digital GaAs circuits for systems that require superior electronic performance. Eleven contracts were awarded in May 1989 to nine firms (see Table 12).

Table 12
GaAs Contracts

Firm	Service	Application
E-Systems	Army	Distributed array processor
E-Systems ECI	Army	Modem/synthesizer for AN/PRC-126
Grumman	Navy	Radar signal processor/ E-2C aircraft
Honeywell	Air Force	Digital map computer for V-22, others
ITT Avionics	Army	Digital radio frequency memory for AN/ALQ-136 jammer
KOR Electronics	MS	Digital radio frequency memory for ULQ-21 jam simul., ALQ-167
Martin Marietta	Army	Signal processor for Hellfire
Martin Marietta	MS	Spacecraft on-board processor
McDonnell Douglas	Army	Mast-mounted sight processor for OH-58D
Sanders	Navy	Digital radio frequency memory for tactical aircraft for ALQ-126
Texas Instruments	Navy	Upgrade APS-137 airborne search radar

MS = Multiservice

Source: U.S. Department of Defense

The air force also is sponsoring gallium arsenide research. The Materials Lab at the Aerospace Systems Division is conducting a research and manufacturing program, designed to improve the yield of GaAs chips and establish an optimal process for growing GaAs substrates. In the exploratory development stage, contractors include Cominco, AT&T, and Westinghouse. A separate program under the air force is for GaAs manufacturing technology; Applied Solar Energy Corp. and Westinghouse are the contractors. Applied Solar Energy is developing manufacturing technology for GaAs on germanium substrate under a two-year, $2 million contract.

© 1989 Dataquest Incorporated November

SDI funded gallium arsenide research on the level of about $35 million per year in 1987, but enthusiasm seems to be waning within SDIO for using gallium arsenide in rad-hard applications. Funding was cut to $16 million in 1988, but revived by Congress to $33 million for 1989. Among other things, SDI funds were used to establish the GaAs Heterojunction Pilot Line at AT&T, which aims to develop large-scale integrated circuits operating at clock speeds of 200 MHz.

Diamond Research. The SDIO spends about $4 million per year on research into using diamonds as semiconductors. Diamonds have a naturally high band gap, enabling them to withstand higher temperatures than silicon or gallium arsenide—about 700 degrees C, compared with 125 degrees C. Diamonds also operate at higher power and frequency, and can tolerate more radiation, making them ideal for use on satellites. The major stumbling block for diamonds is synthetic growth techniques.

Displays

High-Definition Television (HDTV). DARPA issued a request for proposals at the start of 1989 for the development of product and/or manufacturing technology for high-definition, low-cost, dynamic, and multimedia displays. These displays will be applied in a wide array of military systems: command and control, battle management, training and simulation, intelligence analysis, cockpits, computer-aided design, and digital maps. More importantly, however, HDTV may become the largest consumer of integrated circuits in the future, and has therefore attracted considerable attention in other areas of the U.S. government and abroad.

DARPA's HDTV program is currently funded at $30 million. Effort and funds have been divided equally into two areas: display technology, including electronic components such as CRTs, projection displays, back projection systems, and solid-state flat panels; and the display processor, which will receive, manipulate, and display video. DARPA received 87 proposals in February 1989, and may boost funding, possibly collected from other defense and nondefense agencies. Although a groundswell of support has developed in industry and in the Congress, a long-term funding plan by DARPA is not yet evident; this year's funds were shifted from other sources. Two bills have been introduced in Congress: the HDTV Competitiveness Act of 1989 (HR 1267) in March 1989 and the Advanced Television Competitiveness Act (HR 2287). HR 1267, if passed, could provide as much as $500 million over the next five years, as well as an R&D tax credit for HDTV-related research. HR 2287 will establish a consortium, similar to Sematech, to conduct research.

Industry has formed a for-profit partnership with three main objectives: to develop, fund, and manage, in partnership with the government, one or more consortia for research and development; to license technology; and to direct technology toward HDTV and related products. The partnership was formed by 17 firms that could receive a large portion of DARPA funding. These include the following:

- Apple Computer
- AVX Corp.
- Cohu Inc.
- Digital Equipment Co.
- Harris
- Hewlett-Packard

 © 1989 Dataquest Incorporated November

- IBM
- Microelectronic and Computer Technology Corp.
- PCO
- Raychem
- Texas Instruments
- Zenith
- ITT
- Motorola
- Prometrix Corp.
- Tektronix
- Varian Associates

Zenith revealed plans for a partnership with AT&T in February 1989; AT&T will design and produce integrated circuits for the receiver and terrestrial transmission system for 35mm film quality images. Estimated to cost about $24 million, the partnership submitted a proposal to DARPA for half that amount in March. AT&T will use its existing 0.9-micron CMOS chip process as well as bipolar and gallium arsenide technologies to design and manufacture microprocessors. These microprocessors will perform signal processing, analog-to-digital and digital-to-analog conversion, error compensations, and horizontal, vertical, and temporal filtering. A demonstration model is expected at the end of this year.

Optoelectronics

Research in optoelectronics began 15 years ago, and is evident today mostly at the equipment and systems levels, for example, in optical disks, laser printers, telecommunications, and in local area networks. At the component level, research has produced optical fibers, lasers, laser-emitting diodes and photodetectors.

Spending by the air force Systems Command in photonics has grown to $30 million per year, and consensus is growing that for many applications, electronics will be supplanted by photonics, using light beams instead of electrons to store and transmit information. The air force announced its intention to substitute photonic devices for electronic ones in Project Forecast 2, completed in 1986.

Fiber optics offer the advantages of high bandwidth, speed, and resistance to electromagnetic pulse, electromagnetic interference, and radio frequency interference. With a fiber optic system, the elimination of copper wiring will reduce weight and decrease generated heat. Optical disk storage will be a growth area for military applications.

One recent application of fiber optics to microelectronics is the development of optical interconnects using laser diodes by the David Sarnoff Research Center under contract to the air force. Using a grating surface emitting array, researchers were able to construct a high-power laser on high-density AlGaAs chips. Optical interconnects will allow better use of VHSIC chips operating at speeds of 100 MHz on the chip itself; current methods of connecting chips with memories slow down overall processing speeds.

© 1989 Dataquest Incorporated November

DARPA put out a request for proposals in May 1989 for projects demonstrating the advantages of optical over electronic processing. In radar applications, DARPA hopes for results in synthetic and inverse synthetic aperture radar processing, and optical null steering processing. Other areas of interest for optical processing include real-time pattern recognition and data base management for sensor fused weapons.

Software

Consolidated DOD Software Program. Following a 1987 Defense Science Board Task Force on Military Software, three software programs were unified in the fiscal 1989 budget request: the Ada standard programming language, the Software Technology for Adaptable, Reliable Systems (STARS) program, and the DOD Software Engineering Institute. Two other software programs under the Strategic Computing Initiative and the Strategic Defense Initiative were not considered because they represent advanced, unique hardware and software configurations, unsuitable for standardization. The DOD is emphasizing the use of standardized and tested common software modules for military applications. This approach will speed development and increase reliability of systems. The DOD Software Engineering Institute, with an annual budget of about $24 million, will help expedite the adoption of advanced software engineering in military systems, aiding developers in all military agencies. The Consolidated Software Program budget request for fiscal year 1990 was $15 million; the request for fiscal year 1991 was $12 million.

© 1989 Dataquest Incorporated November

North America--Production Programs

SUMMARY

When the fiscal 1989 defense budget was trimmed by $32.5 billion, acquisitions suffered most of the spending reductions. Program terminations included A-6 production, Aquila remotely piloted vehicle, Copperhead missile, EH-60 helicopter, naval airship demonstration, Skipper and AGM-130 munitions, high-frequency antijam radio, airborne command post replacement, penetration aids for the Minuteman III ICBM, and the C-27 aircraft. The fiscal implications of these program cuts are summarized in Table 1.

Although procurement funding has suffered from recent budget cuts, it is expected to rise 25 percent over the next five years, from about $80 billion in fiscal 1989 to approximately $100 billion in fiscal 1993. Electronics content will remain relatively constant at approximately 38 percent of total procurement spending, increasing in value from $30 billion to $38 billion. Aircraft systems, communications, and electronics systems account for the largest portions of these totals, as shown in Table 2.

Table 1

Spending Reductions Due to DOD Program Terminations
(Millions of Dollars)

System	Fiscal 1989 Cut	Total Program
	Army	
Aquila RPV	$ 226	$ 1,096
Antitactical Missile	35	149
EH-60 Helicopter	45	45
M198 Howitzer	20	90
120mm Mortar	24	161
Copperhead	106	747
Total Army	$ 455	$ 2,289
	Navy	
A-6F Aircraft	$ 918	$ 5,655
Naval Airship	62	135
Antiradiation Seeker	8	109
Antijam Radio	52	87
Skipper	37	209
Total Navy	$1,077	$ 6,194

(Continued)

© 1988 Dataquest Incorporated August

Table 1 (Continued)

Spending Reductions Due to DOD Program Terminations
(Millions of Dollars)

System	Fiscal 1989 Cut	Total Program
Air Force		
Antisatellite Weapon	$ 786	$ 2,218
Midgetman Missile	2,150	39,790
Minuteman III Penaids	129	561
C-27 Aircraft	65	401
Airborne Command Post	14	140
Total Air Force	$3,237	$43,175
Grand Total	$4,769	$51,658

Source: Congressional Research Service

Table 2

Electronics Content of DOD Procurement
(Billions of Dollars)

	1988	1989	1994	CAGR 1988-1994
Aircraft Systems	$ 7	$ 7	$10	6.1%
Missiles	5	5	5	5.8%
Space Systems	3	3	4	4.9%
Shipboard Systems	4	4	4	0.0%
Communications & Electronics	6	7	9	7.0%
Other	4	4	4	0
Total	$29	$30	$38	4.6%

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

North America--Production Programs

The military services will be under increasing pressure to procure nondevelopmental items to minimize R&D outlays and shorten the time required to field new military systems. This was an important recommendation of the Packard Commission, which will figure more prominently in Department of Defense (DOD) decisions in the future. This practice is already evident in DOD purchases of general purpose computers and production aircraft. The air force, for instance, has selected off-the-shelf aircraft for the C-12, C-18, C-20, C-21, C-22, C-23, and the Air Force One replacement aircraft.

AIRCRAFT SYSTEMS

The prime drivers of aircraft systems are new aircraft under development: the air force advanced technology fighter and B-2 "Stealth" bomber; the navy's advanced tactical aircraft; and the army's new helicopter, the LHX. New avionics systems are also in development for deployed aircraft. Upgrades of existing equipment are likely to become increasingly important as production schedules of new aircraft slip behind. Upgrades also address the problem of structural disarmament—the shrinkage in force levels that results from increasing unit costs.

The United States will see a major generational change in nearly all classes of aircraft in the 1990s, from bombers to airlifters, and from fighters to helicopters. Each of these systems requires increasingly sophisticated avionics to deal with the hostile electronic environment expected in future combat and to achieve 24-hour operation in all types of weather.

Budget appropriations for major aircraft programs are summarized in Table 3.

© 1988 Dataquest Incorporated August

Table 3

Budget Summary for Major Aircraft Programs
(Millions of Dollars)

	1988	1989	1994
Common Avionics Systems			
ICNIA/INEWS	$ 100	$ 130	$ 460
LANTIRN	$ 740	$ 690	$ 300
Aircraft Procurement and Modifications			
A-6	$ 220	$ 180	0
B-2	$2,000	$3,000	$7,500
B-1B	$ 380	$ 250	$ 160
B-52	$ 240	$ 220	0
ATA	$ 700	$ 900	$3,000
ATF	$ 500	$ 700	$3,080
F-14	$1,070	$1,110	$ 800
F-15	$1,800	$1,780	$1,200
F-16	$2,890	$3,820	$2,400
F-18	$2,290	$2,410	0
F-111	$ 250	$ 120	0
V-22	$ 470	$ 640	$ 480
OH-58	$ 160	$ 170	$ 200
AH-64	$ 960	$ 920	$ 800
UH-60	$ 540	$ 540	$ 600
CH-47D	$ 280	$ 260	0
LAMPS	$ 150	$ 130	0
C-17	$1,780	$2,070	$1,800

Source: DOD, Defense Forecasts

Advanced Tactical Fighter (ATF)

The ATF is scheduled to replace the F-15 as the primary air force fighter in the early 21st century. An estimated 750 aircraft will be built. The ATF program has been restructured, delaying initial procurement of the aircraft by one year to fiscal 1993; additional delays are possible. Two contractor teams have been chosen to develop the aircraft: Northrop/McDonnell Douglas and Lockheed/Boeing/General Dynamics. Each team received $691 million in development funding in late 1986 and is expected to spend as much as $400 million of its own funds on the project.

© 1988 Dataquest Incorporated August

The Northrop/McDonnell Douglas team awarded contracts to Martin Marietta and General Dynamics to develop an electro-optic sensor system for the ATF. This team also has selected Unisys Defense Systems to integrate the airborne information on its ATF prototype.

The Lockheed/Boeing/General Dynamics team awarded a contract to Hughes Radar Systems Group last July to develop the common an integrated processor (CIP) for the avionics unit in its prototype. Three versions of the CIP will be prepared: an integrated offensive processor, an integrated defensive processor, and an integrated mission processor. Lear Siegler's Astronics Division and GEC Avionics were selected to supply the digital flight control computer for this ATF team. GEC Avionics will also provide the heads-up display for the Lockheed team.

Both teams chose Westinghouse and Texas Instruments to supply radar for their ATF prototypes for the 45-month demonstration/validation phase.

IBM's Systems Integration Division has been awarded a multimillion dollar full-scale development contract for the ATF mission computers. The computers will incorporate Very High-Speed IC (VHSIC) technology and common avionic modules with the navy Advanced Tactical Aircraft (ATA) (A-12). Westinghouse plans to make the first deliveries of VHSIC chips for the IBM 1750A computer, which will be used on the ATF, in October 1988.

Advanced Tactical Aircraft (ATA)

A team of General Dynamics and McDonnell Douglas has been selected as prime contractor to develop the navy's ATA. The development contract is worth nearly $4.4 billion. As many as 450 ATAs are expected to be built at an estimated cost of $45 billion; schedule slippage is quite possible. The air force is likely to buy a quantity of ATAs to replace the F-111; air force requirements have been communicated to the ATA program office, and the air force has certified that the aircraft can be adapted to its needs. The development subcontracts shown in Table 4 have been awarded by the prime contractors.

Some details of the ATA design have become known. The mission computer for the ATA will feature VHSIC technology. The flight control system will be quad-redundant, self-repairing, and could include fly-by-wire or fly-by-light.

Navy plans call for a second source to compete for production awards after the aircraft enters production. According to a navy official, dual sources will be used for the 30 highest-value ATA subsystems.

© 1988 Dataquest Incorporated August

Table 4

Navy Advanced Tactical Aircraft Contractors

Firm	Subsystem
Westinghouse Electric	Combined function FLIR
Norden Systems Division (United Technologies)	Multifunction radar
Harris	Multifunction antenna
Litton-Amecon Division	Electronic support measures
General Electric Aircraft Electronics	Missile warning set
Garrett Controls (Allied Signal Aerospace)	Air data computer system
Litton/Honeywell	Integrated inertial navigation
Honeywell	Flight control system
SCI Technology	Avionics subsystems
IBM Systems Integration Division	Mission computer (VHSIC chip set)

Source: Defense Forecasts

B-2 Stealth Bomber

Details on the air force's newest bomber, the Northrop B-2 Advanced Technology Bomber, are classified. The B-2's first flight is scheduled for fall of 1988. The production contract awarded to Northrop for the B-2 is reportedly worth approximately $2 billion. An estimated 132 aircraft will be built. Boeing, LTV, and General Electric are major subcontractors. Total program cost is expected to exceed $50 billion, with a program unit cost of about $375 million. There are reports that the unit cost may have risen still further, to a price per aircraft of $450 million.

Light Helicopter Experimental (LHX)

The army's program to develop a family of helicopters to replace its aging fleet of US-1, AH-1, and OH-58 aircraft has been redirected several times in the last two years and is now being restructured. One of the goals of the program is to allow a single crewman to operate the aircraft, its sensors, and its weapons. The army will develop modular mission kits that allow removal of selected equipment depending on the mission. Congress and the DOD are pushing the army to make use of the Integrated Communications, Navigation and Tactical Fighter. Fly-away cost of the LHX is estimated at $7 to $8 million, assuming a total buy of 2,100 aircraft at the production rate of 216 helicopters per year.

 © 1988 Dataquest Incorporated August

In the demonstration/validation phase, contractors will explore avionics requirements for the LHX, including its target acquisition system, wide field of view helmet display, and application of VHSIC. LHX electronics may be adapted as upgrades for helicopters presently in production.

Once the army's LHX plans are approved, the contractor teams of Bell/McDonnell Douglas and Boeing/Sikorsky will begin an 18-month demonstration/validation phase under a contract worth approximately $165 million per team. After this phase is completed in 1990, a single contractor will be chosen to develop the aircraft. First flight is scheduled for May 1993, and initial operating capability should be achieved by March 1996. Additional schedule slippage is likely.

In addition to the major aircraft programs discussed here, replacements for the A-10 close air support aircraft and several tactical airlifters are under consideration. In January 1988, the air force awarded a total of $4.9 million to General Dynamics, Northrop, Lockheed, McDonnell Douglas, and Rockwell International to begin design studies for a close air support aircraft. Any new aircraft development start would likely face problems, however, amid anticipated budget cuts and competition for funding with established development programs.

Integrated Communications, Navigation, and Identification Avionics (ICNIA) and Integrated Electronic Warfare System (INEWS)

ICNIA is, like Pave Pillar, a modular system, combining the 16 radios now used on an aircraft into a single system. If part of the system failed, ICNIA would bypass the faulty component and continue to perform the original tasks for which it was programmed, dropping, if necessary, the least critical function. According to calculations by TRW, ICNIA will increase the time between critical failures up to 67 times that of present discrete avionics systems. The number of different types of circuit boards required will be reduced from over 1,000 to 28.

For combat aircraft of the 1990s, INEWS will fuse the capabilities of jammers, missile detection/warning systems, laser-radiation detection/warning systems, and infrared missile jammers, using VHSIC technology. Each chip will contain as many as 30,000 logic gates.

In June 1986, the air force chose two contractor teams to proceed with the demonstration/validation phase of the program—TRW/Westinghouse and Sanders/General Electric. Contracts for this phase were valued at $48 million. This phase will culminate in 1991 with the selection of a contractor for a full-scale development program. Production is planned for late 1993, corresponding with the schedule of the ATF. ICNIA will not yet be available when the navy ATA enters production; it will have to be substituted later as a block upgrade.

© 1988 Dataquest Incorporated August

The INEWS program office is aiming for a unit price of $1.8 million to $2.8 million, but some observers expect the system to exceed $3 million per aircraft. Considering the number of aircraft which would be equipped with INEWS, it could easily become the largest electronic warfare program to date. In addition to being used in air force and navy fighters, ICNIA and INEWS are intended for the army's LHX helicopter.

Joint Tactical Information Distribution System (JTIDS)

JTIDS is designed to provide a jam-resistant link between aircraft and ground forces. JTIDS-equipped aircraft will automatically send information defining their location and status into an information network through the Tactical Air Navigation (TACAN) signal processing unit in the receiver-transmitter. This information includes target data, altitude, ground speed, direction, fuel reserves, weapon reserves, and radar signature returns.

The DOD request for JTIDS funding in fiscal 1988 came to a total of $302 million from all the armed services. The program is suffering from developmental problems which will result in significant schedule slippage. The team of Singer/Rockwell-Collins has delivered JTIDS terminals to the air force, army, and U.K. Ministry of Defense for testing. Singer was awarded a $12 million contract for program definition of the Multifunction Information Distribution System, the NATO version of JTIDS.

Mark XV Identification of Friend or Foe (IFF)

Air-to-air and surface-to-air missiles now have the ability to attack targets beyond the line of sight. This has raised concerns about the need for effective systems to discriminate friendly from hostile aircraft. The Mark XV program has become a NATO standard and costs an estimated $7 billion. The Senate Armed Services Committee has expressed reservations about the system, which is to be deployed on F-16 and F-18 fighters and army medium- and high-altitude air defenses. In May 1988, the air force issued a request for proposal (RFP) for full-scale development of the Mark XV, with contract award expected early in 1989.

Aircraft Upgrades

Cuts in aircraft procurement funding have resulted in setbacks for avionics production. The F-15 has been reduced from an annual production rate of 42 aircraft to 36, with only 30 aircraft to be procured in fiscal 1990. The navy A-6F program was denied funds by congress in 1988, and marine corps AV-8B Harrier procurement will slip from 42 aircraft in 1987 to 24 each in 1988 and 1989. Table 5 summarizes production schedules for fighter aircraft.

 © 1988 Dataquest Incorporated August

Table 5

U.S. Fighter Aircraft Production

Type	Service	1987	1988	1989
F-14D	Navy	15	12	12
F-15E	Air Force	42	42	36
F-16	Air Force	180	180	180
F/A-18	Navy	84	84	72
A-6F	Navy	11	--	--
AV-8B	Navy	42	24	24

Source: DOD Annual Reports for Fiscal 1987-1989

Fighter Upgrades

Upgrades to several existing aircraft are currently in production; additional upgrades can be expected. The upgrade programs are designed not only to increase aircraft performance but to improve reliability and reduce operation costs. For instance, the new ring-laser-gyro inertial navigation unit on the F-15 should boost mean time between failures from 100 hours to 2,000 hours on the unit it replaces. This improvement in reliability should result in savings of $94.2 million in spare parts alone.

F-16 improvements being made by General Dynamics include a digital flight control system (to be produced by Bendix Flight Systems), full integrated capability for Martin Marietta's LANTIRN, and a global positioning system (GPS). The General Dynamics contract, worth $258.5 million, calls for deliveries to be completed by June 1991. Westinghouse was awarded a $74.5 million increase in a contract for development of the F-16 radar, with work to be completed in December 1988.

For the F-15E, improvements include advanced cockpit technology, LANTIRN, ring-laser-gyro inertial navigation system, and digital light control system.

The F-14D will incorporate a new digital avionics suite, the Airborne Self-Protection Jammer (ASPJ) electronic countermeasures system, and an advanced air-to-air radar. A hybrid radar, the AN/APG-70, is being developed by Hughes Radar under a subcontract to Grumman for the F-14D: it combines improved target detection and tracking, better electronic counter-countermeasures, and beyond-visual-range target indentification and raid assessment modes. The first production unit is scheduled for delivery by September 1989. Total value of the air force fixed-price contract to Grumman is $986 million. General Electric received a $10 million contract for designing an infrared search and track system for the F-14.

© 1988 Dataquest Incorporated August

General Electric's Control Systems Department has been chosen to modify the air force A-10 aircraft. The firm fixed-price contract, valued at $82.9 million, is for modifications of the fleet of 655 Fairchild A-10s with a low altitude safety and targeting enhancement system. The improvements include a ground collision avoidance system and a new weapons delivery system, which allow greater maneuvering in the approach. In a separate program, Sacramento Air Logistics Center plans to equip A-10s with GPS equipment.

McDonnell Douglas was awarded a $300 million add-on to an advanced acquisition contract for 36 AV-8B and 6 TAV-8B Vertical/Short Take Off and Landing (V/STOL) attack aircraft. Work is expected to be completed by September 1989.

Low-Altitude Navigation and Targeting Infrared for Night (LANTIRN)

The LANTIRN system will provide the air force with the ability to conduct offensive tactical missions at night. Martin Marietta is producing the LANTIRN navigation pod under the terms of a $715 million contract it received from the air force in December 1986. The air force plans to install some 700 LANTIRN systems on F-15E and F-16C/D aircraft. The first operational unit will be installed on the F-16 in 1989. Installation on the F-15 model will follow shortly thereafter.

LANTIRN consists of a navigation pod and a targeting pod. The first navigation pod was delivered in April 1987. Martin Marietta will deliver one navigation pod per month by late 1988, 10 per month by late 1989, and 20 per month by late 1990. The first targeting pod was scheduled for delivery in July 1988. Targeting pod production will increase at the same rate as navigation pods but lag one year behind, until all deliveries are complete in February 1991.

Texas Instruments is a major subcontractor for LANTIRN, producing terrain-following radar for the navigation pods under a $101 million contract. A decision to continue full-rate production of LANTIRN has been delayed.

Bomber Upgrades

Although it only entered service in 1986, the Rockwell/Air Force B-1B strategic bomber already has upgrades underway. Major problems have been uncovered in the bomber's defensive avionics (ALQ-161), which are under development by Eaton Corporation's AIL Division. Major subcontractors include IBM, Northrop, and Tasker Research. An upgraded system has been promised by early 1990.

The AIL AN/ALQ-161 consists of 118 line-replaceable units, weighs just under 5,000 pounds, and will cost an estimated $2.5 billion for 100 units. The design has grown in complexity as electronic warfare (EW) requirements have increased during the protracted development of the B-1B. Critics of the system, including House Armed Services Committee Chairman Les Aspin, contend that the offensive and defensive avionics interfere with one another so much that the utility of the B-1B is compromised. According to Rep. Aspin, "the pilot can choose to protect himself or carry out his mission, but not both at the same time."

© 1988 Dataquest Incorporated August

The air force is considering a proposal to replace the AIL system with a competing design by International Telephone & Telegraph (ITT). ITT offers the ALQ-172 system currently being installed in B-52G and B-52H aircraft. Cancellation of the ALQ-161 contract could result in a business loss to AIL of $1 billion.

Electronic Combat Aircraft

The air force F-4G Wild Weasel is being upgraded to cope with Soviet threats into the 1990s. Modifications of the air force EC-13OH electronic countermeasures aircraft also are underway. In fiscal 1988, the air force began a series of upgrades to the EF-111A Raven electronic combat aircraft. The first improvements center on computer processing, while the remainder update the radio receiver and antennas.

The entire F-111 fleet will be upgraded with new avionics. Rockwell International's Collins Government Avionics Division will provide integrated communication navigation sets under a $1.9 million contract with USAF Sacramento Air Logistics Center. First deliveries are scheduled for late 1988. With options, total value of the contract could reach $7.5 million.

The navy EA-6B is being enhanced under the Improved Capability Program (ICAP II). Additional modifications will be made under the Advanced Capability Program (ADVCAP), scheduled to begin in fiscal 1990. An improved electronic countermeasures set for the EA-6B, the Lockheed/Sanders Associates AN/ALQ-149, has been delivered to the navy, increasing the radar and radio frequency-jamming coverage of the aircraft.

Surveillance Aircraft

Major enhancements are planned for the Boeing/air force E-3A AWACS. Boeing was awarded a $241 million contract to develop a joint United States/NATO electronic support measures system for the AWACS, with work to be completed by May 1990. Other upgrades in the works include improvements in data processing (with IBM as subcontractor), and adding GPS capability.

The navy P-3 Orion antisubmarine warfare aircraft will be fitted with modernized avionics. In July 1987, Boeing was awarded a $244 million full-scale development contract for the system. The navy plans to purchase 205 updated systems over the next six years. Rockwell will provide Navstar GPS user equipment for the P-3 under a subcontract to Boeing. Rockwell International's Collins Government Avionics Division, under contract to Boeing Aerospace Company, will supply Navstar GPS user equipment for the navy's P-3 Update IV program. Total number of sets for this segment of the P-3 fleet could exceed 200.

Helicopter Avionics

In light of the growing difficulties of the LHX helicopter development program, procurement of the present generation of combat helicopters has taken on increased importance. The LHX will not be produced until 1995 at the earliest, and fewer than 300 LHXs will be operational by the year 2000. Table 6 shows the procurement plan for the army aircraft modernization program.

© 1988 Dataquest Incorporated August

Table 6

Army Aircraft Modernization Plan
1987 to 1998
(Number of Aircraft Produced)

Model	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
AH-64	101	77	72	48	40	40	40	20				
OH-58D	36	36	24	36	48	54	54	54	36			
UH-60A	82	72	71	61	61	72	72	72	72	72	72	72
MH-60K			1	11	11							
CH-47D	48	47	43	37	48	48						
SEMA		3	10	20	14	21	27	14				
LHX									24	48	96	144

Source: Defense News

Procurement quantities of Sikorsky UH-60 Black Hawk and McDonnell Douglas AH-64 Apache helicopters have been increased beyond DOD plans. In fiscal 1988, Black Hawk funding was increased $28.7 million above the army budget request. Congress has appropriated $752 million for procurement of AH-64 Apache helicopters, $98 million in excess of the amount requested by the army. Orders for the AH-64 total more than $1.6 billion. Congress also directed that fiscal 1987 procurement cost savings be applied to the purchase of additional aircraft. The army expects the budget for its helicopter program to be close to $3.5 billion per year in the fiscal 1990 to 1993 period, although the existing five year plan only budgets $2 billion per year for these programs.

Improvement programs are underway for several operational helicopters. Martin Marietta was awarded a $53.8 million contract for the target acquisition designation sight/pilot night vision sensor (TADS/PNVS) on 46 AH-64 helicopters. Work on TADS/PNVS is expected to be completed by the end of October 1989. Hughes Aircraft has begun production of a night targeting system for the AH-1S attack helicopter under a $67 million army contract. The army has chosen Thomson-CSF/Hamilton Standard to supply 56 heads-up displays for the Bell OH-58C observation helicopter.

Major U.S. helicopter manufacturers are planning to take advantage of new avionics and mission equipment developed for the LHX in their upgrades of existing equipment. Study contracts for these upgrades have been awarded to McDonnell Douglas (AH-64), Bell Helicopter (OH-58), Boeing (CH-47), and Sikorsky (UH-60).

© 1988 Dataquest Incorporated August

The Sikorsky/navy SH-60 B Light Airborne Multi-Purpose System (LAMPS II) helicopter will be equipped with active sonar to detect quieter Soviet submarines. Production units built in 1990 will include the following upgrades, which are now under development: a GPS receiver, Penguin air-to-surface missile, and Advanced Lightweight torpedo. Another navy helicopter upgrade is the conversion of 42 SH-2F LAMPS I helicopters to SH-2Gs.

MISSILES AND WEAPONS

The present generation of fielded missiles, tactical and strategic, is nearing the end of its service life, with a new generation in development or early stages of deployment.

Strategic Weapons

Small ICBM (Midgetman)

Rockwell has a $484.3 million contract for the development and integration of the SICBM guidance and control system. Boeing has been selected to develop the weapons control system, having been awarded a $242 million contract to be completed by January 1992. Under pressure from congress, the air force had planned to procure 645 SICBMs, but the program remains controversial on Capitol Hill and in the Pentagon. The fiscal 1989 budget request included only $200 million for SICBM as a "place holder," to permit the next administration to continue or kill the program. Support in the Senate is weak, and the air force prefers the MX. Most likely, the program will die over the next few years.

Peacekeeper (MX)

The DOD prefers greatly the 10-warhead MX missile to the Midgetman, as does the U.S. Senate. The goal is to deploy a total of 100 Peacekeeper missiles on mobile railroad launchers. Development funding of $792.9 million was requested for fiscal 1989. Initial rail-garrison deployment would begin in late 1991.

In September 1987, Boeing was awarded a $235.5 million contract for the first phase of the rail-based deployment scheme. GTE has been awarded a contract to produce electronic command, control, and communications equipment to be used at airborne launch control centers for Peacekeeper ICBM forces. Most recently, Westinghouse was awarded a $167 million contract to develop the rail-based missile launch car, a contract which included the rail car itself, the missile canister erection system, and the launching mechanism. Rockwell was granted a $161.7 million contract to develop the launch control system.

© 1988 Dataquest Incorporated August

If George Bush is elected in November, he will probably attempt to convince congress to deploy the rail garrison MX in place of Midgetman, an attempt that may or may not be successful. If Michael Dukakis is elected, it is unlikely that any new ICBM would be deployed. In either case, development funding will be stretched and procurement delayed. Eventually, a one- or two-warhead upgrade of the Minuteman system is likely to be deployed in existing silos.

Short-Range Air-to-Ground Missile (SRAM II)

A successor to the short-range air-to-ground missile (SRAM), deployed on the B-52 strategic bomber, is under development. The Air Force plans to purchase a total of 1,633 SRAM II missiles at an estimated price of $2.5 billion. Boeing is the prime contractor for development of this missile, having received a $214.4 million contract that includes initial production options. Boeing has awarded an $8.8 million contract to Litton for development of the inertial navigation element of the SRAM II.

Trident II Missile

Lockheed, the prime contractor for the Trident II, has been awarded approximately $700 million in modifications to a previously awarded contract for development and production of this missile, scheduled to be completed in March 1990. Additional production can be expected. Atlantic Research is subcontractor for development of the postboost control system for the Trident II, under an $80 million contract.

Sea-Launched Cruise Missile (Tomahawk)

The navy's Tomahawk cruise missile, armed with either conventional or nuclear warheads, provides long-range attack capability against a wide range of targets. The conventional land attack version of the Tomahawk will be upgraded with the installation of a Navstar GPS. With this upgrade, the missile no longer will be dependent on terrain contour maps, and unlike the TERCOM terrain matching guidance system, it will work over water. GPS will increase the range of the missile by 20 percent and will simplify mission planning. General Dynamics and McDonnell Douglas are prime contractors for this missile.

A successor to this missile, the Advanced Sea-Launched Cruise Missile (ASLCM), is under consideration. The ASLCM would emphasize long range and low observables.

Advanced Cruise Missile

This classified program, with Boeing as prime contractor, will develop a successor to the Boeing air-launched cruise missile (ALCM) now deployed on B-52 and B-1B bombers. The missile will be even more difficult to detect, incorporating stealth design features.

 © 1988 Dataquest Incorporated August

Tactical Weapons

Army Tactical Missile System (ATACMS)

Several variations of this conventionally armed missile which will be launched from aircraft and as surface-to-surface missiles are in development. Launched from a Multiple Launcher Rocket System (MLRS), the Army Tactical Missile System (ATACMS) is designed to provide army artillery commanders with long-range missiles to strike enemy rear echelon targets. Funding for the ATACMS stands at $84 million in fiscal 1989. LTV is the prime contractor for the system. The ATACMS command and control system began an 18-month program of field tests in May 1988.

Multiple Rocket Launcher System (MLRS)

The fiscal 1989 request is for 36,000 rockets to be produced by LTV, with 24,000 planned for fiscal 1990. This is down from the fiscal 1988 level of 72,000. Even so, MLRS will remain the mainstay of NATO defenses into the next century, and production should continue through the 1990s. Codar Technology has been chosen to provide ruggedized DEC MicroVAX computers for the MLRS launchers.

Air Defense Antitank System (ADATS)

The army chose the Martin Marietta/Oerlikon Air Defense Antitank System (ADATS) as the winner of an intense competition for its Forward Area Air Defense System. The army said it intends to buy four fire units at a cost of about $97 million for delivery in fiscal 1989. The production program for 166 fire units at $1.7 billion could begin in 1990. The army's force goal is 562 fire units.

ADATS' design combines the capabilities of air defense weapons and anti-armor weapons, which up to now had been sufficiently distinct to make optimization for both missions impractical. Oerlikon began to develop the system in the mid-1970s as a successor to ROLAND and RAPIER, teaming with Martin Marietta in this effort in 1979. Martin Marietta has drawn on its experience in development of the Patriot surface-to-air missile and the TADS/PVNS target designation device for the Apache attack helicopter in order to collaborate with Oerlikon on the ADATS project.

ADATS' pulse-doppler surveillance and acquisition radar was developed by Contraves Italiana, based on the SHORAR radar. It can identify stationary and mobile ground and air targets up to a range of 24km and an altitude of 6,000m, working in X band with frequency hopping. The electro-optical module consists of a thermal imaging camera (FLIR), a daylight TV camera, a CO2 a laser for missile guidance, a laser rangefinder, and an IR goniometer.

Congressional action in ADATS funding may delay the program while additional testing is being completed. In May 1988, the Senate Armed Services Committee cut the ADATS budget request of $118.5 million to $33.5 million in the fiscal 1989 defense bill.

© 1988 Dataquest Incorporated August

Advanced Medium-Range Air-to-Air Missile (AMRAAM)

Production of the second lot of AMRAAM continued in fiscal 1988, with a purchase of 500 split between Hughes and Raytheon. A purchase of 1,750 AMRAAMs is planned for fiscal 1989, with an option for an additional buy of 2,800 missiles. Production contracts for AMRAAM include 1987 air force contracts of $125 million for 105 missiles from Hughes, and $59 million for 75 missiles from Raytheon. Production costs for AMRAAM have exceeded original air force projections, with the missile's unit cost climbing to $561,000 in fiscal 1987 from the planned cap of $272,000 in fiscal 1984 dollars. According to congressional testimony, the program has slipped six to seven months behind schedule.

High Speed Anti-Radiation Missile (HARM)

Texas Instruments is producing HARM at the rate of 170 missiles per month and is scheduled to increase its production to 200 missiles per month in September 1988. The navy holds options to buy up to 2,400 low-cost seekers for the HARM through fiscal 1992 from Ford Aerospace, and it expects to buy an additional 2,900 seekers from TI or Ford from fiscal 1993 to fiscal 1994. The current HARM seeker has a unit cost of $140,000; the Ford seeker will have a development cost of $197,000, but this will decrease in production. The new seeker also will have improved performance to counter the Soviet SA-10, SA-11, and SA-12.

Infrared Maverick Missile

Last year, Hughes and Raytheon received contracts to produce 1,556 and 1,203 AGM-65 Infrared Maverick missiles, respectively. Under a $230.6 million contract, Hughes also will produce 600 AGM-65G and 248 AGMF Mavericks, using the same sensor as the AGM-65. The Raytheon Maverick contract is valued at $143.7 million. This year, Raytheon received $150.2 million to produce 1,889 AGM-65Ds and AGM-65Gs, while Hughes got $132.2 million for 1,077 missiles.

One improvement to the Maverick is Rapid Fire, a system intended to automatically select likely targets and aim up to six missiles at them using its infrared sensors. In the time it now takes for a pilot manually to aim a Maverick, a pilot using Rapid Fire can launch four missiles. Hughes will demonstrate the system late this year as part of a $2.6 million development contract.

Patriot Missile

Raytheon is the prime contractor for production of the Patriot air defense system, receiving a $3.5 billion contract for 4,491 Patriot missiles and 45 fire units in a five-year procurement plan. Raytheon was awarded a $790.4 million modification on the first year of the contract for 884 Patriot missiles and 15 sets of ground support equipment. Work is expected to be completed by the end of 1990.

 © 1988 Dataquest Incorporated August

North America--Production Programs

Hellfire Missile

Deliveries of the Hellfire missile continue, with total production shared between Rockwell and Martin Marietta. In fiscal 1988, the army received appropriations of $168 million to procure 5,000 Laser Hellfire missiles. Increases in the number of Apache helicopters, the primary Hellfire platform, will likely increase purchases of the missiles. Procurement will run at approximately 6,000 Hellfires per year. Apache procurement is being increased as a result of delays in the LHX program.

Fiber-Optic Guided Missile (FOG-M)

The FOG-M will be the long-range component of the army's Forward Area Air Defense System. Boeing/Hughes and Raytheon/Martin Marietta are competing for a full scale development contract for the missile. Total production contract value could exceed $1 billion.

Antitank Missiles

The Copperhead II, a fire-and-forget successor to the cancelled Copperhead missile, will not begin until fiscal 1990.

Unmanned Vehicle Systems (UVSs)

A new class of weapons has emerged as a result of progress in drones, cruise missiles, and remotely piloted vehicles. Designed to replace manned fighter aircraft in some electronic warfare missions, unmanned vehicle programs are the subject of increasing interest to congress and the DOD.

The need for unmanned systems is driven by offensive and defensive weapon requirements. The growing lethality of enemy weapons makes decoys useful in diluting enemy fire, thereby increasing the survivability of U.S. forces. At the same time, greater surveillance and target acquisition inputs are necessary for advanced offensive weaponry; for instance, unmanned systems can provide artillery spotting without putting a pilot at risk.

Congress has mandated a DOD tri-service master plan for UVSs, and has frozen funding for UVS programs, including the navy Pioneer remotely piloted vehicle, until a master plan is presented. The services reportedly have agreed on joint development of two unmanned vehicle programs. A medium-range version is planned for the army and marine corps; a long-range vehicle will address navy and air force requirements. Funding for the project was $50 million in fiscal 1988 and will be $34.7 million in fiscal 1989.

© 1988 Dataquest Incorporated August

Tacit Rainbow. The DOD released the first details on the Tacit Rainbow program in 1987. The Tacit Rainbow is a jet-powered drone that could be used to attack enemy air defense radar. The weapon would be launched from an aircraft, then loiter over enemy air defense sites and attack them when their radar was operating. The Northrop-designed Tacit Rainbow is intended to be deployed in large numbers, in both air- and ground-launched variants. Air force procurement funding is $55.1 million for fiscal 1988 and $72 million for fiscal 1989. The navy request for Tacit Rainbow in fiscal 1989 is $90 million. The air force is the lead agency for the joint-service program, with air-launched versions of the system to be deployed by the air force and navy along with a ground-launched version for the army.

The Tacit Rainbow is a year behind schedule, and has failed three flight tests as a result of quality control problems at Northrop. Consequently, the initial decision on whether to proceed with production has slipped to fiscal 1989.

As a result of congressional pressure, the air force has revived the Seek Spinner program to perform a mission similar to Tacit Rainbow. The Boeing mini-drone used as the platform for Seek Spinner is propeller-driven, offering less speed but greater loiter time over the target. The air force has been directed to negotiate a full-scale development contract for the vehicle, with the House earmarking $50 million in the fiscal 1989 budget for the program. Boeing made an unsolicited proposal in March 1986, offering 2,000 units at a total cost of $218 million.

SPACE SYSTEMS

All told, space assets and related ground equipment will account for $5 billion (6 percent) of the total procurement budget in 1989. This is expected to grow to $6 billion in fiscal 1994. The electronics portion of the space procurement budget is high, approximately 65 percent. NASA and DOD space R&D programs bring the total U.S. government space spending to nearly $20 billion annually, as shown in Table 7.

Table 7

U.S. Government Space Spending
(Billions of Dollars)

	1988	1989	1990	1991	1992
NASA	$ 9.5	$ 9.0	$ 9.2	$ 9.5	$10.0
DOD Procurement	4.7	4.8	4.8	4.9	5.0
DOD RDT&E	5.1	5.2	5.3	5.4	5.5
Total	$19.3	$19.0	$19.3	$19.8	$20.5

Source: EIA

© 1988 Dataquest Incorporated August

Most of the unclassified portion of the DOD space budget is devoted to communications satellite programs. Until a strategic defense system reaches the production phase, satellites and their ground support equipment will continue to dominate DOD space procurement. These programs include satellites for communications, intelligence (special programs), and gathering meteorological data. They also include the rockets necessary to launch the satellites into orbit. A substantial number of space programs is highly classified. Consequently, there is a large residual of space funding which is not accounted for in indentifiable budget line items.

The United States already depends on space-based systems to carry out a variety of military functions and is constantly upgrading these capabilities. Technological improvements sought by the DOD include longer operational life, greater autonomy, improved hardening, and lower manufacturing costs for satellites. Key satellite programs are discussed in the following paragraphs.

Navy UHF Satellites

The navy plans to build a network of UHF satellites to provide a backup for current satellite communications, ultimately replacing the FLTSATCOM and LEASATS. Technological improvements in the system include increased channels (35-40), high efficiency linear amplifiers, nuclear hardening, and improved antijamming characteristics. The constellation of eight satellites and one spare will cost $1.5 to $2 billion. Satellite construction is scheduled to be completed by 1992, with the system serving the needs of the navy through the year 2005. Proposals for the navy UHF follow-on were requested in December 1987; TRW, Hughes, and General Electric have expressed interest.

MILSTAR Satellites

The classified MILSTAR Program will provide antijam, nuclear-resistant satellite communications on the extremely high frequency (EHF) bandwidth for all services. MILSTAR will replace the air force defense satellite communications system (DSCS), offering improved survivability through hardening, antijamming techniques, and a higher orbit. Air force MILSTAR funding for terminals is $310 million for fiscal 1989.

MILSTAR will be deployed in three blocks. The first consists of three developmental satellites, with first launch scheduled for 1990. Production satellites will be launched beginning in 1992. The full complement of MILSTAR satellites will be in orbit by the mid-1990s.

Lockheed Missiles and Space Company is the prime contractor for the satellite development program, with a $1.05 billion full-scale engineering development contract. Development contracts are reportedly worth $2 billion, with total costs as high as $10 billion. Raytheon has won air force and navy contracts for ground terminals. Other subcontractors include TRW, Hughes, GE and Ford Aerospace. MILSTAR's schedule is slipping, however, and projected costs are increasing. The total cost of each MILSTAR/Titan-Centaur booster unit is $1 billion. The program may be a prime candidate for delay if further budget cutting is required.

© 1988 Dataquest Incorporated August

Navy Extremely High Frequency SATCOM Program (NESP)

NESP is the navy's portion of the MILSTAR joint service satellite program. Raytheon won contracts to complete development of navy MILSTAR terminals. Potential program value is approximately $550 million.

Defense Meteorological Satellite Program (DMSP)

The air force has awarded a contract to Westinghouse for operational line scan units for DMSP spacecraft, with first delivery scheduled for January 1993. There are presently 2 DMSP satellites in orbit, one launched in June 1987 and another in February 1988. Unit cost for the DMSP, built by GE/RCA, is $141 million. Total program cost is estimated at $1.9 billion over 10 years. Subcontractors include Aerojet, American Satellite, Harris, Hughes Aircraft, and Westinghouse. Study awards for the next generation of DMSP satellites were given to Ford Aerospace, Lockheed Missiles and Space Co., Hughes Space and Communications Group, and General Electric, each valued at some $2.7 million. The acquisition process is expected to result in the launch of a Block-6 DMSP satellite by the year 2000.

Navy Remote Ocean Sensing System

In a related program, the navy will build one to three satellites to fulfill unique navy requirements for ocean surface weather information. Procurement funding is estimated at $140 million per satellite, with launches scheduled to take place from 1993 to 1997.

Navstar Global Positioning System (Navstar GPS)

The largest single air force electronics program is the Navstar GPS, with a total price estimated to be in excess of $4 billion. When its full constellation of 18 radio navigation satellites is operational, Navstar GPS will provide the most precise navigation information available--providing land, sea, and airborne users with three-dimensional positioning with 0.1 meter/second precision and time within 100 nanoseconds. Applications of Navstar GPS include missile guidance, antisubmarine warfare, and close air support. Navstar GPS is a passive ranging system that depends on transmissions from four satellites, transmitting two L-band frequencies: L1, at 1575.42 mHz, and L2, at 1227.6 mHz.

In the fiscal 1990 budget, the DOD will seek funds to expand this satellite system from 21 to 24 spacecraft to eliminate periodic areas of degraded accuracy and to increase redundancy in the system. The prime contractor for the Navstar GPS satellite is Rockwell International's Satellite Systems Division, with subcontractors including IBM, Rockwell Collins, Stanford Telecommunications, and Texas Instruments.

© 1988 Dataquest Incorporated August

The Navstar GPS program's biggest headaches have come from the failure of American space launch capabilities. Initial two-dimensional capability originally scheduled for 1988 has been pushed back to 1990, with three-dimensional capability to follow in 1991. Seventeen Navstar GPS satellites are scheduled for launch on the space shuttle from June 1989 through early 1994. Persistent delays in the shuttle program have put even this schedule in doubt. The air force also plans to use the Medium Launch Vehicle (MLV) (a modified Titan II ICBM) to launch Navstar GPS' starting in 1989. Air force plans call for the system to be fully operational by 1992.

The urgent need for Navstar GPS deployment is not only because of its ability to provide accurate positional information. Navstar GPS satellites will be equipped with an optical sensor, the Integrated Operational Nuclear Detection System (IONDS), developed by Sandia Laboratories to detect nuclear explosions. IONDS will replace the Vela satellites launched by the air force between 1963 and 1970.

Although satellite deployment has been stunted, development of GPS ground receivers continues unabated, with several manufacturers positioned for sales in this market. The DOD estimates purchases of up to 27,000 user sets between now and the year 2000. The Collins Government Avionics Division of Rockwell International produces a family of single-, two-, and five-channel sets which will be used on 214 different types of platforms, ranging from backpacks to F-16s. Under a contract from DARPA, Collins is also developing a miniaturized handheld receiver the same size as a television remote control. Texas Instruments is under contract to the Defense Mapping Agency for its TI 4100 GPS Navigator and has contracted with the air force armament laboratory to manufacture an advanced missiles receiver for precision-guided munitions.

Expendable Launch Vehicles

To ease the backlog created by the failures of the space shuttle and the air force/Martin Marietta Titan 34D rocket, the air force is pressing a variety of expendable vehicles, as shown in Table 8.

The air force and NASA are initiating programs for reinvigorating small launch capabilities. The air force has at least 17 small science payloads for the Space Test Program which await launch. NASA is expected to procure up to 10 Scout-class launchers, with two missions per year from 1991 to 1995. Competitors for the air force and NASA procurements are expected to include American Rocket Company, LTV, and Space Services, Inc. In a related development, LTV and the Italian firm SNIA BPD are upgrading the Scout, the only operational U.S. light launch vehicle. The upgrade will add two Ariance solid rocket boosters to the Scout and will replace its third stage with an improved SNIA BPD motor, doubling the payload to some 1,150 pounds.

In October 1988, the air force plans the first launch of a Titan IV unmanned rocket designed by Martin Marietta. The first launcher was delivered to Cape Canaveral in January 1988 under a $1.5 billion contract for the production of 13 Titan IV launch vehicles. It can be fitted with a General Dynamics Centaur G-Prime upper stage or the Boeing Inertial Upper Stage.

© 1988 Dataquest Incorporated August

Table 8

U.S. Expendable Space Launch Vehicles

Type	Payload*	Status
Scout	260	Operational
Delta	3,500	Operational
Atlas	6,100	Operational
Titan 34D	15,000	Operational
Space Shuttle	26,000	Grounded
Titan II	2,400	Production
Titan IV	17,800	Production
Delta II	5,200	Production

*Approximate payload to 185km in kilograms

Source: DOD Annual Report for Fiscal 1989

For larger payloads, the air force is purchasing 20 Delta II MLVs. The prime contractor for the MLVs is McDonnell Douglas Astronautics. The first seven launch vehicles will be produced under a $316 million contract. The value of all 20 MLVs is estimated at $669 million.

The air force has selected General Dynamics to provide a high performance medium launch vehicle (MLV-2) to launch 10 General Electric DSCS-3 geosynchronous defense communications satellites and one P87-B Navstar technology development satellite. The air force is not buying the launchers, but rather the launch services of General Dynamics, resulting in a cost savings of at least $100 million per flight compared to the space shuttle. The launch schedule calls for four satellite launches in 1991, followed by one per year through 1997.

Special Programs

Spending for highly classified systems is expected to rise sharply as requirements to verify arms control agreements increase. A consensus in congress supports a program to acquire advanced surveillance satellites which would cost an estimated $10 billion over the next ten years. TRW and Lockheed are major contractors in this area, although details are classified.

 © 1988 Dataquest Incorporated August

SHIPBOARD SYSTEMS

The Iraqi attack on the USS Stark in May 1987 triggered a flood of speculation on the vulnerability of U.S. naval forces. Particular attention was focused on the electronic self-defense equipment and warning devices aboard the ship. According to a House Armed Services Committee inquiry, the success of the attack can be attributed to human error: none of the missiles, guns, or chaff decoys were employed once the Iraqi aircraft had locked its radar on the Stark. The only direct result of the Stark incident was a Congressional appropriation of $64 million to buy fire protection devices for surface ship crews.

Table 9 lists the major shipborne systems for the U.S. navy.

Table 9

Major Shipborne Systems

System/Contractor	Description	Status
AEGIS - Raytheon	Surface-air missile system	Operational
ASROC	Antisubmarine weapon	Operational
Vertical Launch ASROC	Antisubmarine weapon (replacement for ASROC)	Production
ASW SOW	Advanced lightweight torpedo	Production
Sea Lance	ASW standoff weapon	Deferred
LAMPS III	Antisubmarine helicopter	Operational
NTDS	Navy tactical data system	Operational
Sea Sparrow Raytheon	Air-to-air missile	Operational
Phalanx General Dynamics General Electric	20mm air defense gun	Operational
SINS	Inertial navigation system	Operational
SIRCS	Ship self-defense system	Development
SLMM	Submarine-launched mobile mine	Operational
SUBACS	Advanced sensor integration, fire control	Development
SUBROC	Antisubmarine missile	Operational
TACTAS Gould	Long-range acoustic detection system	Operational
TOMAHAWK General Dynamics McDonnell Douglas	Long-range cruise missile	Operational

Sources: Jane's Fighting Ships, 1987-88
DOD Annual Report, Fiscal 1989

© 1988 Dataquest Incorporated August

Computers and Signal Processing

As in the case of ground forces and aircraft, naval platforms have taken on a wealth of information processing technology. In addition to the computers needed for virtually every weapon system, for navigation, and for sensor management, there is a need for general purpose computers to perform the daily functions of a ship, in order to cut down the volume of paper produced by administration.

Unisys is providing integration of the high-accuracy navigation system of the Trident II nuclear-powered strategic missile submarine fleet under a contract worth more than $1 billion. Unisys also integrates fire control, command decision, weapons, and other electronics on the navy's FFG-7 Perry-class frigates.

Honeywell has produced an improved version of the Enhanced Modular Signal Processor using VHSIC technology. Designated the AN/UYS-2 navy standard signal processor, the system is used to perform signal processing for antisubmarine warfare and other tactical applications. The Honeywell VSHIC chips can perform 32-bit floating point arithmetic, replacing the existing 16-bit chips. Versions of the AN/UYS-2 are being fitted into submarines, surface ships, helicopters, fixed-wing aircraft, and shore installations.

The navy is in the process of installing the first integrated antisubmarine warfare (ASW) system for surface ships. The AN/SQQ-89 surface ship ASW system will be installed in 133 destroyers, frigates, cruisers, and other ships by 1995. The system includes the GE/Gould AN/SQR-19 tactical towed array sonar (TACTAS) and SQQ-28 Sonar Signal Processing System (SSPS) for the LAMPS Mk III helicopter.

General Electric is performing systems integration for the AN/SQQ-89, while Gould and Edo provide sonar and Unisys supplies data processing equipment. A Westinghouse-led team of IBM, Bendix, and Singer was awarded a second source contract to General Electric for the production of the AN/SQQ-89. The system includes hull-mounted and toward sonar arrays, fusing their data with that obtained from LAMPS Mk III ASW helicopters.

The AN/SQR-17A shipboard sonar signal processor is in production by Diagnostic Retrieval Systems for the FFG-7, DD-963 and CG-47 class ships. Integrated with TACTAS sonar, the system provides a complete ASW combat suite, processing up to eight channels simultaneously.

The wealth of sensor data provided for ASW and other missions places increasing demands on information processing throughput and data display. NAVSEA has begun a program to develop a new generation of onboard computing systems, emphasizing modular components and use of nondevelopmental items under the Next Generation Computer Resources Program.

© 1988 Dataquest Incorporated August

Hughes Aircraft is producing the AN/UYQ-21 surface ship display system for use with sonar and other sensors. Hughes holds orders worth more than $700 million for the displays; the system will be fitted on all U.S. navy surface combatants. A new shipboard display for sonar, the Acoustic Video Processor (AVP), is in development. Hughes is teamed with Honeywell, and Diagnostic Retrieval is teamed with Motorola, for the AVP.

Shipborne ECM

The navy's AN/SLQ-32 is an antiship missile defense system being installed aboard most navy surface combatants and auxiliaries. Plans call for eventual deployment on more than 400 navy ships. Three varieties of the system are being built, depending on the size of the ship and the number of features required. The V-1 model provides warning, identification, and direction of incoming missiles for smaller ships and auxiliaries. The V-2 model, with greater frequency coverage, will be used aboard frigates and destroyers. The largest model, the V-3, includes active electronic countermeasures and will be used on large auxiliaries and cruisers. The V-3 also will be used to replace the Hughes AN/SLQ-17 on aircraft carriers.

The Stark was equipped with the V-2 model of the AN/SLQ-32, which provides warning of an incoming missile but does not automatically jam the missile's radar seeker. Accounts of the incident indicate that operator error was a greater factor than malfunctioning of equipment.

Raytheon is the prime contractor for the AN/SLQ-32; subcontractors include ROLM, Scientific Atlanta Inc., Teledyne CME, Varian, and Watkins-Johnson. Production is scheduled to continue through 1993, and may stretch even further into the future.

The Senate has earmarked $54 million for procurement of the Sidekick electronic warfare system to be deployed on frigates.

Submarine Systems

General Electric has been chosen to develop the AN/BSY-2 combat system for the SSN-21 Seawolf-class attack submarine. The system is currently in full-scale development. The expected cost for development is $1.5 billion. IBM, with Hughes Aircraft, Raytheon, and Rockwell as major subcontractors, has a $1.03 billion contract for development and production of the first five AN/BSY-1 submarine combat systems for the Los Angeles-class (SSN-668) submarines, and has follow-on production contracts totaling $591 million for nine additional systems. IBM also has a $77 million long-lead material contract for four more systems.

© 1988 Dataquest Incorporated August

Unmanned Underwater Vehicles (UUV)

A joint navy/DARPA program is aimed at developing an advanced development model UUV in three or four years. Current funding is $43 million for fiscal 1988-89. Technology for autonomous or remote controlled submarines is further developed than that of similar land vehicles, because navigation in water is simpler than on dry land. Artificial intelligence is being developed for obstacle avoidance and sensor fusion.

Antisubmarine Warfare (ASW) Sensors

ASW is a highly classified area, but a few program details have been made public. The navy is exploring several systems based on distributed signal and data processing, to minimize the time between target detection and delivery of vectoring information to tactical forces. Upgrades to undersea surveillance command, control, and communications (C3) will be required to accommodate these capabilities.

The navy is planning a network of underwater submarine sensors, with spending estimated at $10 million per year for the balance of the 1980s. Total expenditures will be more than $1 billion through the 1990s. Honeywell, AT&T, and McDonnell Douglas are competing for a contract to produce the system. The navy also plans to spend $76 million in 1988 on the Fixed Distribution System, with spending of $112 million planned for 1989. AT&T is the prime contractor, and a second source is being sought.

Antisubmarine Warfare (ASW) Weapons

The Mk 48 ADCAP torpedo has been approved for limited production. Hughes Aircraft will produce 123 torpedoes for $185 million under a navy contract. Hughes and Gould will compete for fiscal 1988 and subsequent orders.

COMMUNICATIONS AND ELECTRONICS

Radar, Sonar, Surveillance, and Reconnaissance

Early Warning Radar

Several programs have made progress in U.S. missile and aircraft detection capabilities. New PAVE PAWS phased array radar have been deployed in Georgia and Texas to close gaps in coverage for warning of submarine-launched ballistic missile (SLBM) attacks. The prime contractor for PAVE PAWS is Raytheon. Upgrades are being performed on the Ballistic Missile Early Warning System (BMEWS). The Distant Early Warning (DEW) line is being replaced by the North Warning System. The SEEK IGLOO program is in the process of replacing all 13 air force long-range radar sites in Alaska with more reliable, solid-state radar to allow lower maintenance and to eliminate the need for on-site radar operators.

 © 1988 Dataquest Incorporated August

A limited portion of the first of four Over-the-Horizon Backscatter (OTH-B) radar stations for the detection of aircraft and cruise missiles has become operational. Located in Columbia Falls, Maine, the east coast OTH-B will detect targets at all altitudes up to the ionosphere at ranges of up to 2,000 nautical miles. Other OTH-B radar will be located on the west coast, the central United States, and Alaska. Production began in 1986 for the west coast system. Site selection is being conducted for the central and Alaska radar systems. Prime contractor for the OTH-B radar is General Electric. Total air force funding for the program is $2.5 billion.

Remotely Monitored Battlefield Sensor System (REMBASS)

The U.S. army REMBASS combines infrared, magnetic, and seismic-acoustic sensors in an early warning and surveillance system. Developed by RCA, REMBASS will be built for hand-emplaced sensors. An earlier version that called for artillery and air-emplaced sensors has been cut for budgetary reasons.

Joint Surveillance Target Attack Radar System (JSTARS)

The army/air force JSTARS has apparently encountered delays in full-scale development, and no date has been published for initial operating capability in the latest DOD Annual Report.

JSTARS is designed to provide a commander with a view of the battlefield stretching back to enemy rear areas. This capability is essential to the deep attacks called for by U.S. Air-Land Battle and NATO's Follow-on Forces Attack (FOFA) doctrine. JSTARS is comprised of a multimode radar aboard an E-8A aircraft (converted Boeing 707-320 jetliner) with associated communications equipment and a mobile ground station for data processing.

Grumman is the prime contractor for R&D of the airborne portion of JSTARS; its team includes Norden Systems and Boeing Military Airplane Company. Motorola was selected as prime contractor for AN/TSQ-132 mobile ground stations, with versions of it to be carried on a five-ton army truck and the AM General High-Mobility Multipurpose Wheeled Vehicle (HMMWV). Approximately half of the total program cost of $4 billion will go toward R&D. Total business volume for JSTARS could reach $20 billion. The air force has requested JSTARS funding of $238 million for fiscal 1989.

Congress has expressed concern about the vulnerability of the JSTARS aircraft, which would be a prime target for enemy surface-to-air missiles (SAMs) and fighters. Consequently, more stealthy platform alternatives are being examined, including an option for an unmanned successor to the E-8A as part of the classified Teal Cameo program.

Advanced Tactical Air Reconnaissance System (ATARS)

The air force/navy ATARS will replace existing film-based sensors on reconnaissance aircraft with electro-optical sensors, allowing recording on digital videotape for replay and analysis. ATARS is in full-scale development. The air force is developing the electro-optical sensor portion, while the navy is responsible for an

 © 1988 Dataquest Incorporated August

unmanned reconnaissance platform, its Mid-Range Remotely Piloted Vehicle. ATARS development funding was $17.7 million in fiscal 1987, $42.8 million in fiscal 1988, and $56.6 million in fiscal 1989. The program is expected to cost as much as $5 billion over the next two decades. Four contractor teams submitted bids for ATARS in July 1987: Control Data, with E-Systems and Northrop; Boeing and General Dynamics; Cubic; and McDonnell Douglas teamed with Unisys. In May 1988, Control Data was awarded a $118 million ATARS development contract for a 56-month program.

Army Night Navigation and Pilotage System

General Dynamic's M1 will be the army's main battle tank well into the next century, and will be utilized by many foreign nations as well. The current production rate of 600 per month is likely to be maintained beyond the year 2000. The army has not begun to formulate plans for a follow-on vehicle.

Upgrades to the basic M1 are in the works for the 1990s. The Army plans to solicit industry bids this summer for a program to develop a thermal night sight, position navigation system, and intervehicular information system for the M1. Hughes is working with the Army to develop a thermal viewer for M1A1 drivers.

Night Vision Systems

New production models of the army UH-60 Black Hawk are being equipped with internal and external lighting systems compatible with night vision goggles. A refit of the entire existing fleet is planned. The army plans to procure 23 MH-60K special operations Black Hawks with integrated avionics systems, external fuel tanks, a mid-air refueling probe, upgraded engines, a FLIR, a terrain-avoidance radar, and a provision for Stinger missiles. According to the prime contractor, Sikorsky, the requirement could increase to 50 aircraft, and deliveries would begin by mid-1991. Sikorsky has awarded IBM a contract to develop the CRT cockpit display for the MH-60K.

Litton was awarded a $278.9 million army contract in 1985 to produce several night vision devices (9,289 AN/PVS-7A night vision goggles, 4,109 AN/PVA-4 night vision goggles, 1,480 MX-9916/UV image intensifier assemblies, 1,942 MX-9644/UV image intensifier assemblies, and 430 MX-10130A image intensifier assemblies). Major subcontractors for the multiyear program are Optic-Electronic and Varian.

Sonar Systems

A new program start for the Advanced Lightweight Sonar (ALWS) is in the works, although a delay to its 1990 budget is likely. The ALWS would replace the AWS-13F presently in service. The program carries a price tag of between $500 million and $1 billion. The AQS-13F is built by Allied-Bendix, which would be a strong competitor for the follow-on.

 © 1988 Dataquest Incorporated August

New sonar and other electronic systems will be needed for naval vessels now in development. The navy's next attack submarine, the SSN-21, is scheduled for initial operational capability in the mid-1990s, but this schedule will likely slip to as late as 1998. The most ambitious change planned for the SSN-21, the Advanced Conformal Sonar Array System (ACSAS), has been dropped because it is too technologically risky and costly. Major modifications to the submarine's hull would have been required for ACSAS, and development could have stretched out as long as 20 years.

Arguably the least glamorous electronic hardware discussed here, sonobuoys play an important role in ASW and are undergoing continual refinement. Sonobuoys are independent, floating systems which gather acoustic intelligence. Low-cost ($30 per unit) sensors are anticipated, as are high-performance recoverable sensors.

Navy Radar Systems

Raytheon produces the AN/SPY-1 radar, the AN/SPS-49 long-range air-search radar, and the MD-99 fire control system for the Aegis-class cruisers. The navy has considered seeking a second source for the SPY-1 radar, but no decisive steps have been taken to achieve this.

Electronic Warfare (EW)

Conventional EW missions can be divided into offensive and defensive—jammers and antijamming equipment. Procurement of new EW equipment has leveled off and may even suffer some small cutbacks in the near-term DOD budget, as shown in Table 10. Requirements for spares, however, will continue to grow.

Table 10

Electronic Warfare Market

Budget Category	1987	1988	1987-1988 Increase (%)	1991	1987-1991 Increase (%)
Procurement	$2.5B	$3.1B	24%	$2.8B	12%
Spares	$351M			$677M	93%

Source: Journal of Electronic Defense

Electronic warfare equipment is fielded in a bewildering variety of systems. Table 11 lists air force EW programs, to give an idea of the number of programs involved.

© 1988 Dataquest Incorporated August

Table 11

Air Force Electronic Warfare Programs

F/FB/EF-111 Self-Protection
EF-11A Upgrade Program
F-4G Wild Weasel PUP
TEREC/ALQ-125
Technique 101 Subsystem
AFEWES Testing-FMS
ASPJ
ASPJ/F-16 Integration and Test
ALQ-131 (V) ECM Pod (R/P)
Countermeasures Systems (QRC 85-04)
EW Area Reprogramming Capability (ARC)
INEWS
MJU-10/B Infrared Flare
Real Time Electronic Digitally Controlled Analyzer and Processor (REDCAP)
RR-180 Dual Chaff
IRCM/Have Charcoal
AN/ALE-47

Source: Journal of Electronic Defense

The following paragraphs survey the larger electronic warfare programs of the Department of Defense.

Airborne Self-Protection Jammer (ASPJ)

ASPJ is an internally mounted electronic countermeasures system for air force and navy tactical aircraft. The ASPJ consists of five line-replaceable units which are interchangeable among all the aircraft equipped with the system. The ASPJ will replace the navy AN/ALQ-126B and air force AN/ALQ-131 on the F-14, F-16, F/A-18, A-6E, EA-6B, and AV-8B aircraft.

The ASPJ has been developed by Consolidated Electronic Countermeasures (CEC), a joint venture formed by ITT Avionics and Westinghouse's Electronic Warfare Division. Production will be split equally between the companies. In late 1987, the navy awarded a $376 million contract to CEC for production of the AN/ALQ-165 ASPJ. Table 12 shows funding and production quantities.

© 1988 Dataquest Incorporated August

Table 12

Airborne Self-Protection Jammer

Procurement	FY 1987	FY 1988	FY 1989
Quantity	6	24	197
Dollars (Millions)	$90	$251	$410

Source: DOD Annual Report for Fiscal 1989

The program currently is in full-scale engineering development, with limited production (192 units) originally scheduled to begin in the first quarter of fiscal 1989. So far, the ASPJ delivery schedule has slipped by two years from navy and air force projections, and the total number of units to be purchased has not yet been established. The plan calls for 2,500 ASPJ systems at a cost of $1.8 billion. CEC is now replacing hybrid circuits with 1.5-um and 2.0-um gate arrays to save space, boost reliability, and cut costs.

F-4G Performance Update Program

The F-4G Wild Weasel has been the mainstay of air force electronic countermeasures platforms. Its capabilities are being enhanced by improved receiver and signal processing capabilities. Under a 1986 contract to McDonnell Douglas, some 150 new units, including spares, will be produced for 119 F-4G aircraft. Unisys is performing the signal processor portion of the program under a $55 million subcontract. A steered, channelized receiver for the F-4G made of five line-replaceable units is being built by E-Systems. A production decision on the units is expected in fiscal 1990.

EF-111A

Several updates are in progress for the EF-111A, including a new pulse processor and an improved system receiver. The 1750A processor, manufactured by GM-Delco under subcontract to Eaton AIL, is a year and a half behind schedule, with test and evaluation to begin in January 1989. Although the 16-bit 1750A standard is being modified to include new requirements, it may be dropped as the Pentagon moves to 32-bit instruction set architecture.

Communications

Upgrades

Antijam capability is being created for fielded communication systems. The Hazeltine CP-1380/VCR Steerable Null Antenna Processor (SNAP), for example, sorts out a desired signal from jamming signals for U.S. army AN/VCR012 VHF-FM transceivers.

© 1988 Dataquest Incorporated August

Mobile Subscriber Equipment (MSE)

Deliveries have begun on test units of the MSE system. Scheduled to be fielded late this year, MSE will feature encrypted, jam-resistant radios based on the French RITA system. MSE was codeveloped by GTE Government Systems Division and Thomson-CSF. U.S. army procurement will include 25,000 telephones, 8,000 mobile radios, and 1,400 switching centers. Total cost of the program is estimated at $4.3 billion, with production expected to last until 1994-95.

MSE must be compatible with a wide range of communications equipment, including Single Channel Ground and Airborne Radio System (SINCGARS), JTIDS, and TRI-TAC. It also will be used in conjunction with army and NATO satellites.

The army, navy, and air force are planning major programs to replace aging inventories of tactical radios. Frequency-hopping capability will be featured in all three systems. Obsolescence is a serious problem: the army still has World War II vintage VRC-12 and PRC-77 radios in service.

Single Channel Ground and Airborne Radio System (SINCGARS)

The SINCGARS will provide frequency hopping VHF communication for a wide range of army units. The army has a requirement for 250,000 to 300,000 radios between through the year 2000 at a cost of approximately $5.5 billion. Annual funding is estimated at $300 million. An airborne version, the AN/ARC-201, is planned for army helicopters.

Unreliable VRC-12 radios in Korea forced the army to ship new SINCGARS units that were still in preproduction. A successful army testing program has increased the mean time between failures (MTBF) of SINCGARS from 200 hours to more than 2,000 hours. ITT has a contract to produce 44,100 SINCGARS if the army exercises all its options.

The U.S. army Communications-Electronic Command (CECOM) dropped Cincinnati Electronics and Magnavox from SINCGARS competition in February 1988. In June 1988, General Dynamics and Tadiran were chosen as a second-source team for SINCGARS.

The House Armed Services Committee has called for a slowdown in the program to allow for additional testing. Accordingly, the house cut the fiscal 1989 budget request for SINCGARS from the $267.2 million requested to $113.2 million.

Have Synch

The air force plans to complete development of the AN/ARC-205 airborne tactical radio and move the program into production by the end of 1988. The service seeks 5,000 Have Synch radios, although budget cuts have forced completion of procurement to stretch from 1994 until 2000. The radio will be installed in close air support aircraft, including the F-16, the A-7 and the A-10. Cincinnati Electronics, a division of the U.K. firm Marconi, is lead developer of Have Synch, with McDonnell Douglas the follower.

© 1988 Dataquest Incorporated August

UHF Have Quick Antijam Radios

Magnavox Electronic Systems Company has been selected as the initial producer of the Have Quick IIA airborne radio. The company already has produced between 12,000 and 15,000 units of the basic Have Quick radio; quantities for the Have Quick IIA have not been released by the air force. A ground vehicle version of the radio is planned.

Army Command and Control System

The army's Command and Control System is composed of five elements: Maneuver Control System, Forward Area Air Defense Command Control and Intelligence System, the Advanced Field Artillery Tactical Data System, the All-Source Analysis System, and the Combat Service Support Control System. The total budget for these elements is slightly more than $7 billion, of which $1.65 billion is to be spent on development.

Advanced Field Artillery Tactical Data System (AFATDS). The army has moved to the forefront in the use of computerized decision aids with the ambitious development of AFATDS. AFATDS is a successor to the Tactical Fire Direction System (TACFIRE); it provides field artillery units with fire control, target analysis, and intelligence. The system consists of processors and workstations for users, who include fire support teams, maneuver commanders, operations people, logistic staff, and intelligence officers.

The program has not been proceeding as quickly or smoothly as planned. Magnavox notified the Army that the development of AFATDS has slipped another nine months, putting the program a total of three years behind schedule. The delays have occurred as a result of serious problems in software development, despite a reduction in the capabilities of the system. The software already surpasses 500,000 lines of code. Its target of 770,000 lines makes it the largest known DOD project to use Ada, a new high-level programming language developed for use on U.S. defense systems. Funding for fiscal 1989 is $17.7 million, up from $14.7 million in 1988 and $10.3 million in 1987.

Light Field Artillery Tactical Data System (LFATDS). The army awarded Litton a sole source contract worth $24.3 million to produce a tactical fire direction system for the seven light infantry divisions. Work on the system is scheduled to be completed by January 1993. This award was made despite the preference of the army for the AFATDS now under development for army heavy-artillery divisions.

Simulation and Training

As funds for field exercises face the budget squeeze, simulations will become even more attractive because of their potential to reduce costs and increase training hours. Although this is particularly true for aircraft, the changing nature of warfare makes armored and even infantry battle sufficiently complex to warrant simulations.

© 1988 Dataquest Incorporated August

All of the services face the same fundamental training dilemma. As weapons and combat become more complex, greater training time is essential. Budget cuts, however, make live exercises with major weapon systems unaffordable. To fill this gap, computerized training systems are growing in importance. Training and simulation hardware and software are approximately a $2 billion market, with moderate growth forecast for the next five years, as illustrated in Table 13.

Table 13

DOD Training Market
Fiscal 1988 to 1992
(Millions of Dollars)

Service	1988	1989	1990	1991	1992
Army	$ 730	$ 870	$ 735	$ 865	$ 900
Navy	1,000	950	900	935	970
Air Force	600	620	745	600	620
Total	$2,330	$2,440	$2,380	$2,395	$2,485

Source: EIA Ten Year Forecast

The architecture of training systems is shifting as greater reliance is being placed on software and simulation data. In many cases, generic interfaces are employed to allow quick changing of different simulated systems. In fact, one can argue that as simulators are more closely resembling fielded systems, systems are becoming more and more like simulators. Sensor results are displayed on computer screens, and no emphasis is given to relying on human eyesight.

Simulators not only are useful in training operators; they also play a valuable role in gathering data on the performance of systems before they are deployed. Pilot workload in various cockpit configurations can be measured and applied to the design of a new aircraft. Other human factors can be applied in simulated combat situations in order to assess human reasoning and reaction time.

The development of new weapon systems depends increasingly upon simulation. Simulation reduces the cost of building a prototype and is safer than flying an untested prototype. R&D simulators also are employed for subsystems such as avionics and weapons to simulate sensor inputs.

 © 1988 Dataquest Incorporated August

Embedded Training

The cost and time required to develop full-mission trainers has increased the appeal of embedded training—using the weapon system itself as the trainer by connecting software-driven scenarios to the system. Embedded training offers the advantage of greater realism and ensures that the trainer is as up-to-date as the operational system. Embedded training also carries drawbacks, however. Costs for adding embedded training equipment to large numbers of systems are high and include not only acquisition but also logistic support. The effectiveness of embedded training may be degraded if prime contractors do not place as much emphasis on the quality of the system's training capabilities as specialized training manufacturers have done in the past.

Software Improvements

Software is central to simulation; therefore, its development can improve simulator performance even more than increases in hardware features can. Grumman Data Systems is exploring a new approach to compressing images of natural scenery on simulators. Rather than depicting every leaf or blade of grass, Grumman portrays objects with simple quadratic shapes such as spheres and cones. This method is 10 times faster than other simulation techniques and uses less storage capacity.

Simulator Networking

Improved training methods have been achieved by linking together a number of simulators in a network, allowing trainees to fight with and against other humans in a simulated environment. The most ambitious program of this kind is Simnet, sponsored by DARPA. The prime contractors are Perceptronics and BB&N. So far, 80 tank and helicopter simulators have been linked successfully in this project, and a network of hundreds is envisioned. The network contains simulations of M1 tanks, Bradley fighting vehicles, a platoon of anti-aircraft missiles, two scout-attack helicopters, two close air support helicopters, and related support elements. The Senate Armed Services Committee has endorsed the Simnet program, authorizing $24 million in fiscal 1989 procurement as part of the army's plan to buy 2,500 Simnet units beginning in 1990.

Other initiatives are underway to connect simulators. The navy is exploring simulator networks for training in antisubmarine warfare, using both surface vessels and helicopters. Singer's Link Flight Simulation Division has connected army AH-64, AH-1S, and UH-60 helicopter simulators together.

Northrop Corporation has developed a manned flight simulator which allows up to nine pilots to fly simultaneously in a variety of scenarios. The laboratory has three cockpits with projection domes and seven simplified cockpits resembling video games. The pilots can simulate different types of aircraft, allowing simulation of operations such as providing air cover for ground attack aircraft. The laboratory is being used in the development of the air force Advanced Tactical Aircraft (ATA), the navy ATA, and the B-2 bomber. It also is employed in a contract for cockpit automation technology by the air force Human Systems Division.

© 1988 Dataquest Incorporated August

The result of these simulator networks is a push toward common standards for simulators. These would include hardware connectivity and shared symbol sets. Singer is developing a black box to connect a number of different simulators.

New Starts

Each major new weapons system in development carries with it unique simulator requirements. For example, Loral has been selected to develop an integrated aircrew instruction program for Lockheed's entry for the air force Advanced Tactical Fighter (ATF).

Naval Simulations

The navy is turning to simulators not only for aircraft training, but also for training in antisubmarine warfare and other operations. Embedded training is more practical for ships than for aircraft due to the smaller premium placed on weight and space aboard a ship. Moreover, computer simulation equipment can be packaged in large containers and loaded aboard or stationed pierside during simulation exercises.

AAI has developed the 20B5 pierside trainer for major Perry-class frigates. The system is housed in a trailer which is parked alongside one or two frigates at the pier. The simulator computer is then connected to the sensors and weapon systems of the ship itself, allowing the crew to work at its actual stations rather than in simulated facilities. Up to 100 targets can be presented in a scenario, ranging from aircraft and missiles to submarines and torpedoes. As shown in Table 14, a wide range of shipborne systems can be simulated.

Table 14

Major Perry-Class (FFG-7)
Systems Modeled by the 20B5 Pierside Trainer

Radar	Weapon Systems
AN/SPS-49	Mk-13 launcher
AN/SPS-55	Mk-75 gun
Mk-92 CAS	Mk-15 Phalanx CIWS
Mk-92 STIR	Mk-309 torpedo tubes
Mk-12 IFF/SIF	Mk-46 torpedo
	Harpoon missile
Communications	Electronic Warfare Receiver
Link-14	AN/SLQ-32
ASW Systems	Decoy Systems
AN/SQS-56	SUBROC chaff launcher
AN/SQR-17	Prairie masker
	NIXIE

Source: Armed Forces Journal

 © 1988 Dataquest Incorporated August

Westinghouse has developed a simulator for the launch of ten Trident II strategic missiles: the Simulated Underwater Partial Launch System (SUPLS II). The simulator can be used for studying effects of the launch on the submarine and for missile launching practice that would not be practical with an operational submarine.

Miscellaneous

The armed forces are turning to modified versions of civilian computers to fulfill military requirements, rather than designing new systems. These non-developmental items (NDI) represent the state of the art, which is driven more by commercial than military needs, and are less expensive to acquire and operate. Gould Computer Systems estimates that commercial equipment is suitable for 80 to 90 percent of defense applications and costs only 10 to 20 percent as much as a computer developed to military specifications.

Each service has a number of programs which entail large computer upgrades, as shown in Table 15. Most funding for automated data processing (ADP) improvements comes from operations and maintenance accounts or industrial funds.

Table 15

Automated Data Processing Modernization Programs
(Millions of Dollars)

	Contract Value
Army	
Standard Depot Systems	$545
Reserve Component Automation System	$500
CALS/TIMS	$250
Corps of Engineers Automation Plan	$178
Integrated Procurement System	$163
Department of the Army Information Network	N/A
Supercomputers	N/A
Commodity Command Standard System	$ 76
Transcoordinator Auto C2 Information System	N/A
Theater Auto C2 Information Management System	$ 50
EUCOM Intel Support System	$ 25

(Continued)

© 1988 Dataquest Incorporated August

Table 15 (Continued)

Automated Data Processing Modernization Programs
(Millions of Dollars)

	Contract Value
Navy	
Engineering Data Management Information and Control System	$200
Personnel and Pay Systems Follow-on	$ 93
DoN Office Automation and Communication System	$ 40
Basis and Stations Information System	$300
Shipyard Upgrades--Numerous Programs	N/A
Paperless Ship Programs	N/A
Consolidated Communications System Replacement	N/A
Information Engineering Automated Support Tools	$ 45
Hardware/Software Material Planning Depots	$ 62
ADP Support AIR-41	$ 49
Software Support NALCOMIS	$ 30
Hardware/Software Replacement Casis II	$ 20
Air Force	
Command and Control System	$437
Capability Assessment Program	$250
Strategic Air Command Ware Planning System	$242
Headquarters Replacement Program	$200
Logistics Information Management Support System	$170
Intelligence Data Handling System	$ 80
AF Logistics Modernization Programs	$ 40
Depot Maintenance MIS	$150
Contract Data Management System	$ 30
Pacific Distribution System	$ 30

N/A = Not Available

Source: EIA Ten-Year Forecast

General Purpose Computers

In addition to microprocessors used in weapon systems and dedicated processors for target acquisition, tracking, and battle management, the U.S. military purchases a substantial number of general purpose computers. The Air Force Computer Acquisition Center (AFCAC) at Hanscom AFB, Massachusetts, presently manages an estimated $1.7 billion in computer contracts.

 © 1988 Dataquest Incorporated August

Zenith has won four major contracts from the air force to supply microcomputers at a value of more than $500 million. These sales are likely to exceed the face value of the contracts. A 1986 air force contract to buy Zenith Z-248 microcomputers over a three-year period resulted in the sale of all 90,000 computers specified for the period in the first year of the contract.

The armed services also represent a large market for superminicomputers and minisupercomputers. Militarized versions of commercial minicomputers are being developed to cater to the government market. Raytheon has introduced a new line of militarized VAX computers matching the commercial VAX 6200 series produced by Digital Equipment Corporation. A request for proposals was issued in late 1987 for purchases of minicomputers worth approximately $4.5 billion in the 1990s. Digital and Wang have chosen to forgo bidding, claiming that system specifications favor AT&T and its UNIX operating system.

New weapon systems introduced into the force posture create commensurate increases in data processing requirements. For instance, the air force Strategic Air Command will need to increase computing capability some 300 percent over the next few years, as new weapons such as the B-2 bomber and rail-based Peacekeeper are deployed.

Software Upgrades

The air force Communications Command will award a contract in the fall of 1988 for the development, integration, and support of standard command and control software and specialized software for all major air force commands. Contract value could exceed $100 million. TRW has teamed with Harris Corporation, Systems Research and Applications Corporation, and Input Output Computer Services, Inc., to bid on the program.

CONCLUSION

This section presented an overview of the major electronics-intensive, production-phase programs. Their status changes periodically, as the annual budget review and program prioritization cycle proceed each fiscal year. The 1988 presidential election will most certainly have an impact on controversial programs; however, in general, we expect most of the policy trends set in place during 1987 through 1988 to continue until the end of the decade.

© 1988 Dataquest Incorporated August

(Page intentionally left blank)

 © 1988 Dataquest Incorporated August

North America—Research and Development Programs

OVERVIEW

North America continues to dominate world production of defense electronics, and the U.S. Department of Defense (DOD) is, by far, the largest buyer. The U.S. R&D budget is particularly electronics intensive, and will become even more so over the next five years. The Electronic Industries Association predicts that the electronics content of the R&D budget will increase from 42 percent to 47 percent in dollar value between 1988 and 1994. New weapons will embody greater electronic content due to the emphasis placed on very high accuracies, sensors able to detect even low-observable targets and to redirect munitions, and new automated techniques for battle management. Electronics are also used extensively in R&D for testing and evaluation of weapon systems and in scientific research and engineering design.

The dollar value of the electronics content of defense R&D is likely to rise from $16 billion in fiscal 1989 to $19 billion in 1994. Communications, surveillance, and related systems will account for the largest portions of these totals (see Table 1).

Table 1

Electronics Content of U.S. Defense R&D Budget
(Billions of Dollars)

Category	1988	1989	1994	CAGR 1988-1994
Aircraft Systems	$ 2	$ 2	$ 2	0
Missiles and Weapons	3	3	4	4.9%
Space Systems	3	3	4	4.9%
Communication and Electronics	3	4	5	8.9%
Other	5	4	4	(3.7%)
Total	$16	$16	$19	2.9%

Source: Defense Forecasts

This section describes DOD technological initiatives that have not yet reached full-scale development, as well as technologies with broad applications across a number of weapon systems.

AIRCRAFT SYSTEMS

The defense department is seeking to develop greater commonality in the avionics of future aircraft, integrating advanced electronic technologies to develop a variety of highly capable, yet more reliable systems. Congress is expected to reinforce its

© 1988 Dataquest Incorporated August

emphasis on avionics commonality. In October 1986, Congress mandated a joint plan with the DOD for fully integrated electronics on all aircraft under development. The armed services responded with the delivery of the Joint Integrated Avionics Plan for New Aircraft to congress in March 1987, followed by the Common Avionics Baseline specifications in June 1987.

The other side of the commonality coin is the growing complexity of avionics software. The Advanced Tactical Fighter (ATF), for instance, is expected to contain about 6 million lines of code per aircraft, double to triple that of the F-15. Another unanswered question is the percentage of commonality that is desirable among a number of systems with discrete missions.

Pave Pillar

The Avionics Laboratory at Wright-Patterson Air Force Base is pursuing the Pave Pillar program to achieve improvements in availability, cost, and mission effectiveness of all future combat aircraft through integration of electronic subsystems. The application of fiber-optic multiplexing and Very-High-Speed Integrated Circuit (VHSIC) technologies can cut the 1,553 cables and 86,000 connections on present tactical aircraft by as much as 35 percent.

Modular system architecture, in both hardware and software, will allow for new mission requirements and upgrades. Pave Pillar divides avionics architecture into mission management, sensor management, and vehicle management. The system is designed around common modules from a limited VHSIC chip set, reducing the maintenance burden. On-board circuitry will isolate faults to the single-module level. The Pave Pillar approach will serve as the model for the ATF avionics suite. According to the DOD Joint Integrated Avionics Plan for New Aircraft issued in March 1987, next-generation fighter aircraft will share the standard 1750A air force architecture.

Modular Avionics Systems Architecture

In a 30-month program that began in December 1987, the air force is holding forums to analyze how Pave Pillar concepts can be applied throughout aircraft in service. If these meetings are successful, the new avionics architecture will be introduced through scheduled modifications.

Pave Pace

The latest DOD avionics initiative, Pave Pace, is aimed at creating the next generation of avionics technologies, including a 32-bit computer, parallel processing, artificial intelligence, neural networks, and optoelectronics. The system is planned to be fault tolerant, allowing malfunctioning components to be bypassed, without seriously degrading system performance. Funding of $150 million is being sought over the next 7 to 10 years.

© 1988 Dataquest Incorporated August

North America—Research and Development Programs

Pilot's Associate

The air force's Wright Aeronautical Laboratories is developing expert systems to help the pilot perform a number of functions, including mission planning, flight control, coordination with friendly aircraft, monitoring of weapons, and warning of threats. Contractors for the $23 million project include Lockheed and McDonnell Douglas.

Cockpit Displays

All the armed services are exploring new technologies for displaying flight information in military aircraft. Air force programs include the McDonnell Douglas Panoramic Cockpit Control and Display System and the Lear Siegler Advanced Graphics Avionics Display System.

Advanced Flight Controls

Many avionics programs are exploring the possibility of new methods of flight control. Voice recognition systems would reduce a pilot's work load by allowing him to call up displays and flight data or perform nonflight critical functions such as changing radio frequencies with his voice. Allied-Signal Aerospace has built a prototype voice recognition system that fits in a 12 x 7.5 x 5-inch box. The next hurdle is to build a system that will recognize any voice, even when subjected to the stresses of high-g flight.

An even more exotic solution is to use the brain waves of the pilot to control flight functions. The Wright-Patterson Aerospace Medical Research Laboratory has performed experiments wherein a human subject could willfully change the intensity of a light and volume of an audio tone by changing his brain waves at certain frequencies. Additional experiments are planned using this control in a roll-axis flight simulator.

Helicopter Avionics

While combat helicopters are included in many joint avionics programs, such as Integrated Electronic Warfare System (INEWS) and Integrated Communications Navigation and Idenfitication Avionics (ICNIA), they have unique requirements. Consequently, R&D is being conducted in avionics for the LHX and V-22 helicopters now in development. When the V-22 is deployed in the early 1990s, it will be the first military aircraft for which full-color displays have been specified from the outset. IBM is subcontractor to Bell/Boeing for integration of the V-22 avionics, with Bendix supplying the processors (two three-channel 1750As) and cockpit displays.

© 1988 Dataquest Incorporated August

MISSILES AND WEAPONS

The U.S. military has to plan for contingencies in which it may fight outnumbered, outgunned, and far away from the United States. To redress these disadvantages, the United States is relying on sophisticated technology to increase the lethality of weapons, along with command and control systems to direct forces where they are needed most. Accuracy has improved dramatically from earlier systems, and on-board guidance for antitank and antiaircraft systems, and even mines, has become commonplace. This increasing technological sophistication has come at an economic price that results in smaller quantities of weapons purchased, however. New missiles and weapons now in development represent the epitome of this approach.

Air Defense Initiative (ADI)

Conceptual development is under way for demonstrating new technologies for air defense deployment in the late 1990s. The primary thrust of the program is to develop broad-area surveillance capable of detecting cruise missiles and low observable aircraft. Contractors participating include Alphatec, Eaton, General Dynamics, IBM Systems Integration Division, ITT, Lockheed, Sensis, Sparta, Syracuse Research Center, TASC, TRW, and Verac.

The master plan for the ADI would include integrated sensors, radar, and weapons aimed at destroying Soviet Blackjack and Backfire bombers and cruise missiles.

Progress in the ADI cannot be expected to follow that of the high spending for the Strategic Defense Initiative (SDI). For fiscal 1989, for instance, the U.S. House of Representatives cut the air force request of $138.9 million for ADI surveillance technology to zero.

Advanced Interdiction Weapon System (AIWS)

Three teams, Boeing/Honeywell, Texas Instruments/TRW, and McDonnell Douglas/ Hughes, have been formed to compete for the navy's AIWS, a program to replace several of its older air-to-surface missiles. The navy intends to award four competitive 18-month demonstration/validation contracts this summer.

Focal Plane Array Initiative

The focal plane array initiative aims at developing reliable manufacturing techniques for infrared sensor arrays. The program was decimated by a congressional budget cut from the $45.1 million requested to only $2.0 million for fiscal 1988. Further cuts were made in the fiscal 1989 budget, with the administration requesting only $23.5 million, less than one-third of what was sought for the program. Officials hope for a program start in fall 1988.

 © 1988 Dataquest Incorporated August

SPACE

Space R&D includes satellite communication and surveillance, military space vehicle research, and space-based weapons. All other defense R&D programs for space are dwarfed by the SDI. Nearly $12 billion has already been spent on the early stages of SDI, with expenditure of roughly $4 to $5 billion per year expected through the early 1990s.

Strategic Defense Initiative

The largest single U.S. military R&D effort is the SDI, which is actually a conglomeration of dozens of programs and includes participation from all the military services.

SDI is now at a crossroads. Some individual technologies that would be applied in the system have shown considerable progress in research. Consequently, the Defense Acquisition Board recommended in September 1987 that a phase-I system, incorporating both ground-based and space-based components, be advanced to the demonstration and validation phases.

Despite technological progress, doubts about the feasibility of strategic defenses remain. The fate of SDI will rest in the hands of congress and the next administration. Skepticism on Capitol Hill has been reinforced by the May 1988 report on SDI by the Office of Technology Assessment (OTA). According to excerpts from the report, the OTA concludes, "Many questions remain about the feasibility of meeting SDI goals." The report also concluded that the software needed to destroy thousands of incoming missile warheads probably could not be produced in the foreseeable future and cautioned that the sheer complexity of a strategic defense system suggested that "there would always be irresolvable questions about how dependable...(the computer) software was." An internal DOD study raised additional questions about the feasibility of the space-based SDI components and suggested that the system initially be restricted to ground-based interceptors. This would be comparable to a plan advanced by Senator Sam Nunn (D-Ga.), chairman of the Senate Armed Services Committee, who suggested that the SDI be used initially to protect against accidental launch of ballistic missiles.

In fiscal 1988, congress cut the SDI request from $4.8 billion to $3.7 billion. As a result, many SDI programs have been restructured. The Rockwell Space-Based Interceptor project was allocated $205 million of the $296 million requested, for example. The Lockheed Exoatmospheric Reentry Vehicle Interceptor System (ERIS) was allocated $140 million in 1988, $70 million less than requested. The Boost Surveillance and Tracking System (BSTS), with Grumman and Lockheed designing competing versions, also is being restructured, as is a $332 million contract with McDonnell Douglas for a five-year effort on the High Endoatmospheric Defense Interceptor (HEDI). Major subcontractors for HEDI include Hughes and Aerojet.

© 1988 Dataquest Incorporated August

Despite budget cuts, at roughly $4 billion per year, SDI remains a big business. The top SDI contractor thus far, Lockheed, has received awards totalling $1.6 billion. General Motors came in second, with $881 million. Moreover, a large proportion of SDI funding is devoted to electronics. In 1988, for instance, the surveillance, acquisition, tracking, and kill assessment portion of SDI came to $1.5 billion, while $1.1 billion was spent on directed energy weapons.

In 1988, the SDI Organization (SDIO) is expected to issue sensor system research contracts for a neutral particle-beam sensor system ($25 to $35 million), a long-wave infrared sensor mated with a ground-launch system ($700 to $800 million), and an optical sensor requirements contract ($5 to $7 million). The SDI components of greatest interest from an electronics perspective include the following:

- The Battle Management and C3 (BM/C3) systems would tie together the elements of any strategic defense system, processing raw data from sensors, issuing target assignments to interceptor weapons, conveying this information to the Strategic Defense System (SDS) commander, carrying out the orders of the commander, monitoring the results of the engagement, and refining responses. The BM/C3 system, much of which necessarily would be in space, must be able to withstand enemy jamming as well as nuclear blasts.

- The Boost Surveillance Tracking System (BSTS) is a surveillance satellite with potential applications beyond SDI. The BSTS is in the demonstration/ validation phase. Major contractors include Lockheed ($329.9 million) and Grumman ($329.4 million).

- The Space-Based Surveillance and Tracking System (SSTS) is a lower-altitude satellite system than the BSTS. Trade-off studies have been under way for the past two years on the design of the system, with high cost a persistent problem cited by the SDIO. LTV's Missile Division was awarded a $30 million contract for advanced electronic subsystems for the kinetic kill vehicle of the space-based interceptor program.

- The Ground-Based Surveillance and Tracking System (GSTS) is the subject of a major contract due to be awarded in 1988. Boeing, Lockheed, and McDonnell Douglas are the leading contenders. Raytheon is the prime contractor for a ground-based radar experiment to serve as an SDS midcourse sensor. Raytheon claims that a ground-based sensor system could be deployed and maintained for less than $5 billion over its lifetime—considerably less than the cost of space-based sensors—and is proposing a rail-mobile, phased-array radar.

- The Exoatmospheric Reentry Vehicle Interceptor System (ERIS) contract awarded to Lockheed in 1986 was originally valued at $468 million over a five-year period. Under a subcontract to Lockheed, Texas Instruments will build the seeker for ERIS.

 © 1988 Dataquest Incorporated August

- The SDI Test Bed contract was awarded to Martin Marietta in early 1988. It was a five-year, $508 million contract to build and operate an SDI "test bed" to simulate and test concepts for a strategic defense system. The test bed program is likely to take on increasing importance, as cuts in the SDI budget make expensive space testing less feasible. Major subcontractors for the test bed are: Carnegie-Mellon University, Computer Technology Associates, Ferranti (United Kingdom), Hughes, IBM, Nichols Research, Ralph M. Parsons Co., and Singer-Link.

Beyond the present hardware R&D work, the SDIO is beginning to consider the operation of a space-based defense system. According to an SDS architecture report, space-based support capabilities would be required to service and upgrade elements of the system in space. The support would be provided by space-based support platforms, telerobotic services, orbital maneuvering vehicles, and fluid transfer systems. In May 1988, the SDIO selected General Electric to serve as systems engineer and integrator under a $236 million contract.

The defense industry has found SDI contracts to be a mixed blessing. Contractors are reportedly becoming disillusioned with the procurement instability of the SDIO. According to an air force memo, "We have broken faith with the government/industry team by wasting (its) time and talent on false starts and terminated contracts."

Satellites

LIGHTSAT is a five-year Defense Advanced Research Projects Agency (DARPA) program whose goal is to demonstrate a low-cost satellite responsive to the commanders' needs in war. Guidelines call for limiting booster and payload costs to less than $20 million. LIGHTSAT design contracts worth $300 million were awarded to Lockheed, LTV, Space Services, Inc., and TRW. Other companies that have shown interest in the program include American Rocket and Orbital Sciences. DARPA has plans to develop a variety of LIGHTSATs, including communications satellites, position-locating satellites, and at least one sensor package for weapons targeting. Defense Systems Inc. has been awarded a contract for the LIGHTSAT payload design. Plans call for launch of six LIGHTSAT spacecraft in July 1989 on two launch vehicles. An LTV Scout rocket launcher will be used for at least one launch; a booster deployed from a B-52 aircraft is also being explored.

Antisatellite Warfare

In 1985, congress halted testing of the air-launched miniature vehicle (ALMV) antisatellite (ASAT) program, built by LTV, which was just entering production. The defense department has now terminated the program and is shifting its efforts toward the development of advanced technologies, especially ground based lasers, for the antisatellite mission.

© 1988 Dataquest Incorporated August

Future Launch Vehicles

Listed below are some of the more important developments in vehicles that lift payloads into orbit:

- The Advanced Launch System (ALS) is an air force program whose goal is to find new ways to launch large payloads, such as those required for SDI, into orbit. The goal of the program is to develop the capability to lift payloads from 40,000 to 150,000 pounds into low earth orbit, at a cost of no more than $300 per pound. The ALS will emphasize reliability through redundancy and technological features such as fiber optics, simple avionics, and prepackaged payloads. The program is worth approximately $10 billion over the next 10 years, with an electronics content of about 40 percent.

- General Dynamics won an air force competition to develop the Medium Launch Vehicle II (MLV II), an expendable launch vehicle for military and commercial applications; the ultimate value of the contract will exceed $500 million. The General Dynamics Atlas Centaur II missile will be able to launch 6,000 pounds into geosynchronous transfer orbit. A modification of the current Atlas Centaur, the new system will feature increased booster engine thrust, stretched propellant tanks, a low-cost avionics system, and a flight computer. The losing contract team was that of McDonnell Douglas and Martin Marietta.

- DARPA is also launching development of a Standard Small Launch Vehicle (SSLV), with plans to fund multiple, concurrent four-month studies at $300,000 each. Characteristics of the SSLV would include inexpensive production and operation, use of unimproved launch sites, horizontal prelaunch, and launch flexibility.

National Aerospace Plane (NASP)

The DARPA $3.3 billion X-30 NASP is the largest experimental aircraft project ever undertaken by the United States. The goal of the program is to develop hypersonic technology (Mach 5 to 15), using hydrogen-fueled scramjet propulsion. The program is highly classified and contains a number of military objectives. A civilian transport could emerge from the research eventually, but is not likely before the turn of the century.

The program has been delayed by at least one year due to funding constraints, and further delays can be expected. Current plans call for phase-II, exploratory development to continue until 1990, when a decision would be made whether or not to proceed with full-scale development. If so, three experimental vehicles would be built, with first flight anticipated in 1994 or 1995. Annual appropriations, planned for $350 million in fiscal 1989, will rise to $620 million in fiscal 1991 and then decline until actual procurement begins.

© 1988 Dataquest Incorporated August

General Dynamics, McDonnell Douglas, and Rockwell have been selected for airframe designs, while Pratt & Whitney and Rocketdyne are collaborating on the scramjet element of the program. Rocketdyne, with the assistance of Aerojet, will begin hypersonic engine tests in late 1988. If the program continues as planned, one engine and one airframe contractor will be chosen to develop the X-30 prototypes. Contractors are said to have invested $120 million of their own funds in the program.

During the past year, the program has concentrated on basic designs, computational fluid dynamics modeling, and materials. The major contractors are expected to subcontract about 70 percent of the materials work to universities and other companies. General Dynamics will lead work on carbon structures; McDonnell Douglas on a titanium matrix using silicon carbide fibers; and Rockwell on titanium aluminides. A significant milestone was reached when the initial test of the Pratt & Whitney Mach-14 engine was conducted early this year. Development of electronics for the NASP will likely begin in two to three years.

COMMUNICATIONS AND ELECTRONICS

Electronic Warfare (EW)

More than 400 signals intelligence and EW systems are in the U.S. inventory. The market for EW systems grew at an average rate of 25 percent from fiscal 1982 through 1985 but has since leveled off at about $3 billion annually. This figure is likely to increase in the early 1990s, however, when the next generation of EW systems goes into production.

A total of $554 million in DOD funding for EW R&D was approved in fiscal 1988, 75 percent of the original budget request (see Table 2). The importance of EW is reflected in the fact that these programs, though suffering some cutbacks from the proposed fiscal 1989 budget, have emerged largely intact from the budget maelstrom. As shown in Table 2, army programs have even taken a significant upturn in funding.

Table 2

Electronic Warfare RDT&E Funds
(Millions of Dollars)

	1988 Request	1988 Appropriation	1989 Request
Army	$ 50	$ 85	$ 91
Navy	310	196	205
Air Force	284	273	253
Total	$644	$554	$549

Source: Defense News

© 1988 Dataquest Incorporated August

The key programs include those described in the following paragraphs.

INEWS

The largest EW program in history, INEWS will be standard equipment aboard the next generation of combat aircraft, including the air force's ATF and B-2, and the navy's ATA. It will be used to replace the AN/ALQ-165 airborne self-protection jammer on existing aircraft.

In a radical departure from past designs, INEWS will share common processors and antennas among the aircraft's electronic systems, allowing weight, space, and cost reduction. INEWS will incorporate the latest microelectronics technologies, including VHSIC and Microwave/Millimeter Wave Integrated Circuit (MIMIC).

Two industry teams are working on demonstration and validation of the system: TRW/Westinghouse (with Honeywell, Perkin-Elmer, and Tracor as subcontractors) and Sanders Associates/General Electric (with HRB-Singer and Motorola as subcontractors). Full-scale development (FSD) is scheduled to last from late 1988, when an FSD contract is awarded, to fiscal 1992. The development cost of INEWS has been estimated at $500 million, with production estimates of $7 billion. The contractor teams that develop the system will compete for the production contract.

Airlift EW

The need to protect airlifters from missile attack has spurred new programs for electronic countermeasures (ECM). The air force is testing the Lockheed Survivability Augmentation for Transport Aircraft-Now (SATIN) ECM package for the C-130 transport. Lockheed is also conducting design studies on the C-141 and C-5 transports. The SATIN system is unique because it can be installed temporarily in a single eight-hour shift, allowing kits to be prepositioned in high-threat areas, rather than fitted to the entire cargo fleet. Lockheed has delivered a similar prototype of a defensive electronic countermeasures system for the marine corps' fleet of KC-130 Hercules tanker aircraft. The marine corps version is not removable; it includes the APR-39 (V)1 radar warning receiver, AAR-47 missile detection system, and ALE-39 chaff and flare dispensing system.

A U.S. Government Accounting Office (GAO) report renewed criticism of the navy and air force for failing to promote commonality in their radar warning receivers. The report cited failed attempts to merge the air force's AN/ALR-69 upgrade (now designated AN/ALR-74) with the navy's AN/ALR-76. The report said that the two services are acquiring nine different radar warning receivers at a total cost of more than $6.6 billion. The air force is conducting a fly-off competition between the Litton AN/ALR-74 and the Loral AN/ALR-56M for the General Dynamics F-16 aircraft.

Expendable Jammers

The DOD is conducting a classified program to develop expendable jammers. The fiscal 1988 budget request was fully funded by congress.

 © 1988 Dataquest Incorporated August

Electro-Optic Countermeasures (EOCM)

A new niche is beginning to appear in the defense electronics market. As every military measure begets a countermeasure, the increasing use of laser guidance and optical detection will create a need for EOCM.

The largest current DOD EOCM program is the advanced optical countermeasures (Coronet Prince) program, a pod-mounted system that warns aircraft crews when they are spotted with a laser. The system would respond with a laser to blind air defense personnel and disrupt optical tracking. After testing several EOCM systems aboard an E-4 aircraft, the air force has selected the Westinghouse AN/ALQ-179 EOCM pod for production. The system will be used on high-performance tactical and special-purpose aircraft.

Additional possibilities for EOCM abound. Optical chaff could be developed to confuse laser-seeking missiles, or optical decoys may be deployed in the same way that electronic decoys are presently used.

Communications

Even as advances in microelectronics have reduced the cost of telecommunications components, new measures to ensure the survivability of communication have stretched development and increased unit costs. Each of the services is modernizing its own communications systems, and commonality among the services is being promoted.

TRI-TAC

The DOD Joint Tactical Communications Program, TRI-TAC, provides common ground-based tactical digital communication for all the services. The program includes mobile and transportable multichannel systems for voice and data communication. Contractors are Martin Marietta, Raytheon Co., and General Atronics Corporation.

Worldwide Military Command Control System (WWMCCS) Information System

The WWMCCS Information System (also known as WIS) will provide crisis planning and execution aids to the National Command Authorities and specified and unified commands. When it is completed after 1993, it will replace the WWMCCS hardware and modernize its software. WIS includes local area networks, automated message handling, intelligent workstations, modern processors, data base management, and multilevel security systems. The prime contractor is GTE Government Systems Corporation.

Ground-Wave Emergency Network (GWEN)

GWEN will provide U.S. strategic forces with critical communication, despite high-altitude nuclear bursts, by proliferated radio relays using ground-wave radio equipment. The prime contractor is RCA.

© 1988 Dataquest Incorporated August

Aircraft Alerting Communications Electro Magnetic Pulse (EMP) Program

BDM Corporation is the air force's prime contractor for the development of assured, EMP-hardened, end-to-end communication from the commander in chief of the Strategic Air Command to his alert aircraft forces.

Maneuver Control System

Lockheed Missiles and Space Company demonstrated the first phase of the maneuver planning systems under a three-year, $19 million contract for the army and DARPA. The program is aimed at demonstrating the capability of an expert system to speed mission planning, based on army doctrine and practice for corps operations.

Joint Tactical Fusion

The Joint Tactical Fusion program involves coordination of the army's All-Source Analysis System (ASAS) and the air force's Enemy Situation Correlation Element (ENSCE) to analyze target data from all sources on the battlefield and in the air. The prime contractor is the Jet Propulsion Lab, with Martin Marietta serving as systems integrator. Principal subcontractors include American Development Corporation, Analytic Inc., BDM Corp., Boeing Aerospace, Cyberchron, Electrospace Systems Inc., Emerson Electric, Ford Aerospace, GE, HRB-Singer, Informatics General, McDonnell Douglas, Mitre, TRW, and United Technologies, Norden Division.

Table 3 shows the sources of intelligence data to be fused by ASAS/ENSCE:

Table 3

ASAS/ENSCE Components

System	Service
AN/USD-9 Guardrail	Army
AN/ALQ-133 Quick Look	Army
AN/APS-94 Side-Looking Radar	Army
AN/ALQ-151 Quick Fix	Army
AN/MSQ-103A Teampack	Army
AN/TXQ-114 Trailblazer	Army
AN/MLQ-34 Tacjam	Army
AN/TSQ-112 Tacelis	Army
REMBASS	Army
RF-4C	Air force
SR-71	Air force
TR-1	Air force
EC-135	Air force

Source: Defense Electronics

© 1988 Dataquest Incorporated August

Information Processing System

The air force is developing a new command and control system for the Military Airlift Command (MAC) to automate tracking of airlift aircraft and crews worldwide. The Information Processing Systems (IPS) will link 155 nodes, each ranging from a single microcomputer to a network of 20 terminals, by high-frequency radio, UHF, VHF, and UHF satellite terminal systems. Four companies have been selected for systems architecture and engineering studies on IPS: Computer Sciences Corporation, Contel, GTE, and TRW. Each contractor will receive $900,000 to develop specifications for the system. The production contract for IPS is expected to be worth from $200 to $300 million.

Data from the system will be fed into MAC's Global Decision Support System (GDSS), which tracks all operations for command authorities. Three of the seven GDSS sites will be equipped with 12 x 35-foot large-screen displays developed by TRW. GDSS was developed in two years, at a cost of $28 million. The project was thought originally to require 10 years and $100 million for completion. The savings are a result of using off-the-shelf Digital Equipment Corporation computers along with custom software written by the Jet Propulsion Laboratory.

COMPUTING TECHNOLOGY

DOD is pursuing several technological initiatives that will have application to large numbers of future weapon systems. Particular emphasis is being placed on semiconductor programs, because of their centrality to nearly every modern major weapon system. Military systems require extremely fast processing for advanced sensors, avionics, electronic warfare, and fire control systems. Unlike commercial computer applications, in which delays may be tolerable, in military applications, human lives depend on faster military computers.

Artificial intelligence is employed increasingly for surveillance and target acquisition systems. Radar, optical, and infrared systems must be able to distinguish their targets from ground clutter and other signals, even in the midst of a complex, rapidly changing battlefield environment.

Computers are also used away from the battlefield, in the DOD offices and research laboratories. Management information systems have become ubiquitous in all the armed services. Computer-aided design, modeling, and other automated tools are used to speed development of new systems, and for testing and evaluation.

The management of some of the Pentagon's biggest electronic projects has been shifted from DOD to DARPA. In April 1988, five programs were moved to DARPA: the industrial consortium SEMATECH, MIMIC, infrared focal plane array, and two software programs—the Software Engineering Institute and Joint Software Technology for Adaptable, Reliable Systems (STARS).

© 1988 Dataquest Incorporated August

VHSIC

The VHSIC program is a DOD program for developing very-large-scale integrated circuits for military systems. Launched in the early 1980s, the $1 billion program has resulted in faster chips that will be used for real-time processing of images and signals, automatic target recognition, infrared focal plane steering and scanning arrays, and fusion of sensor data.

Phase I of the program resulted in 1.25-micron chips with functional throughput 100 times greater than that of commercially available integrated circuits. The six contractors participating in phase-I contracts are Hughes Aircraft, Honeywell, IBM, Texas Instruments, TRW (teamed with Motorola), and Westinghouse (teamed with National Semiconductor).

Phase II has produced 0.5-micron chips that increase processing power by 1,000 percent. IBM claims to be the first to produce a functional phase-II chip containing 37,000 logic gates and operating at 100 MHz, four times faster than phase-I chips. Other phase-II contractors include Honeywell, Motorola, TRW, and Westinghouse.

The first operational installation of VHSIC was in the F-111D signal transfer unit, replacing 102 integrated circuits with one VHSIC chip. As a result, reliability of the unit increased by a factor of 125, while the cost dropped from $24,000 to $2,000. In congressional testimony, acting Deputy Undersecretary of Defense for Research and Advanced Technology George Millburn noted that, by 1989, the VHSIC program will complete development of a chip containing components as small as 0.5 microns, yielding a fifty to a hundredfold increase in signal-processing capability over present VHSIC devices. Air force VHSIC funding is $44.1 million for fiscal 1989.

MIMIC

A growing number of military systems depends on sophisticated sensors for operation, but analog circuitry for such sensors continues to be very expensive. The MIMIC program is aimed at reducing the cost of these components, making advanced sensor technology more widely available and affordable than ever before. The means for this improvement is monolithic solid-state technology, using materials such as gallium arsenide. In addition to operating at higher frequencies (MIMIC targets 300 GHz), gallium arsenide offers the advantages of greater radiation hardness than silicon, extremely low-noise signal amplification, and a wide range of operating temperatures.

Commercial demonstrations of MIMIC technology already have been made on a small scale; the MIMIC program will mobilize the U.S. electronics industry behind this effort. The market for such devices could be huge. Industry observers predict that individual defense programs could require as many as 200,000 GaAs chips per month; the entire U.S. electronics industry produced only 300,000 GaAs chips in 1987.

© 1988 Dataquest Incorporated August

An integral part of the MIMIC program is the creation of faster, less expensive tools for radio frequency (RF) circuit design. The TRW MIMIC team is developing expert-based software to cut the design and layout time by as much as 97 percent—from four weeks to two hours. Libraries of circuit designs will be stored to guide engineers in developing new chips.

Like VHSIC, MIMIC will have broad application in a number of military systems, as shown in Table 4. The program has been divided into four phases. Initial study contracts (so-called phase 0) for the MIMIC program will be completed in 1988. Sixteen teams from 48 organizations were chosen in January 1986 for phase I of MIMIC, to explore a wide range of fabrication technologies for gallium arsenide. The teams that have received major phase-0 contracts ($750,000 to $1 million) are listed in Table 5.

Table 4

MIMIC Applications

Contractor	System Type	Army	Navy	Air Force
Allied-Bendix	Communication Radar	Mark XV Fuze Patriot	Mark XV	Mark XV
Ball	Communication Radar	MILSTAR	MILSTAR Airborne Multimode	MILSTAR
Eaton	EW	MEDFLI	ALR-77	ALQ-161
E-Systems	Communication	GPS	GPS	GPS
Ford	Smart weapons	HARM, Low-Cost Seeker	AMRAAM	
	EW	APR-39	Expendable decoys, APR-39	ALR-46,-62,-74 APR-39
	Radar	Phased array	Phased array	Phased array
Harris	Communication	MILSTAR, GPS, Antijam datalinks, JTIDS	MILSTAR, GPS, Antijam datalinks, JTIDS	MILSTAR, GPS, Antijam datalinks, JTIDS
Hittite	Smart weapons	MOFA		

(Continued)

 © 1988 Dataquest Incorporated August

Table 4 (Continued)

MIMIC Applications

Contractor	System Type	Army	Navy	Air Force
Hughes	Smart weapons	TOW	OABM	AMMW seeker
	EW		ASAP, expendable decoy	
	Radar	Firefinder	SBR	ATF, ATSR, SBR
ITT	EW	ALQ-136, LHX	ALQ-136,165, INEWS	ALQ-165, INEWS
	Radar	ETAS, Firefinder		ATSR, SBR
Loral	EW	RWR, expendables	RWR, expendables	RWR, expendables
Martin Marietta	Smart weapons	SADARM, MLRS, TGW	Low-Cost Seeker	Terminal, guidance
Raytheon/TI	Smart weapons	SADARM, MOFA	HARM	Terminal, guidance
	EW			Active arrays
	Communication	MILSTAR, GPS	MILSTAR, GPS, ICNIA	MILSTAR, GPS, ICNIA
	Radar	ETAS, Patriot	SBR, shared aperture	ATSR, SBR
Sanders	Smart weapons	MOFA	EX-60	INEWS
	EW	INEWS	INEWS, AAED, expendable decoys, ASAP, ALQ-126	
	Communication	MILSTAR	MILSTAR	MILSTAR
TRW	Smart weapons	SADARM, MLRS-TGW	Standard missile	AMRAAM
	EW	MEDFLI	INEWS	INEWS
	Communication	MILSTAR, GPS	MILSTAR, GPS, ICNIA	MILSTAR, GPS, ICNIA

(Continued)

© 1988 Dataquest Incorporated August

Table 4 (Continued)

MIMIC Applications

Contractor	System Type	Army	Navy	Air Force
Unisys	Smart weapons	MLRS-TGW, SADARM, STAFF		AMMWS
	Communication	Tactical radio	Tactical radio, MMW Spacelinks	Tactical radio, MMW Spacelinks
Westinghouse	EW	INEWS	ASPJ, INEWS	ASPJ, ALQ-131, INEWS
	Communication	GPS, JTIDS	GPS, JTIDS, ICNIA	GPS, JTIDS, ICNIA
	Radar		ATA, ASAP	ATF

Source: Defense Electronics

Table 5

MIMIC Phase-0 Contractors

Army	Navy	Air Force
Eaton	Allied Bendix	Harris
ITT	Ford	Hughes
Martin Marietta	Raytheon	Sperry
TRW	Sanders (Lockheed)	Westinghouse

Source: Dataquest
August 1988

Phase I, with a planned three-year duration, will culminate in a demonstration of MIMIC hardware in an operational environment. DOD has narrowed the number of phase-I contractors to four teams. These are led by Martin Marietta/ITT (Watkins-Johnson and Pacific Monolithics as subcontractors), TRW, Raytheon/Texas Instruments (Teledyne, Monolithic Microwave, and Consilium as subcontractors), and Hughes/General Electric (Harris Microwave as subcontractor). The Martin Marietta/ITT

 © 1988 Dataquest Incorporated August

and TRW teams will develop MIMIC for the army. The navy contractors are Raytheon/Texas Instruments; Hughes/General Electric will work on air force applications. Second sources will be selected for all components in this phase.

During another three-year phase (phase II), technological improvements to MIMIC will continue, perhaps using more exotic materials, with additional technological demonstrations. Phase III will run concurrently with phases I and II of the program. Its activities will center on ancillary research, including computer-aided circuit design and new testing approaches. The MIMIC budget totals $536 million from fiscal 1987 through 1993. The fiscal 1989 request was for $67.1 million.

Semiconductor Manufacturing Technology

This year, DOD launched a new initiative aimed at redressing the erosion of the U.S. defense industrial base semiconductor manufacturing capability and reducing dependence on imported semiconductors. According to congressional testimony, this new initiative—the Semiconductor Manufacturing Technology program—is aimed at establishing a facility in which a wide range of manufacturers can jointly pioneer advanced semiconductor manufacturing techniques.

The research will be carried out by SEMATECH. The DOD funding for Semiconductor Manufacturing Technology was $98 million in fiscal 1988. Congress raised the DOD funding request of $44.8 million in fiscal 1989 to $100 million. The total annual operating budget of the consortium is estimated at $250 million, to be shared evenly between government and industry. After five years of DOD funding, SEMATECH plans to become autonomous.

SEMATECH has begun construction of a research facility in Austin, Texas. Completion of the facility's first clean room has been delayed from August to November to achieve a lower particulate count and better humidity, temperature, and vibration control.

DARPA Strategic Computing Program

The Strategic Computing Program is aimed at developing machine intelligence and parallel processing architecture to serve the needs of the military and keep the United States at the forefront of commercial computing technology. Using advanced very-large-scale integration (VLSI) chips in multiprocessor systems, the program engineers intend to demonstrate performance that is 1,000 times faster than that of existing computers. Other initiatives are aimed at exploring artificial intelligence for military systems, such as the development of the Martin Marietta autonomous unmanned vehicle. The Pilot's Associate Program applies artificial intelligence, advanced sensors, and a voice interface to the cockpit, creating an artificial "copilot." Artificial intelligence will also be used increasingly as a decision tool in battle management.

© 1988 Dataquest Incorporated August

North America—Research and Development Programs

Consolidated DOD Software Program

First unified in the fiscal 1989 budget request, the Consolidated DOD Software Program contains three elements: the Ada standard programming language, the STARS program, and the DOD Software Engineering Institute. DOD is emphasizing the use of standardized, tested common software modules for military applications. This approach will speed development and increase reliability of systems. The DOD Software Engineering Institute will help expedite the adoption of advanced software engineering in military systems, aiding developers in all military agencies.

Future DARPA Initiatives

Spurred by the success of MIMIC, DARPA is pushing for speedy introduction of GaAs circuits in current military systems. In the spring, DARPA solicited proposals for a program to design, demonstrate, and test digital GaAs circuits for systems that require superior electronic performance. A contract award is anticipated this year. Military radar would be a prime candidate for such an application. KOR Electronics has squeezed the functions of 16 100K ECL chips into a single GaAs gate array, cutting power requirements and size, and boosting speed.

DARPA and the air force are starting a program for faster production of military application-specific integrated circuits (ASICs), as part of the Microelectronics Manufacturing Science and Technology program. Texas Instruments is a front-runner as contractor for the program.

Photonics

Although no specific programs for research into photonics technologies have been initiated, a growing consensus is that, for many applications, electronics will be supplanted by photonics, using light beams instead of electrons to store and transmit information. The most widespread application of photonics, at present, is in fiber optics. It offers the advantages of high bandwidth, speed, and resistance to electromagnetic pulse and other effects that damage electronic components. Optical disk storage will also be a growth area for military applications.

© 1988 Dataquest Incorporated August

Western Europe Military Electronics Programs

OVERVIEW

Within Western Europe, key market segments are dominated by France, West Germany, and the United Kingdom. Some of these distinctions will fall with the internal trade barriers in Europe in 1992; other distinctions began to fade in the early 1980s with such collaborative programs as ESPRIT, EUREKA, and the MEGA-Projekt between Philips and Siemens. Although these projects seek to improve civilian electronics technologies, Western European and NATO military programs are certain to benefit. Greater collaboration, as well as rationalization of national industries through 1992, will have a further effect on U.S. ability to penetrate the Western European military electronics market.

FRANCE—OVERVIEW

France procures a full array of weapon systems, including advanced aircraft, strategic and tactical missiles, nuclear-powered aircraft carriers, frigates, nuclear attack submarines, and space systems. Fiscal pressures, however, are causing stretch-outs in many French weapon programs. Budget cuts announced in 1989 have prompted rescheduling of the following programs:

- AMX-30 B2 modernization program—Cut
- Amethyste-class nuclear attack submarine—18-month delay
- Atlantique 2 surveillance aircraft—From 5 year to 3 year procured
- Battlefield surveillance radar (on Super Puma)—One-year delay
- Charles de Gaulle-class aircraft carrier—Two-year delay
- LeClerc main battle tank—Total buy cut from 1,400 to 1,050
- Light frigates—One-year delay
- Mirage 2000 aircraft—From 33 year to 28 year procured
- Rafale aircraft—11-month delay
- Rafale naval version—Introduction delay to 2002

The fate of two major missile programs, the S-4 mobile land-based strategic system and the Hades short-range missile, was still formally undecided in June 1989, but it seems increasingly likely that the S-4 will never be deployed, while elimination of the Hades is a near certainty.

© 1989 Dataquest Incorporated October

PROGRAMS

Rafale Aircraft

France dropped out of the European Fighter Aircraft (EFA) program in 1986 to pursue its own new fighter aircraft, the Rafale. The Rafale will serve primarily in an air-defense capacity for France, which will rely on the Mirage 2000 N for strike roles. The Rafale will be armed with an antiradar missile and laser-guided missiles, as well as the MICA and Magic 2 air-to-air missiles. The Rafale also will incorporate terrain-avoidance capability, with track-while-scan radar and simultaneous ground attack/air defense scan modes.

A joint company, Avion de Combat European (ACE) International, was established by the four primary Rafale contractors—Dassault-Breguet (60 percent), SNECMA (20 percent), Thomson-CSF (10 percent), and Electronique Serge Dassault (ESD) (10 percent). Dassault-Breguet will build the airframe and SNECMA will manufacture the M88 engine for the Rafale. Thomson-CSF and ESD competed for the radar contract; a decision was made in December 1988 for collaborative development. The radar will be based on Thomson-CSF's RBG (formerly RDX) multimode phased array radar. Thomson-CSF, with 66 percent of the work, will concentrate on the antenna and air-to-air operating modes; ESD will be responsible for electronic counter-counter measures (ECCM) and air-to-ground operating modes. The $318 million radar contract, which eventual worth could total approximately $1.6 billion, was awarded to Thomson-CSF and ESD in April 1989. The contract covers prototypes and flight testing. The radar features the passive electronically scanned Radant antenna, currently scheduled for flight tests in 1991. Based on a programmable signal processor operating at 1 Gflops, the radar will have simultaneous bidirectional scanning. Avionics will include the following:

- GPS navigation receiver—Crouzet
- Main mission computer—ESD and Sagem
- Sigma RL 90 gyro laser inertial navigation system—Sagem
- Holographic HUD, eye-level display, radant antenna—Thomson-CSF
- ECM suite—Thomson, with ESD and Matra
- Optronic air-to-air fire control—To be determined

Rafale development is expected to cost approximately $6.4 billion, with about $2.7 billion to be spent between 1988 and 1991. In April 1989, $2.5 billion worth of incrementally funded contracts were awarded to Dassault and SNECMA for development and prototype production of the Rafale and its engine. The first prototype is scheduled to fly in 1991, with full-scale production beginning in 1994 and service introduction in 1996.

© 1989 Dataquest Incorporated October

Production costs for 300 aircraft were estimated in May 1989 at $15.9 billion, or $53 million per aircraft; export sales are expected to raise the contractors' revenue base significantly. In early 1989, Belgium decided not to participate in Rafale procurement, thus eliminating one potential customer.

Atlantique 2 Maritime Surveillance Aircraft

Manufactured by Dassault-Breguet, first-lot production Atlantique 2 (ATL 2) aircraft entered the flight-testing phase of development in early 1989. The French navy plans to order 11 aircraft, and the Italian navy is considering upgrading its own fleet of ATL-1 aircraft. Given the small number being procured, the program stretch-out from five per year to three per year will have a major impact on cost.

Missile Programs

Aerospatiale is the largest French manufacturer of missiles, followed by Matra. Three key French missile programs are the Aster, the MICA, and the MISTRAL. The Aster, a version of the Terrier, is a new antimissile missile developed by Aerospatiale. In late 1988, an agreement between the French and Italian governments made the program bilateral. France plans to deploy a 15km-range version of the Aster with the Thomson-CSF Arabel radar on Charles de Gaulle-class aircraft carrier in 1998. Italy plans to deploy its own Empar radar (developed by Marconi and Selenia) on a 30km version and add the Thomson-CSF Astral long-range surveillance radar. The MICA is an air-to-air missile developed by Matra. Marconi and ESD are collaborating on an active seeker for the MICA. The MISTRAL is a 90mm missile with a 6km-range for use against aircraft. Armed with a 3kg warhead, the MISTRAL uses an infrared seeker. The French army ordered 2,300 in early 1989; Italy may negotiate a licensing agreement for the MISTRAL.

Ships and Shipboard Equipment

The first Charles de Gaulle-class nuclear-powered aircraft carrier was scheduled for commission in 1996, but it appears that its introduction into the French navy will be delayed until 1998. The first sections were assembled at Brest Naval Dockyard in April. France plans to procure two carriers to replace Foch and Clemenceau conventionally powered aircraft carriers.

In 1989, France completed two large shipbuilding programs: the Georges Leygues-class destroyer program and the Eridan-class minehunter. At present, France is developing a prototype for the Iris-class P 140 antiaircraft warfare patrol boat, that was built by Chantiers de l'Esterel. Shiphandling and engine trials were completed in March 1989; the prototype was fitted with Thomson-CSF's Crotale Modulaire surface-to-air missile in the summer of 1989 and began weapon trials in the fall.

© 1989 Dataquest Incorporated October

France's nuclear-powered attack submarine program reached a milestone last year when the fifth Rubis-class SSN, the Amethyste, was launched. France plans to procure eight submarines from 1988 through 1995. The Amethyste is a considerable improvement over the initial four SSNs, which will be upgraded to the Amethyste standard in the upcoming years. Work on the sixth and seventh submarines in the class has started; the eighth and final submarine will be ordered at the end of 1989 and will enter into service after 1995. A follow-on program to the Rubis-class SSN is planned by France for the next century. DCN is the program manager; other contractors include the following:

- Technicatome—Nuclear reactor
- Thomson-Sintra ASM—Underwater detection equipment
- Thomson-CSF—Communications equipment
- Sagem—Control station, search and attack periscopes, integrated navigation system, and data management
- Creusot-Loire—Sheet steel
- Framatome—Turbines
- Jeumont-Schneider—Diesel-electric propulsion
- Merlin Gerin—Electric equipment

The first of a new generation of nuclear-powered ballistic missile submarines, Le Triomphant, is under construction and is planned to enter service in mid-1994. Delays in developing the M5 missile for the vessel have resulted in plans to procure an interim missile, the M45.

LeClerc Tank

Fiscal 1990 defense budget cuts are expected to trim procurement of the LeClerc main battle tank from 1,400 to 1,050 tanks. Expected to enter service in 1991, 65 percent of the $4.5 million tank's cost is allocated for electronic systems. GIAT is the prime contractor; subcontractors include the following:

- ESD—Main computer
- CSEE—On-board video equipment and electric motors
- Sagem—Gunner's sight
- SFIM—Tank commander's sight

 © 1989 Dataquest Incorporated October

Space Program

France has an active space program and will be expanding its military satellite program. In December 1988, Minister of Defense Jean-Pierre Chevenement revealed a 15-year military space program that would increase funding, as well as increase European cooperative efforts. The plan calls for spending approximately $7.4 billion. In addition to existing programs, the plan would add a radar-based reconnaissance satellite, a ground-based space surveillance system, and an electronic intelligence satellite.

France will contribute about $1.1 billion between 1987 and 1991 to two satellite programs developed jointly with Italy and Spain. The programs are the Helios military observation satellite and the Syracuse communications systems satellite. Another major program is the Telecom satellite. Helios is the successor to the SAMRO program, which was abandoned by France and West Germany in the early 1980s. Initiated in 1986, three Helios observation satellites should be launched beginning in 1993. Syracuse I provides secure telegraph and telephone communications; it will be replaced by Syracuse II beginning in 1992. Approximately 50 receiving stations will be procured and will be tied to tactical receiving stations on submarines, light navy vessels, and aircraft. Syracuse I and II satellites compose the military segment of the Telecom satellite program. In 1991, France hopes to launch three Telecom 2 satellites, which will operate in the super high-frequency range. Telecom 3 satellites are scheduled to be launched in 1998 and will expand coverage to the extremely high-frequency range.

RAMSES

The French Ministry of Defense formally accepted the initial components of a new command and control network that will link France's nuclear forces with government authorities. The RAMSES system was designed and will be produced by Thomson-CSF and is scheduled to become fully operational in 1993.

UNITED KINGDOM—OVERVIEW

Defense spending in the United Kingdom is increasing relative to other members of NATO, but only within the context of depressed defense budgets worldwide.

PROGRAMS

Aircraft

Of the $14.0 billion the United Kingdom plans to spend on development and procurement during the next fiscal year, $4.2 billion is allocated for new aircraft and support equipment and about $1.1 billion for aeronautical development, including the U.K.'s portion of the EFA. Table 1 shows aircraft that the United Kingdom has on order.

© 1989 Dataquest Incorporated October

Table 1

U.K. Aircraft on Order

Aircraft	Number	Manufacturer
Tornado GR.1 strike/attack	53	Panavia
Tornado F.3 air defense	55	Panavia
Harrier GR.5 support	60	British Aerospace
E-3 early warning	7	Boeing
Tristar tankers	5	Lockheed
Tucano trainers	118	Short Bros./Embraer
Sea King helicopters	7	Westland and Sikorsky
Lynx helicopters	16	Westland

Source: Defense Forecasts

The Mid-Life Update program for the Tornado GR.1 strike/attack aircraft will cost approximately $204 million in development; 11 contracts were awarded in March 1989, split among Ferranti, GEC, and Smith. Among the improvements to the Tornado are a GEC forward-looking infrared system, Ferranti night-vision goggles, a Smith head-up display, a GEC Spartan terrain navigation system, and a Ferranti terrain following system. All weapons will be compatible with the MilStd 1760 architecture. Marconi also will supply a new radar and the Sky Shadow jammer to upgrade the Tornado's electronic warfare capability. The air-defense version of the Tornado also is being upgraded: Stage 2 of the upgrade, scheduled to start in mid-1991, will incorporate a new computer and tracking system software.

Upgrades of the Lynx and Sea King helicopters are in progress as well. In the spring of 1989, Ferranti was awarded a $17 million contract to provide Lynx and Gazelle helicopters with the AWARE radar warning receiver. The Lynx also will receive new sensors such as the GEC Sea Owl thermal sensor and the CAE/Normalair-Garrett magnetic anomaly detector. The Mk6 version of the Sea King entered service in the summer of 1989; two improvements were the addition of GEC's AQS-902G-DS processing system and Plessey's Type 2069 improved dipping sonar.

Ships and Shipboard Equipment

The Royal Navy is authorized to procure two Vanguard-class nuclear submarines that are now under construction and plans to procure two additional Vanguard submarines. All of these will be used to carry Trident missiles. The Vanguard is the single most expensive U.K. naval procurement program. Early in 1989, Plessey delivered the prototype Sonar 2054 to the Royal Navy; Plessey holds contracts for two production sonars, each of which is valued at $35 million.

 © 1989 Dataquest Incorporated October

Yarrow Shipbuilders launched the first and third Duke-class (Type 23) frigates in mid-1989; five more are planned. The United Kingdom also plans to buy Sandown-class minehunters; the first of five was completed in early 1989 by Vosper Thorneycroft. The Sandown will be the basis for the Single-Role Minehunter program, a joint venture between the United Kingdom and Spain. Under this program, a total of 12 ships will be procured through 1995. Spain plans to buy 4 minehunters and 4 minesweepers, each fitted with two Pluto remotely piloted vehicles built by the Italian company Intermarine.

Future programs for the Royal Navy include a design for replacing the light aircraft carrier HMS Invincible. Likely to be conventionally propelled, the follow-on to the Invincible will feature space for 20 to 25 aircraft and a flat deck and launching ramp for VSTOL aircraft and helicopters. In March 1988, a request for proposals for the next-generation attack submarines, designated the W- or SSN-20 class, was issued. The SSN-20 class will replace Valiant- and Churchill-class submarines. The first SSN-20 submarine was to be ordered in 1990 and scheduled for completion in 1997, but the order has been postponed by at least three years.

Command and Control Systems

The Improved U.K. Air Defense Ground Environment C2 System (IUKADGE/ICCS) program is about five years behind schedule and $200 million over budget. Designed to link air- and ground-based radars and command centers for U.K. air defense, the largest obstacle for the IUKADGE has been software; contractors have been using a mix of CORAL, FORTRAN, and RTL 2 programming languages. The total program cost is estimated to be approximately $1.7 billion; the prime contractor is UKADGE Systems Ltd., a consortium that comprises Hughes Aircraft, Marconi, and Plessey. More than 80 percent of the IUKADGE program is funded by NATO.

The U.K.'s army will attempt to overcome certain software and hardware barriers to command, control, communications, and intelligence (C3I) by creating the Land System Reference Center, a facility to develop prototypes and test battlefield C3I systems. The Land System Reference Center, which should open its doors in 1992 or 1993, will allow testing in a simulated battlefield environment; namely, software test and configuration tools will be developed and evaluated.

Missiles

Key British missile programs currently in development include the air-launched anti-radiation missile (ALARM), the anti-radiation drone, and the low-level laser-guided bomb. British Aerospace developed the ALARM for Harrier, Jaguar, and Tornado aircraft, but it encountered several setbacks. When the original motor failed to meet specifications, the introduction date slipped to the mid-1990s.

© 1989 Dataquest Incorporated October

The United Kingdom announced its requirement for an antiradiation drone, or SR(A) 1232, in late 1988. A less expensive way of defeating rear-echelon forces than the ALARM, the drone is the subject of a study by Hunting Engineering and Marconi. Collaboration with West Germany is possible, given their similar requirement. Expected to be introduced into service in the mid-1990s, the drone will use a laser-guided bomb to attack high-value stationary targets. Four contractors have lined up to compete for the low-level laser-guided bomb program: British Aerospace, Matra, Tricon/Texas Instruments, and the U.S. Naval Weapons Center in China Lake, California. Matra's proposal will build on its experience in developing laser guidance; China Lake will offer a modified AGM 123A Skipper developed from the Paveway II. Texas Instruments and Tricon have teamed to offer the Paveway III. Tricon is a consortium established in 1988 of MBM Technologies, Computing Devices, and Portsmouth Aviation.

FEDERAL REPUBLIC OF GERMANY—OVERVIEW

As part of the allocation of limited West German defense funds away from procurement towards research for the EFA (see the following subsection), several programs, including modernization of the Alpha jet-bomber and the procurement of six submarines from Thyssen and Howaldtswerke-Deutsche Werft, were cut. Unlike France and the United Kingdom, there are few major indigenous West German procurement programs. West Germany places a strong emphasis on cooperative programs.

PROGRAMS

Aircraft

After canceling Alpha modernization, West Germany opted to buy 35 additional Tornados at prices ranging from $100 million to $200 million. The reconnaissance version of the Tornado, the ECR, will be fitted with improved optical and electronic sensors. In April 1989, CAE Electronics GmbH was awarded a $49 million contract to develop a simulator testbed to improve low-level flight training. Following completion of the testbed, CAE expects to win a $305 million, two-year contract to upgrade the seven flight and tactics simulators originally built for the Tornado. The West German air force also hopes to upgrade the RF 4E Phantom to improve accuracy and reliability of the inertial platform.

Type 123 Frigate

The Frigate 123 is the largest West German procurement program for 1989. Four F-123-class frigates are planned to enter service from 1994 through 1996. The original design was a collaboration by the Blohm & Voss and Bremer Vulkan shipyards, but each subsequently submitted separate and competing proposals; the Blohm & Voss design was

© 1989 Dataquest Incorporated October

selected in October 1988. Blohm & Voss teamed up with Howaldtswerke-Deutsche Werft and Thyssen Nordseewerke; work will be shared equally among them. The total program will cost approximately $1.2 billion.

In May 1989, Hollandse Signaal Apparaten (NL) was selected to provide radar equipment for the frigates after intense competition from Hughes Aircraft and Plessey. Signaal's system combines the LW08 high-power, long-range, D-band surveillance and target indication radar with the SMART F-band acquisition radar and the Signaal Track and Illumination Radar (STIR). Other subcontractors include the following:

- AEG—FL-1800 S Step II Electronic Warfare system; optical laying devices
- Anschuetz/Teldix—Navigation systems
- Krupp Atlas Elektronik—Sonar system
- Krupp/Unisys—Integration of surface components of weapon control system
- Hagenuk, Rohde, & Schwarz—Communication equipment

Future procurement of ships for West Germany will include a Type 124-class frigate in 2000 to replace Type 122 frigates, Type 212 submarines, which could enter service by 1995, and Type 332 minehunters. Messerschmitt-Boelkow-Blohm (MBB), which is developing the combat system for the minehunters and is the prime contractor, expects the Type 332 to enter into service in 1992.

ITALY—OVERVIEW

Although procurement scandals rocked the Italian defense establishment earlier this year, major acquisitions have been proposed between 1989 and 2000 for the Italian armed forces. The proposals relate to air defense, particularly ship-based, and enhancement of the mobility and infrastructure of the ground forces. The Ministry of Defense's ambitious plan calls for $20.5 billion to be spent during the next decade; a more modest and realistic plan of $8.9 billion, however, could be presented to the Italian Parliament this year.

Among the programs, the Garibaldi light aircraft carrier will be equipped with fixed-wing aircraft, most likely AV-B Harriers or Sea Harriers. The Italian defense budget allocated $22 million in fiscal year 1990 and $72 million in fiscal year 1991 for this purpose. A new main battle tank, the C-1 Ariete, will replace the army's current fleet of 300 M60A1 tanks, and a new tank destroyer, the B-1 Centauro, will replace 450 M47 tanks. The budget calls for $362 million from fiscal year 1989 through fiscal year 1991 for armored vehicles, most of which will go toward the C-1. The Italian army's fleet of Leopard 1 vehicles currently in service will be upgraded; in particular, a new fire-control system will be applied. Further in the future, a new infantry fighting vehicle, the VCC-80, is expected to be procured. Total funding for these fighting vehicles from fiscal years 1989 to 1991 is $448 million.

© 1989 Dataquest Incorporated October

PROGRAMS

Aircraft

The largest Italian procurement program is the AMX tactical fighter, developed jointly with Embraer of Brazil. The defense budget included $1.8 billion from fiscal year 1989 through fiscal year 1991 for this program. A total of 17 aircraft are on order by both Italy and Brazil. In March 1989, Aeritalia and Aermacchi contracted FIAR to provide the GRIFO ASV multimode radar for the AMX fighter. The first flight test for the radar is scheduled for 1990, with integration of the radar and aircraft scheduled for 1991. Italy expects the AMX to be in service in 1991 or 1992. The AMX will supplement the Tornado attack aircraft for the maritime strike role.

Italy also entered into a cooperative development program for the EH-101 multirole helicopter with the United Kingdom and Canada. The Italian armed forces expect to spend close to $79 million during the fiscal years 1990 and 1991 on the EH-101. A contract for radio communications and navigation systems for the navy version was awarded in February 1989 to Elmer ISC, an Italian subsidiary of Ferranti. The internal communications system will use fiber-optic technology for data transmission and meets Tempest requirements. Other components include a high-frequency transceiver with an AN/16-C loop antenna and a modem compliant with MilStd 188-203-1A. Italy expects to procure 42 EH-101 aircraft beginning in 1993; the United Kingdom requires 50, and Canada is considering purchasing 50 as well.

C-1 Ariete Rank

The Ariete main battle tank marks a decisive move for Italy away from foreign licensing practices of the past. The first prototype of the C-1 was manufactured in 1986; all six prototypes were completed last year. OTO-Melara, the prime contractor, has teamed with Iveco Fiat. Melara will be responsible for the body of the tank, and Fiat will focus on the turret and weapons. The C-1 will incorporate the Officine Galileo Tank Universally Reconfigurable Modular System (TURMS). The Italian army may accept the C-1 in late 1989 or early 1990, with initial production expected to begin in 1992; total procurement is expected to be 200 to 250 tanks.

Ships and Shipboard Systems

The fifth of eight vessels in the Minerva-class corvette program was launched in early 1989, as were the first three of four Cassiopea-class patrol vessels. All were built by Fincantieri. Two guided-missile destroyers, the Animoso and the Ardimentoso, currently are under construction as well.

 © 1989 Dataquest Incorporated October

Satellites

Italy will invest $637 million to launch Satellite Italiano per Comunicazione Rapide e Allarmi (SICRAL), its first military telecommunications satellite, by 1994. Research and development (R&D) of the satellite, the prime contractor of which is Selenio Spazio, will cost $159 million; procurement and launch will run another $478 million. The two satellites will use UHF, SHF, and EHF bands.

CATRIN

A consortium of six major Italian companies was awarded a $650 million contract to design and develop CATRIN, an advanced network of sensors and communications gear for surveillance, targeting, fire control, and data management on the battlefield. Italtel, Marconi Italiana, Telettra and are responsible for the communications subsystem (SOTRIN), Agusta and Selenia for the air defense subsystem (SOATCC), and Aeritalia for the surveillance and target acquisition subsystem (SORAO). The Italian defense budget for fiscal years 1990 and 1991 includes a total of $180 million for CATRIN.

SIACCON

The Italian army is drawing up plans for SIACCON, an automated command-and-control system. Although the program is still in its early stages, two Italian industry consortia have already formed to bid for contracts. One group consists of Agusta, Honeywell Bull, Italtel, Selenia, SEPA, and Telettra, and the other comprises Aeritalia, Marconi Italiana, and Olivetti. SIACCON will interface with several existing and planned C3I systems, the major example of which is the CATRIN integrated communications and information system.

NORWAY—OVERVIEW

Norway spends on a per capita basis more for defense than any other West European country. Although legislation restricts markets for foreign sales, Norwegian companies have had some successes in penetrating the U.S. and other markets in recent years.

PROGRAMS

Norwegian Advanced Surface-to-Air Missile System (NASAMS)

The NASAMS will adapt the Hughes' AIM-20 AMRAAM for surface-to-air use as part of the Norwegian southern air-defense system upgrade. Beginning in 1991 or 1992, Norway hopes to replace Nike missile batteries with two full batteries of NASAMS. The

© 1989 Dataquest Incorporated October

six-year program will include a total of 18 launchers with 118 AMRAAM missiles; the three-phase contract is valued at $215 million.

The NASAMS fire unit will consist of a Hughes TPQ-36A 3-D low-altitude surveillance radar, a fire distribution center manufactured by Norsk Forsvarsteknologi A/S (NFT), and three missile launcher subunits, each with six missiles. A battery will consist of three fire units.

HKV, a joint venture of Hughes Aircraft and NFT, was awarded $13 million in early 1989 for a Phase I demonstration and evaluation of the surface-to-air application of the AMRAAM. The contract involves software modification rather than hardware modification. Hughes will act as the systems integrator, conducting flight tests and analyses and developing system specifications. NFT will analyze and modify software as well as develop launcher specifications.

Phase II of the contract will include full-scale development of the system; Phase III includes production. The contract also includes an option to replace six adapted HAWK northern air-defense batteries.

Penguin Mk 3

NFT began series production of the Penguin Mk 3 antiship missile in mid-1989. This third-generation antiship weapon will be used on Norway's F-16 A/Bs; it also is being procured in the United States. The Penguin Mk 3 features a passive infrared seeker and a 120kg warhead; it has a range of more than 50 kilometers.

SWEDEN—OVERVIEW

Sweden does not belong to NATO and therefore has both an independent military and arms industry. Like Norway, its arms exports are restricted but sophisticated. Sweden has had some success in exporting electronic components such as radars.

PROGRAMS

JAS-39 Gripen

The Swedish fourth-generation fighter program, the JAS-39 Gripen, suffered serious problems early this year beginning with the February crash of one of the prototypes. Since then, debates in the Swedish government have led to the possibility of canceling the program and buying U.S. F-16s. In March 1989, both the F-16 and the JAS-39 were chosen as finalists in the competition to replace the fleet of Drakens (43 in total) by 1996.

© 1989 Dataquest Incorporated October

Already one year behind schedule, cost overruns have equaled approximately $1.2 billion in a program that was projected to cost only $6.4 billion altogether. The current estimate of the program's total cost of $7.6 billion equals the entire 1987 to 1988 Swedish defense budget.

Sweden planned to build five prototypes and 30 initial production planes with an option for 110 aircraft overall. The prime contractor is Saab-Scandia, which will act as systems integrator. Other contractors include the following:

- Volvo-Flygmotor—Engine
- Ericsson Radio Systems—Multimode radar, on-board computers, avionics
- FFV Aerotech—Support, maintenance
- Lear-Siegler—Flight control

RBS 90 SAM

Bofors' RBS 90 surface-to-air defense missile currently is in production for the Swedish government; first deliveries are expected in 1990. RBS 90 consists of Ericsson Radar Electronics' helicopter/aircraft radio detection system (HART), the Giraffe 75 command, control, and communications system, and the RBS 70 Mk2 missile. In early 1989, Ericsson Radar Electronics was awarded a $70 million contract for Giraffe systems, which will track, identify, classify, and designate targets. Bofors was awarded a $33 million contract in January 1989 for an undisclosed number of RBS 90 systems.

JOINT EUROPEAN PROGRAMS—OVERVIEW

A surge of joint European defense programs in recent years is making an effort to achieve economies of scale and reduce dependence on military technology from abroad. Many of these projects stumbled because of divergent requirements of individual nations, as well as funding difficulties that multiply with the number of countries involved. In cases where U.S. technology is involved, export restrictions sometimes have been a drawback. The major European projects that will have significant electronic content are described in the following subsections:

European Fighter Aircraft (EFA)

The EFA is being developed jointly by Italy, Spain, the United Kingdom, and West Germany. A multirole fighter, the EFA will feature fly-by-wire controls, stealth characteristics, composite materials, look-down-shoot-down radar, terrain-following capability, and multiple target-acquisition systems.

© 1989 Dataquest Incorporated October

Development work on the aircraft has been divided among the four members of the Eurofighter consortium, according to the proportion of planes each country plans to buy: British Aerospace of the United Kingdom (33 percent), MBB of West Germany (33 percent), Aeritalia of Italy (21 percent), and CASA of Spain (13 percent). A four-country agreement was signed in May 1988, authorizing full-scale development of the EFA, with contracts worth close to $8 billion signed in early 1989. Production is scheduled to begin in 1995, with initial deployment in 1996, but this schedule is not likely to be met. The program calls for 765 aircraft to be produced through 2005, although more may be added later to accommodate foreign sales. Development costs for the EFA are estimated at $10.8 billion, with procurement to run another $36.0 billion.

Electronics manufacturers will be the main beneficiaries of the EFA program, because avionics systems are expected to account for at least one-half—and perhaps as much as 65 percent—of the total cost. Although most of the electronic components still are in early conceptual stages, a four-country consortium has formed to bid on design and production of the EFA's digital fly-by-wire flight control system. The consortium is made up of Aeritalia, Bodenseewerk Geratetechnik (West Germany), GEC Avionics (United Kingdom), and Inisel (Spain). A group led by FIAR of Italy also was formed to develop the infrared search and track system for the EFA. Other members of the group include Eltro of West Germany and Thorn-EMI of the United Kingdom.

Of the EFA's components, its multimode pulse-Doppler radar system requires the longest lead time in development and paces the development of other items. The Eurofighter consortium planned to award a development contract in September 1988, but controversies led to a delay. Two multinational industry teams—one led by Ferranti Defense Systems (United Kingdom), and the other by AEG (West Germany) and Marconi Defense Systems (United Kingdom)—are bidding fiercely for the contract. Ferranti's proposal, the ECR-90, is based on radars developed for Sweden's JAS-39 Gripen program and in service with the United Kingdom's Royal Navy Harriers. The ECR-90 will use a high-power signal processor that incorporates Ericsson's 32-bit D80A chip and will have a computational throughput that is six times greater than the Hughes (United States) APG-65. AEG's proposal, the MSD 2000, is based on Hughes' APG-65 radar.

The radar selection already is one year overdue and, accordingly, the delivery of the first 12 flyable preproduction radar units has slipped to November 1991. The entire radar program is expected to be worth approximately $1.8 billion. Work on radar development and production eventually will be divided among the four EFA participating countries in the same ratio used for the program overall—33 percent each for the United Kingdom and West Germany, 21 percent for Italy, and 13 percent for Spain.

Selecting a contractor for the EFA's aircrew training system was much easier. Rediffusion Simulation (United Kingdom) won a contract from the U.K.'s Ministry of Defense for the second stage of a three-phase study in training analyses. Rediffusion Simulation will look at the most cost-effective way of integrating training devices with actual flight training.

 © 1989 Dataquest Incorporated October

Advanced Airlifter

Lockheed (United States) formed a study team in 1987—the Future International Military/Civil Airlifter (FIMA) group—to design a replacement for C-130s and C.160 Transall European airlift aircraft. Other companies involved in this study include Aeritalia, Aerospatiale (France), British Aerospace, CASA, and MBB. In June 1989, the European participants decided to abandon FIMA and form their own European Future Large Aircraft Group (Euroflag). Euroflag members estimate a total requirement of 1,500 airlift aircraft; a feasibility study funded at $15 million annually is under way.

PAH-2/HAC-3GT/HAP Franco-German Helicopter

France and West Germany are working together to develop and produce a new combat helicopter that will be produced in the late 1990s. The constant dollar cost of the program is projected at $8.5 billion, with development costs of $1.8 billion and production costs of $6.5 billion (tooling and finance costs round out the total). The total cost in current dollars is estimated at $16.9 billion. Two versions of the helicopter are to be produced, one for antitank missions and one for escort and fire support. West Germany plans to purchase 212 PAH-2 antitank versions, and France expects to purchase 140 HAC-3GT antitank versions and 75 HAP escort versions.

Of the real procurement costs, $1.3 billion is earmarked for mission equipment packages, that include navigation aids, observation equipment, weapon sights, fire control gear, and a mast-mounted avionics package. The main contractor for the mission equipment packages will be SOFRADIR, a French joint venture owned jointly by CEA Industries, SAT Control, and Thomson-CSF. French and West German subcontractors will be involved. In January, three teams made bids for the avionics and mission management contracts valued at more than $100 million. The teams comprise ESD (France) and Litef (West Germany); Bodenseewerk Geratetechnik and Societe Francaise d'Instruments de Mesure (SFIM) (France); and a team made up of Crouzet (France), MBB's Dynamics Division (West Germany), SFENA (France), and Teldix (Bosch) (West Germany). The division of labor for the third team is as follows:

- Crouzet—Sextan strap-down inertial navigation computer; sensors
- SFENA—Laser ring gyros
- Teldix—CMA 2012 pulse doppler radar
- Dynamics Division—Compact radio altimeter

France and West Germany also will jointly develop infrared charge-coupled device (IRCCD) technology for the helicopter's optronic systems. The main contractor for the helicopter program as a whole is Eurocopter, a consortium of Aerospatiale and MBB. The first helicopter prototype is scheduled to fly in April 1991, with production deliveries scheduled to begin in 1995 and 1996. It should be noted that the program already has a long and difficult history and that both France and West Germany are

© 1989 Dataquest Incorporated October

rumored to want to drop out because of cost projections, which are much higher than originally expected. These pressures may be behind negotiations with Westland Helicopters (United Kingdom) to join the program.

Tonal LAH Helicopter

The Tonal LAH helicopter program, which involves Italy, the Netherlands, Spain, and the United Kingdom, will produce an improved version of the Agusta A-129 Mangusta helicopter. A feasibility and cost definition contract was awarded in May 1987 to Joint European Helicopters, a joint venture of Italy's Agusta (38 percent), Westland Helicopters (38 percent), the Netherlands' Fokker (19 percent), and CASA (5 percent). Decisions on the major design options, including the choice of an avionics package, were to have been made in late 1988, but delays pushed those decisions to late 1989 or 1990. The program has been fraught with disagreements on technical requirements for the helicopter. Italy, under the strain of defense budget cuts that equal one-half its $22 billion procurement budget, seeks a less expensive and ambitious plan than the one put forward by the United Kingdom and the Netherlands. In particular, Italy wants to stick close to the A-129 Mangusta, a light helicopter that probably could not carry TriGAT antitank missiles. The Netherlands, on the other hand, stated that it would pull out of the program if the LAH compromise does not include the ability to carry TriGAT missiles and maintenance of the original time schedule. The Netherlands, which does not have a combat helicopter fleet, plans to procure 50 Tonal LAH helicopters for $850 million.

Possible commonality with the Franco-German helicopter is also being explored by the Tonal LAH sponsors, with common avionics, engines, optronics, and weapon systems all being considered in the interest of economy.

NATO Helicopter for the 1990s (NH-90)

France, Italy, the Netherlands, and West Germany are cooperating in the development of the NH-90, a twin-engine helicopter designed for two missions: army/land utility missions (troop transport) and naval missions (ASW, antiship). Contractors for the project are Aerospatiale (35 percent), Agusta (35 percent), MBB (25 percent), and Fokker (5 percent).

The NH-90 program was delayed more than six months by funding uncertainties, particularly on the part of the West German government. In 1988, the West German Parliament cut 50 percent of its funds for the NH-90; West Germany originally was to have contributed $434 million to full-scale development. The project definition phase was authorized in April 1989, but French defense budget cuts may pose a new problem for the NH-90 program. The Memorandum of Understanding for the development phase is not expected to be signed until January 1990 at the earliest.

© 1989 Dataquest Incorporated October

Development is expected to cost about $2.1 billion, with a first flight test projected for 1992 and initial operating capability sought for 1997. Participating countries' plans call for 712 helicopters with flyaway costs for the utility and naval versions projected at $11 million and $20 million, respectively. Production is now expected to begin in late 1997 or early 1998.

Currently, the industrial teams are in a 10-month transition period during which approximately $14 million will be spent to reduce the NH-90's maximum takeoff weight. The teams were told to find ways to cut development costs by 20 percent. If costs can be reduced without greatly degrading performance, full-scale development could begin by the end of 1989. Conflicting operational requirements of the participants, however, are proving difficult to reconcile and could lead the consortium to collapse.

The development program of the NH-90 will focus on the air vehicle and mission systems; the engine will be supplied by the governments involved. The breakdown is as follows:

- Aerospatiale—Main rotor, hubs, and blades; flight control; mission systems, utility version
- Agusta—Main gear box, mission systems, naval version
- MBB—Tail rotor; avionics

In addition, groups have formed to compete for other systems: AEG, FIAR, NRC, and Thomson-CSF (the Netherlands) will compete for the naval radar, and AEG, Elettronica (Italy), and Thomson-CSF have formed a team for the electronic warfare system. Aerospatiale began flight trials in April to evaluate a fly-by-wire systems, SFENA (France) supplied the computers, and SAMM supplied the servocontrols.

Battlefield Remotely Piloted Vehicle (Brevel)

Matra (France) and MBB formed a team in early 1989 to develop a remotely piloted vehicle to perform battlefield reconnaissance. The Brevel will use television cameras and/or forward-looking infrared technology and will have a range of 30 to 50 kilometers. Matra will develop the ground system and optronic sensors, and MBB will design the vehicle. Between 200 and 300 systems are expected to be procured.

TriGAT Antimissile Program

A Third-Generation Antitank Missile (TriGAT) is being developed by France, West Germany, and the United Kingdom to replace Milan and HOT systems in the mid-1990s. The program is being run by Euromissile Dynamics Group, a Paris-based joint venture of British Aerospace, Aerospatiale, and MBB. A development contract was awarded in September 1988 for $1.3 billion. Two variants of the TriGAT are sought: a man-launched, medium-range (2.5km) version that will utilize a laser designator and be

© 1989 Dataquest Incorporated October

built by Aerospatiale, and a helicopter-launched, long-range (4KM) version to be built by MBB. The medium-range version will incorporate a thermal imaging sight; the long-range version will have a passive infrared seeker and/or videocamera. The Satel group, which comprises Thorn-EMI, Eltro, and SAT will develop the thermal imaging system.

The medium-range missile will take approximately six years to develop at a cost of $300 million and is expected to enter service in the mid-1990s. The long-range version will take more than eight years to develop at a cost of $900 million. The helicopter-launched version of the TriGAT will be employed on the Franco-German and Tonal LAH helicopters.

In April 1989, Belgium, the Netherlands, and Spain joined the TriGAT program. Together, they will contribute $43 million, or 5 percent of the development costs. Development work has been allotted as follows:

- Medium version
  - Missile and ammunition—Aerospatiale
- Long-range version
  - Missile and ammunition—British Aerospace
  - Helicopter integration--MBB
- Both
  - Optronics, homing warheads—British Aerospace
  - Firing units, active warheads--MBB

Modular Stand-Off Weapon (MSOW)

With France and Canada having recently dropped out, five nations--Italy, Spain, the United Kingdom, the United States, and West Germany—remain in this project to develop a family of air-to-ground missiles. The MSOW is expected to be installed on Tornados, Hawks, F-15s, F-16s, and AV-8B Harriers. Three types of the missile will ultimately be produced: a short-range (18 to 30 miles), a long-range (more than 100 miles) version for use against fixed targets, and a version for use against mobile targets. It has not yet been determined whether to seek a single missile with interchangeable parts or three separate missiles with common components.

The R&D phase was to begin with a contract award in September 1988 and last two and a half to three years, but with the mid-1988 departure of France and Canada from the program, the schedule slipped by about a year. The first phase of development will cost $450 million; the entire program will cost approximately $7 billion during the next decade. A total purchase of about 30,000 missiles is expected, with the short-range version to be fielded in 1994, the long-range version in 1995, and the mobile-target version in 1996. The cost of the entire program could top $10 billion. The following two multinational teams formed to bid on the program:

- Team 1
  - Rockwell (United States)--Leader
  - British Aerospace
  - CASA
  - CASMU (Italy)
  - MBB
- Team 2
  - General Dynamics (United States)—Leader
  - Agusta
  - Brunswick (United States)
  - Dornier (West Germany)
  - Hunting Engineering (United Kingdom)
  - Sener (Spain)

The Rockwell team was selected in June 1989 to build and demonstrate flying prototypes; the formal $400 million contract will be signed in September or October 1989. The project definition phase will last 30 months and will be followed by a three-year, full-scale development phase. Rockwell will provide systems integration, British Aerospace will develop the navigation module, CASMU and CASA will develop the aftbody and payload modules, and MBB will develop the hardback dispenser.

A memorandum of understanding on cost sharing and production must be completed before full-scale engineering development begins. It is estimated that the United States, the United Kingdom, and West Germany each will contribute 22 percent of the cost, and that Spain will contribute 12 percent. U.S. contribution to R&D is estimated to be approximately $200 million per year for the next several years.

ASRAAM

The Advanced Short-Range Air-to-Air Missile (ASRAAM), currently in the concept definition stage, is a wingless, infrared-guided, fire-and-forget missile with an estimated 15km range. Under development by European contractors as the next generation of air-to-air missile for close combat in NATO fighter aircraft, the missile already is five years behind schedule. Production would begin in 1995 at the earliest.

© 1989 Dataquest Incorporated October

The ASRAAM is intended to replace the AIM-9 Sidewinder on Western tactical aircraft and will complement the AMRAAM. The program is led by the British Aerospace Corporation and includes Bodenseewerk Geratetechnik, Garrett (Canada), and Raufoss Ammunisjonsfabrikker (Norway). British Aerospace recommended moving to full-scale development in January 1989, but the program was not, and still has not been endorsed by the United States, which has a potential requirement for more than two-thirds of the planned 60,000 missiles to be produced. In March 1989, a six-month-long major redesign of the $800 million program was authorized to address weight and drag problems. In particular, a U.S. requirement for using a universal rail launcher that also fits the Sidewinder and AMRAAM would add 50 pounds of weight to the missile; the full-scale development decision now is expected at the end of 1989.

The fate of the program is in jeopardy; there are reports that delays will cause the missile to be bypassed in favor of a now-classified missile to equip the ATF and replace the Sidewinder on already deployed aircraft. Such a development would be a setback to NATO defense cooperation. It may be necessary, however, as the venerable Sidewinder missile nears the end of its useful life in the 1990s.

Hypersonic Missile

Aerospatiale, MBB, and Thomson-CSF announced plans to develop the Sol-Air Courte Portee (SACP) in early 1989. The SACP, a hypersonic (Mach 4) short-range surface-to-air missile, would replace the Crotale and Roland systems in the mid-1990s. With a range of 12 to 15 kilometers, the radar-guided missile may use Crotale and Roland launchers. Matra also has expressed an interest in the development program.

Autonomous Precision Guided Munition (APGM)

The APGM multinational program was revised after a December 1988 meeting in which West Germany announced that it would reduce its contribution by 50 percent. The APGM, as currently envisioned, is a "smart" bullet for the standard 155mm artillery howitzer. The APGM will fly at approximately 22km during the ballistic flight phase and release its submunitions, which, guided by individual seekers, would then home in on tanks. Phase I is scheduled for 32 months and will include demonstration of key subassemblies and modules. Two $80 million contracts were awarded in June 1989. The total cost of the APGM program is estimated at approximately $5 billion. Two consortia have been created: Alliance Development Corporation led by Hughes and the All-Weather Smart Projectile Team, led by General Dynamics. Members of the consortia and percentage of work are shown in Table 2.

Plans call for both teams to proceed through Phase II with concept definition and complete system demonstration. One team will be selected for the third phase of full-scale development.

 © 1989 Dataquest Incorporated October

Table 2

APGM Consortia

Country	Alliance Development Corp.	All-Weather Smart Projectile
United States	Hughes--40%	General Dynamics--33%
France	GIAT; ESD--12%	Matra--12%
West Germany	AEG; Rheinmetall--15%	Dornier; MBB--14%
Italy	Selenia--17%	OTO Melara with SMA, Galileo--16%
Canada	Garrett, Honeywell--6%	Computing Devices--5%
Netherlands	Fokker, Natl. Aerospace--6%; Signaalapparaten--6%	Hollandse Lab
Spain	Expal--2%	Ensab with Inisel--10%
Turkey	MKEK--4%	Aselsan--4%

Source: Defense Forecasts

Multiple Launch Rocket System

The Multiple Launch Rocket System (MLRS), deployed in South Korea, the United States, and West Germany, carries 12 conventionally armed rockets and supplements cannon artillery fire. A European consortium was formed in mid-1988 to build the MLRS in Europe: France, Italy, the United Kingdom, and West Germany are participants. France plans to buy 80 systems; Italy, 20; the United Kingdom, 67; and West Germany, 200.

An international joint-venture company consisting of Diehl GmbH (West Germany), Martin Marietta (United States), Thomson-CSF, and Thorn-EMI completed component field tests for the terminally guided warhead in late 1988. Diehl was responsible for the terminally guided submunition signal processor electronics during the 51-month component demonstration phase that ended in February 1989. The Component Demonstration Substage Program was longer than expected because of a requirement to redesign the system to use three instead of six terminally guided submunition units.

Future developments include the establishment of an automated test equipment center for the fire control system at Marconi, announced in February 1989. Marconi developed the fire control unit and electronics unit and Selenia (Italy) developed the fire control panel. Full-scale production of the fire control system will begin this year; the contract is worth $44 million. The automated test equipment will use a Hewlett-Packard (United States) ATS 1000 system. Another development for the MLRS is the incorporation of a new signal processing technique, doppler beam sharpening, used to increase the resolution of the millimeter wave radar. The 42-month demonstration phase began in March 1989. Full-scale development is slated to begin in 1991.

 © 1989 Dataquest Incorporated October

NATO Anti-Air Warfare System (AAWS)

Canada, England, the Netherlands, Spain, the United States, and West Germany are involved in the concept definition phase of the prospective NATO AAWS program; France and Italy may join at a later stage. The program is aimed at providing integrated late-1990s and 21st-century short-range defenses against aircraft and cruise missiles for the NFR-90 frigate and other ships of that size. Items for development include radar, infrared and other sensors, and a distributed computer architecture. Although the AAWS originally was planned with a 1998 initial operating capability, an interim system may be developed based on technological advances made in the development program.

Development costs for the AAWS are estimated at $900 million. Phase I contracts were awarded in May 1988. These 10-month, $3 million, cost-sharing contracts were won by two consortia led by Westinghouse and General Electric, both of the United States. Westinghouse is joined by 22 other companies and has formed the Universal Naval Integrated Surface-to-Air Missile System (UNISAMS) team. General Electric has teamed with 9 other large companies. Raytheon (United States) entered the competition in June 1989 with a bid for a Phase II contract with six other companies: AEG, Bristol Aerospace (Canada), ERIA (Spain), Fokker, Martin Marietta, and MBB. A request for demonstration/validation proposals is expected in the fall, but the timing depends on the completion of a memorandum of understanding among the nations that defines that phase of the project.

Two other groups have been formed to write specifications for surface-to-air antimissile defenses. The Family of Anti-Air Missile System (FAAMS) group has been formed by France, Italy, Spain, and the United Kingdom; it may consider using the French Aster antimissile missile. The independent European program group, which comprises France, Holland, Italy, Norway, Spain, the United Kingdom, and West Germany, is interested in a Hawk follow-on.

Command, Control, Communications, and Intelligence (C3I) Programs

Constraints on defense resources in the European nations will place a premium on so-called force multipliers. Accordingly, spending on C3I is likely to increase over the next five years, despite the general pattern of level budgets. One industry study has predicted that Western European spending for C3I will increase by 23.6 percent between 1988 and 1992. A breakdown of this prognosis is given in Table 3.

 © 1989 Dataquest Incorporated October

Table 3

National Expenditure on C3I
(Millions of Dollars)

	France	West Germany	Italy	England	NATO-Wide	Other European Countries	Total
1988	$ 880	$ 735	$315	$760	$271	$403	$3,364
1992	$1,090	$1,075	$460	$950	$345	$483	$4,403

Source: Defense News

West Germany in particular, faced with a manpower shortage in the 1990s that will reduce the size of its army, has indicated that it will look to technology to compensate. Changes envisioned include increased reliance on microelectronics to provide deep reconnaissance, powerful command systems, accurate firepower at maximum range, and better coordination among these assets. Commenting on the field as a whole, Dennis Kloske, former U.S. deputy undersecretary of defense for planning and resources, predicted that the next big electronics industry skirmish will be over the international C3I market as the Western European defense industry invests heavily in command and control technology.

The NATO Communications and Information Systems Agency (NACISA) oversees NATO C3I programs. Although the NACISA budget is expected to peak in 1991 at $60 million, it probably will decline thereafter, as individual nations take greater responsibility for C3I tasks. The NACISA is responsible for the Command and Control Information System (CCIS), NATO IV Satellites, and the NATO Terrestrial Transmission System (NTTS). NTTS will replace the ACE High network by 1996; it comprises several national communications systems connected by NATO-owned links.

Command and Control Information System (CCIS)

After almost 15 years of discussion, the NATO Command and Control Information System (CCIS) recently began. CCIS will be an integrated NATO-wide communications network for strategic planning, using other NATO programs such as the NATO Air Command and Control System (ACCS) and the Battlefield Integrated Collection and Exploitation System (BICES). The ACCS program focuses on air-air and air-ground communications networks and the BICES program will create an umbrella for national networks.

© 1989 Dataquest Incorporated October

A two-year systems design and integration study, awarded in early 1989 to a consortium led by Hughes, will audit existing NATO information systems and design a proposal for a NATO-wide automated CCIS for the next century. The design proposal is scheduled to be completed in May 1990; an implementation plan is expected in August 1990. Members of the consortium include Datamat (Italy), Scicon (United Kingdom), SCS (West Germany), Selenia, and Thomson-CSF.

This NATO-wide CCIS is expected to focus on evolutionary acquisition and rapid prototyping to minimize risk. One example of a project is a joint testbed for the systems design and integration study and BICES to examine basic data fusion algorithms and concepts for man-machine interaction.

NATO Air Command and Control System (ACCS)

In 1981, representatives were assigned to the NATO ACCS team to develop the ACCS master plan. Although this generic system design of NATO's ACCS Sigma Star was to be finished by the end of 1987, the program is two years behind schedule; results were released in mid-1989. Although the original estimate of the program's cost was $25 billion, serious effort has been made to scale back operations.

When deployed (in the year 2000 at the earliest), ACCS will integrate, process, and relay NATO air-defense tracking and targeting information, providing an automated command and control system to support all European air operations. Data will be gathered into mobile, ground-based automated data processing systems and then channeled into a Combined Air Operations Center for dissemination. The ACCS consists of eight elements: AFATDS, ASAS, FAADC2I, CSSCS, MCS, MSE, and SINCGARS. ACCS funding will double, going from $4 billion in fiscal 1988 to $8 billion by fiscal 1992. ACCS will replace the existing NATO Air Defense Ground Environment system. Work is expected to begin in 1991 and last 18 years. France indicated that it may participate.

ACCS will interface with NATO command and control systems already under development: the NATO identification friend-or-foe system, the Multipurpose Information Distribution System (NATO's version of JTIDS class-2 terminals), and the BICES, which will link the battlefield intelligence systems of individual NATO countries and relay information to division commanders.

Authorization for a two-year study to define specifications for these programs was made in April 1989. Two consortia have been formed, one under Hughes and one under Boeing.

© 1989 Dataquest Incorporated October

Battlefield Integration Collection and Exploitation System (BICES)

For an estimated $1 billion, BICES will connect national C3I systems to provide an integrated display of the entire NATO front from the northern to the southern flanks. An 18-month pilot study worth several million dollars will be awarded in 1989, and contracting teams have begun to line up. Aeritalia, Ferranti, and GEC teamed up as the BICES Cooperative Group and began a feasibility study in December 1988; Booz Allen Hamilton (United States) formed a group called BICON. Members of BICON include the following:

- Philips (Netherlands)—Automated data processing systems
- Agusta—Communications subsystems
- Sirti (Italy)—Communications system architecture
- Systemtechnik (West Germany)—Data elaboration and fusion

BICES is expected to reach initial operating capability in 1993 or 1994, with full operational capability after 2000.

European Data Distribution System (EDDS)

Nine Western European countries are planning a Europe-wide computerized data transfer network. EDDS design began in 1988; implementation of the network is not expected until the late 1990s. The nine countries involved are Belgium, Denmark, the United Kingdom, France, Italy, the Netherlands, Norway, Spain, and West Germany.

Multifunction Information Distribution System (MIDS)

A consortium was formed in mid-1989 to develop the NATO Multifunction Information Distribution System (MIDS). Thomson-CSF, which developed the RITA communications system, has overall technical responsibility and is joined by CDC (Canada), Inisel, Italtel (Italy), Plessey (United Kingdom), and Siemens (West Germany). NATO hopes for operational capacity in the mid-1990s; development costs are projected at approximately $350 million.

Satellites

France, Italy, and Spain are teaming together to work on the post-Helios military reconnaissance satellite program. France's share will be 79.0 percent, Italy's share will be 14.5 percent, and Spain's share will be 6.5 percent. Plans call for two heliosynchronous satellites to be produced, with an option for a third. Helios is expected to enter service in 1993. Matra is the prime contractor, with ground-based control and data processing stations to be manufactured by French companies Aerospatiale, CNES, and SAT Control. The prime contractors for the Italian portion of the program are Aeritalia, Selenia, and Laben. The estimated cost of the entire Helios program is $1.3 billion, of which $456 million will be spent between 1988 and 1991. Spain is planning to launch its own satellite communications program in the near future.

© 1989 Dataquest Incorporated October

The Skynet 4B satellite was launched on an Ariane 4 rocket in mid–December 1988, the first of a new generation of European military communications satellites. Skynet 4A, boosted from a Titan 3 rocket, followed in August 1989, and Skynet 4C is scheduled for launch on an Ariane 4 rocket in May 1990. Phase II of the Skynet program will include two satellites, the first of which will be launched in 1995. Phase III will begin after 1999; these satellites will expand coverage to the super high and extremely high frequencies.

Counter–Battery Radar (COBRA)

Initiated in 1986, the COBRA program is conducted by three nations: France, the United Kingdom, and West Germany. The Euroart consortium, the prime contractor, consists of Thomson–CSF, Thorn–EMI, General Electric Co. (United Kingdom), and Siemens. COBRA is a highly mobile radar system that is designed to locate enemy artillery by tracking and analyzing artillery shell trajectories. Originally scheduled to be deployed in 1995 or 1996, COBRA already is 18 months behind schedule; funding cuts by West Germany have further delayed progress. The total cost of the program is $860 million.

Table 4 summarizes European participation in the multinational programs discussed in this section. Tables 5 and 6 summarize European missile and aircraft programs, respectively.

© 1989 Dataquest Incorporated October

Table 4

European Participation in Major Multilateral Defense Programs

Country/Program	England	West Germany	Netherlands	France	Spain	Italy
EFA	British Aero.	MBB			CASA	Aeritalia
ECR Radar MSD 2000	Ferranti or Marconi	Siemens or AEG			Inisel	FIAR
PAH-2 Helicopter		MBB		Aerospatiale		
Tonal Helicopter	Westland		Fokker		CASA	Agusta
NH-90		MBB	Fokker	Aerospatiale		Agusta
TriGAT	British Aero.	MBB		Aerospatiale		
MSOW	British Aero. or Hunting Engineering	MBB or Dornier			CASA or Sener	CASMU or Agusta
ASRAAM	British Aero.	Boden. Gerat.				
APGM*						
ADC Consortium		AEG, Rheinmetall		GIAT, ESD	Expal	Selenia
AWSPT Consortium		Dornier, MBB		Matra	Ensab	Inisel, OTO Melara
NFR-90	x	x	x	x	x	x
NATO AAWS	x	x	x	?	x	?
Helios				Matra		Aeritalia, Laben, and Selenia
Cobra	GEC/Thorn-EMI	Siemens		Thomson-CSF		
APGM	AEG, Rheinmetall Dornier, MBB	GIAT, ESD Matra	Epal Ensab	Selesia Inisel, to Melbara		

x Denotes participation where contractor is not known
? Denotes country that may participate in the future
*U.S. participation: Hughes leads ADC; General Dynamics leads AWSPT.

Source: Defense Forecasts

Table 5

Status of Western European Missile Systems

System	Manufacturers: Prime	Manufacturers: Guidance	Status/Plans
ALARM	British Aerospace	Marconi	Enter British service mid-1990s
ANS	Aerospatiale/MBB	----	In development; replaces Exocet
Apache	Matra/Aerospatiale	----	In development
AS30 Laser	Aerospatiale	Thomson-CSF	800 ordered for France, exports
AS15TT	Aerospatiale	Thomson-CSF	
ASMP	Aerospatiale	Thomson-CSF	Upgrade planned
ASRAAM	British Aerospace/ Raufoss	----	Development expected in 1989
Aster	Aerospatiale	Thomson-CSF	French naval use
Blowpipe/Javelin	Short Brothers	Short Brothers	British army, marines, export production
Crotale	Thomson-CSF/ Matra	Thomson-CSF	Upgrade planned
Eryx	Aerospatiale	----	French army, production by 1990
Exocet	Aerospatiale	EMD	Continued production
Hades	Aerospatiale	SFENA	Replace Pluton by 1992
HOT	Euromissile	SAT/Eltro	Upgrade day/night launchers
M4	Aerospatiale	SAGEM/EMD	Deployed in 1994

(Continued)

© 1989 Dataquest Incorporated October

Table 5 (Continued)

Status of Western European Missile Systems

System	Manufacturers: Prime	Manufacturers: Guidance	Status/Plans
Magic	Matra	SAT	Magic 2--possible U.S. aircraft use
MICA	Matra	ESD	Under development
Milan	Euromissile	SAT/Eltro	Milan 2 in production
MISTRAL	Matra	SAT	Deliveries under way
Otomat	Matra/OTO Melera	Thomson-CSF	French-Italian use, upgrade planned
Rapier/2000	British Aerospace	----	Development continuing
RBS.15	Saab/Bofors	----	Swedish and Finnish naval use
RBS.56 Bill	Bofors	----	Swedish army use, U.S. evaluation
RBS.90	Bofors	----	First deliveries in 1990
Roland	Euromissile	Sagem, SAT	In production
S3 SSBS	Aerospatiale	EMD-Sagem	Upgraded, S4 planned
Sea Dart	British Aerospace	GE, Sperry	British use being upgraded
Sea Eagle	British Aerospace	Marconi	In service in Britain, India
Sea Skua	British Aerospace	Marconi	Ship-launched version in development
Sea Wolf	British Aerospace	Marconi	British use, new versions ordered

(Continued)

© 1989 Dataquest Incorporated October

Table 5 (Continued)

Status of Western European Missile Systems

System	Manufacturers Prime	Manufacturers Guidance	Status/Plans
Seacat	Short Brothers	Short Brothers	Export orders
Skyflash	British Aerospace	Marconi	Active radar upgrade
Starstreak	Starstreak	----	1990 production for Britain
Super 530D	Matra	ESD	In production
Swingfire	British Aerospace	----	Produced in Egypt
TriGAT	Euromissile Dynamics		In development

Source: Aviation Week
Dataquest
October 1989

© 1989 Dataquest Incorporated October

Table 6

Status of Western European Aircraft

Aircraft	Manufacturer	Status
Tactical/Support		
Alpha Jet	Dassault-Breguet/Dornier	Cockpit, armament changes
AMX	Aeritalia/Embraer/Aermacchi	1989 deliveries
Egrett-1	Grab/E-Systems	Testing
EAP	British Aerospace	EFA test bed
Epsilon	Aerospatiale	171 ordered
EFA	4 Nations	In development
Harrier	British Aerospace	96 GR-5s ordered; FRS.1 to FRS.2 upgrade
HS.1102 Hawk	British Aerospace	Trainers delivered
J35 Draken	Saab/Scandia	J versions to be upgraded
JA37 Viggin	Saab/Scandia	Winding down by 1990
JAS-39 Gripen	Saab	Crash has forced reevaluation
Jaguar	Sepecat/Hindustan	Production continues in India
MB-339C	Aermacchi	Upgraded version available
Mirage 3/5/50	Dassault-Breguet	Retrofit market
Mirage 2000	Dassault-Breguet	406 orders
Mirage F1	Dassault-Breguet	Winding down in 1990
Rafale	Dassault-Breguet	Prototypes being built
S.211	Siai-Marchetti-Agusta	In production
SF.260	Siai-Marchetti-Agusta	In production
SF.600	Siai-Marchetti-Agusta	Certified
Super Entendard	Dassault-Breguet	Naval version in development
Supersonic V/STOL	British Aerospace	Under study
Tornado	Panavia	280 on order
Tucano T.MK	Short Brothers/Embraer	In production
Airlift		
Advanced Airlifter	NATO	C-130, Transall replacement study
C-23 Sherpa	Short Brothers	In production
C212	CASA	Upgraded
CN235	CASA/IPTN	67 on order
DO.228-100/200	Dornier	152 ordered, Indian production

(Continued)

Table 6 (Continued)

Status of Western European Aircraft

Aircraft	Manufacturer	Status
ASW Patrol		
ATL 2	Dassault-Breguet	In production
CN235-MP	CASA/IPTN	In development
Helicopters		
A109	Agusta	In production
A129	Agusta	In production
ALH	MBB/Hindustan Aero.	In development
BK.117	MBB/Kawasaki	Production of 3/month
BO.105	MBB	Production of 3/month
BO.108	MBB	Prototypes
EH-101	EH Industries	British, Italian, Canadian orders
Lynx	Westland	Upgrade available
NH-90	NATO	Definition complete
PAH-2/HAC-3/HAP	MBB/Aerospatiale	In development
SA342 Gazelle	Aerospatiale	In production
SA365 Dauphin	Aerospatiale	In production
Sea King	Sikorsky/Westland	Phasing out by 1990
Super Puma	Aerospatiale	In development

Source: Aviation Week
Dataquest
October 1989

 © 1989 Dataquest Incorporated October

Western Europe--Business Overview and Forecast

SUMMARY

In general, the Western European (also known as European in this binder) military electronics industry operates under the same missions and constraints as the U.S. electronics industry. This is because the countries involved are all members of the North Atlantic Treaty Organization (NATO) and share a common defense policy. In fact, the equipment made to support NATO programs is becoming increasingly international in nature, with many countries sharing the development and production. Perhaps the one aspect that differentiates the European industry from that of the United States is a greater dependence on exports to non-NATO countries. This aspect of the European industry is expected to continue and be a viable part of its growth.

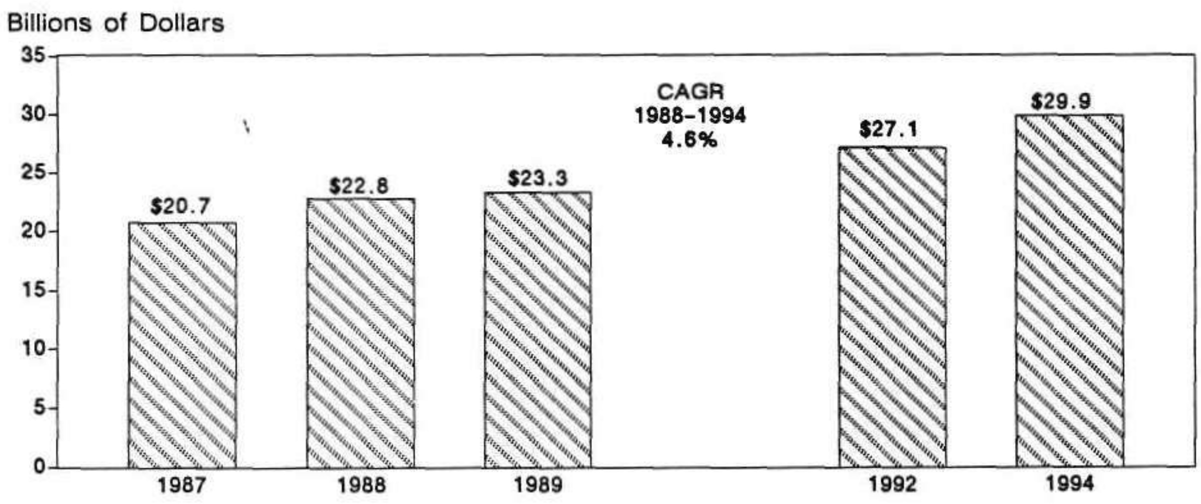
The single most important variable in assessing the future of the European military electronics industry is the impact of the Intermediate Nuclear Forces (INF) treaty between the United States and the Soviet Union. We believe that there will be the following three primary market factors to watch over the coming years:

- How much the European nations are willing to spend on defense in the age of reconciliation with the Soviets
- Increased American pressure on European nations to share more of the European defense burden
- The perceived imbalance of power left by the INF treaty

European production of military electronic equipment is expected to grow from its 1988 level of $22.8 billion to $29.9 billion by 1994, a 4.6 percent compound annual growth rate (CAGR) (see Figure 1).

Figure 1

Military Electronic Equipment Production Forecast
Western Europe



Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

MILITARY ELECTRONICS SPENDING

Table 1 presents the estimated electronics content of European defense spending by budget category. The spending represents outlays by the various ministries of defense for NATO-related programs for their own national purposes. At $18.0 billion in 1987, electronics-related spending is expected to grow about 10 percent in 1988 in U.S. dollars, or 3 percent in European currency units (ECUs). Electronics-related spending is expected to continue growing at a 4.5 percent CAGR through 1994.

Table 1

**Estimated Electronics Content of Defense Purchases
Western Europe
(Millions of Dollars)**

	1987	1988	1989	1992	1994	CAGR 1988-1994
Aircraft	$ 3,884	$ 4,261	$ 4,303	$ 4,785	$ 5,106	3.1%
Missiles	1,701	1,878	1,915	2,179	2,348	3.8%
Space	1,021	1,139	1,179	1,432	1,630	6.2%
Ships	1,573	1,743	1,743	2,087	2,359	5.2%
Ordnance, Weapons, and Vehicle	854	929	943	1,107	1,232	4.8%
Electronics and Communication	2,370	2,607	2,680	3,111	3,430	4.7%
RDT&E	6,139	6,746	6,908	8,112	9,029	5.0%
Other	468	516	528	613	669	4.4%
Total*	$18,009	$19,818	$20,199	$23,427	$25,804	4.5%

*Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Western Europe--Business Overview and Forecast

MILITARY ELECTRONICS PRODUCTION FORECAST

Overview

Table 2 presents the forecast for military electronic equipment produced in Western Europe. Overall production is expected to grow at a 4.6 percent CAGR through 1994. Export-related electronics is estimated at 13.0 percent of total production in 1988. Figure 2 presents a breakout of production by European district. The U.K. and Irish district is expected to remain the largest producer of military electronics in Europe, staying at about 35 percent of the total. However, France and West Germany are expected to gain some share over time, as production aligns more with defense spending patterns.

Table 2

Military Electronic Equipment Production Forecast
Western Europe
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Radar	$ 3,041	$ 3,336	$ 3,370	$ 3,747	$ 3,998	3.1%
Sonar	692	763	779	886	955	3.8%
Missile and Weapon	2,935	3,273	3,387	4,115	4,684	6.2%
Space	1,375	1,523	1,523	1,825	2,062	5.2%
Navigation	558	607	617	724	806	4.8%
Communication	2,209	2,430	2,498	2,901	3,198	4.7%
Electronic Warfare	1,523	1,680	1,719	1,995	2,179	4.4%
Reconnaissance	978	1,075	1,101	1,293	1,439	5.0%
Aircraft Systems	1,986	2,163	2,198	2,618	2,941	5.3%
Computer Systems	1,967	2,150	2,193	2,619	2,948	5.4%
Simulation and Training	263	291	300	373	429	6.7%
Miscellaneous Equipment	3,200	3,485	3,579	3,968	4,251	3.4%
Total*	$20,729	$22,776	$23,264	$27,063	$29,890	4.6%

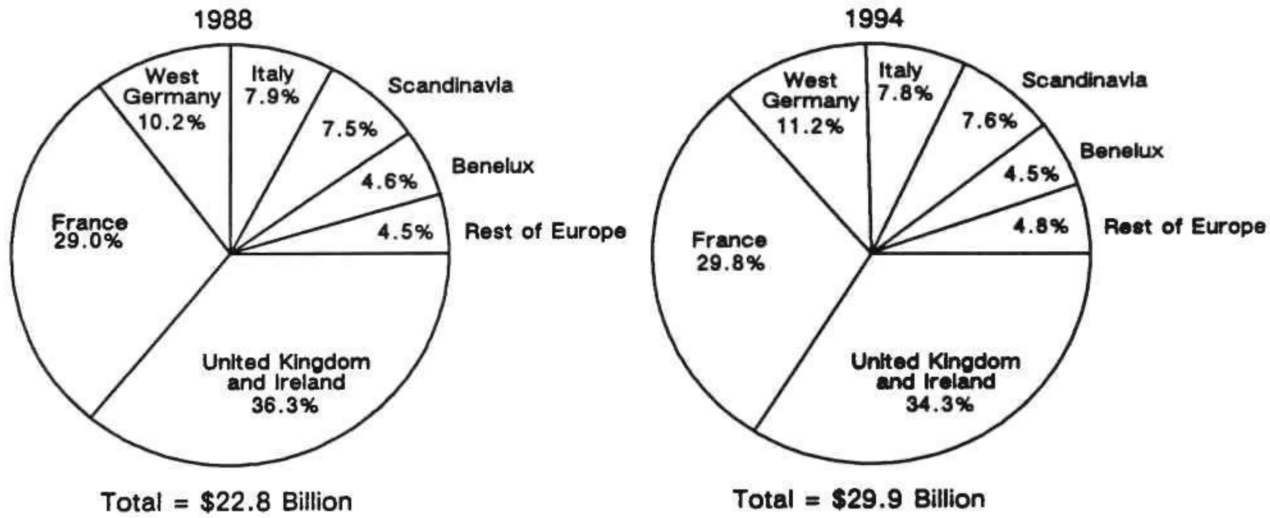
*Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Figure 2

Estimated Western European Military Electronics Production by Country



Source: Dataquest
August 1988

Highlights

The following are highlights of the electronic equipment production forecast presented in Table 2:

- The largest electronics categories in 1988 are as follows:
  - Radar systems—$3.3 billion
  - Missile and weapon—$3.3 billion

- The fastest growing electronics categories, according to 1988 through 1994 CAGR are as follows:
  - Simulation and training—6.7 percent
  - Missile and weapon—6.2 percent

 © 1988 Dataquest Incorporated August

Forecast Assumptions

The following assumptions are based on the production data presented in Table 2:

- The level of NATO spending will be maintained, but a larger percentage of it will be spent by Europeans on European contractors.
- Continued emphasis is on force multipliers: smarter missiles, better C3I, and advanced electronic warfare and reconnaissance techniques.
- The European Fighter Aircraft (EFA) project will be implemented.
- Upgrades of avionics and shipboard systems will occur, just as they will in the United States.
- Aggressiveness in developing space programs will continue.

© 1988 Dataquest Incorporated August

(Page intentionally left blank)

 © 1988 Dataquest Incorporated August

Western Europe--Programs

The major European projects that will have significant electronic content are described in this section.

EUROPEAN FIGHTER AIRCRAFT (EFA)

The EFA is being developed jointly by Britain, West Germany, Italy, and Spain. Developmental work on the aircraft has been divided among the four members of the Eurofighter consortium, as follows: British Aerospace (33 percent), Messerschmitt-Boelkow-Blohm (MBB) of Germany (33 percent), Aeritalia (21 percent), and CASA of Spain (13 percent). A four-country agreement was signed in May 1988, authorizing full-scale development of the EFA, with contracts to follow. Production is scheduled to begin in 1995, with initial deployment in 1997, but this schedule is likely to slip. The program calls for 765 aircraft to be produced, though more may be added later to accommodate foreign sales. Developmental costs for the EFA are estimated at $10.8 billion, with procurement to run another $36 billion.

Electronics manufacturers will be the main beneficiaries of the EFA program, as avionics systems are expected to account for at least half, and perhaps as much as 65 percent, of the total cost. Though most electronic components are still in the early conceptual stages, a four-country consortium was formed to bid on design and production of the EFA's digital fly-by-wire flight control system. The principals involved are Aeritalia, Bodenseewerk Geratetechnik (Germany), GEC Avionics (United Kingdom), and Inisel (Spain).

Of the EFA's components, its multimode, pulse-Doppler radar system requires the longest lead time in development, and accordingly, the Eurofighter consortium plans to award a development contract in September. Two multinational industry teams, one led by AEG (Germany) and Marconi Defense Systems (United Kingdom) and the other led by Ferranti Defense Systems (United Kingdom), are bidding fiercely for the contract. The radar selection is already a year overdue, and consequently, the delivery of the first 12 flyable preproduction radar units has slipped to spring 1991. The entire radar program is expected to be worth about $1.8 billion. Work on radar development and production will be divided eventually among the four participants in the Eurofighter consortium in the same ratio as the one used for that program.

RAFALE AIRCRAFT

France dropped out of the EFA program in 1986 to pursue its own new fighter aircraft, the Rafale. A jointly owned company, Avion de Conbat European (ACE) International, was established by the four primary Rafale contractors—Dassault-Breguet (60 percent), SNECMA (20 percent), Electronique Serge Dassault (10 percent), and Thomson-CSF (10 percent). Dassault will build the airframe, SNECMA will manufacture the engine, and the latter two will supply the electronics. The plane will be fitted either with Thomson-CSF's RDX multimode phased-array radar or the competing Electronique Serge Dassault's Antilope 50 radar. A decision on the radar is expected by the end of 1988.

© 1988 Dataquest Incorporated July

Development of the Rafale is expected to cost $6.15 billion, with about $2.70 billion to be spent between 1988 and 1991. Indeed, in April, incrementally funded contracts worth $2.46 billion were awarded to Dassault-Breguet and SNECMA for development and prototype production of the Rafale and its engine. Avionics for the fighter are still being defined. Procurement of the planned 330 aircraft is expected to cost $24.90 billion; export sales are expected to raise this figure, however. The prototype is scheduled to fly in 1990, with full-scale production coming in 1994.

FRANCO-GERMAN HELICOPTER

France and Germany are working together to develop and produce a new combat helicopter that will be fielded in the late 1990s. The total real cost of the program is projected at $8.50 billion, with developmental costs of $1.80 billion and production costs of $6.45 billion (tooling and finance costs round out the total). The total cost in current dollars is estimated at $16.90 billion. Two versions of the helicopter are to be produced--one for antitank missions and one for escort and fire support.

Of the real procurement costs, $1.27 billion is earmarked for mission equipment packages, including navigational aids, observation equipment, weapons sights, fire control gear, and a mast-mounted avionics package. The main contractor for the mission equipment packages will be SOFRADIR, a French concern owned jointly by CEA Industries, SAT Control, and Thomson-CSF. French and German subcontractors will be involved. France and Germany also will jointly develop infrared charge-coupled device (IRCCD) technology for the helicopter's optronic systems. The main contractor for the helicopter program as a whole is Eurocopter, a consortium of Aerospatiale (France) and MBB (Germany). An interim development contract was awarded at the end of 1987, with a final development contract expected in late 1988. The helicopter prototype is to fly in the mid-1990s, with production deliveries to begin in 1995 and 1996. It should be noted, however, that the program has already had a long and difficult history. Moreover, it is now rumored that both France and Germany want to drop out because of the cost projections, which are much higher than had been expected.

TONAL LIGHT ATTACK HELICOPTER (LAH)

Britain, Italy, the Netherlands, and Spain are teaming to develop the Tonal LAH. A feasibility and cost definition contract was awarded in May 1987 to European Helicopters, a joint venture of Italy's Agusta (38 percent), Britain's Westland (38 percent), the Netherlands' Fokker (19 percent), and Spain's CASA (5 percent). In late 1988, decisions on the major design options, including the choice of an avionics package, will be made. Possible commonality with the Franco-German helicopter is being explored, with common avionics, engines, optronics, and weapon systems all being considered in the interest of economy.

© 1988 Dataquest Incorporated July

Western Europe—Programs

NATO HELICOPTER FOR THE 1990s (NH-90)

France, Italy, West Germany, and the Netherlands are cooperating in the development of the NH-90, two versions of which are to be developed—one for army/land utility missions and one for naval missions. Contractors for the project are Aerospatiale (35 percent), Agusta (35 percent), MBB (25 percent), and Fokker (5 percent). The NH-90's project definition phase will conclude in September, after which full-scale development is planned. Development is expected to cost about $2.1 billion, with a first flight test projected for 1991 and initial operating capability sought for 1994 or 1995. Participating countries' plans call for 614 helicopters, with flyaway costs for the utility and naval versions projected at $10.5 million and $20.1 million, respectively. It should be noted that conflicting operational requirements of the participants are proving difficult to reconcile and could lead the consortium to collapse.

THIRD-GENERATION ANTITANK MISSILE (TRIGAT) PROGRAM

Trigat is being developed by France, Germany, and England. The program is run by Euromissile Dynamics Group, a Paris-based joint venture of British Aerospace, Aerospatiale, and MBB. A development contract is expected to be awarded this year, with total development costs estimated at $1.5 billion. The following three variants of the Trigat are sought:

- A man-launched, medium-range (2-km) version that will utilize a laser designator (Aerospatiale)
- A vehicle-launched, long-range (5 km) version (British Aerospace)
- A helicopter-launched, long-range version (MBB)

The medium-range missile is expected to enter service in the mid-1990s, with the long-range versions to follow in the late 1990s. The helicopter-launched version will be employed on the Franco-German helicopters and Tonal LAHs.

MODULAR STAND OFF WEAPON (MSOW)

With France having recently dropped out of the MSOW project, six nations—Britain, West Germany, the United States, Italy, Canada, and Spain—remain to develop a family of air-to-ground missiles. Three types of the missile will ultimately be produced: a short-range (18 to 30-mile) and a long-range (more than 100-mile) version for use against fixed targets, and a third version for use against mobile targets. It has not yet been determined whether to seek a single missile with interchangeable parts or three separate missiles with common components.

© 1988 Dataquest Incorporated July

The research and development phase is expected to begin with a contract award in September, and will last two-and-one-half to three years. The first phase of development will cost $450 million. A total purchase of about 30,000 vehicles is expected, with the short-range version to be fielded in 1994, the long-range version in 1995, and the mobile-target version in 1996. The cost of the entire program could top $10 billion. Two multinational teams were formed to bid on the program. One team, headed by Rockwell, includes British Aerospace, CASMU (Italy), General Dynamics, and MBB. The second team consists of Agusta (Italy), Brunswick (United States), Dornier (West Germany), Garret (Canada), Hunting Engineering (United Kingdom), and Sener (Spain). When France was still involved in the program, it was planning to allot Canada and Spain 10 percent of the developmental work, and the other five countries 16 percent each. It is not clear how the responsibilities will be reallocated, and the possibility remains that the program could collapse, if the remaining members cannot agree on how to pick up the slack.

THE ADVANDED SHORT-RANGE AIR-TO-AIR MISSILE (ASRAAM)

ASRAAM is under development by European contractors as the next-generation air-to-air missile for close combat in NATO fighter aircraft. The missile is already five years behind schedule, with production to begin in 1995, at the earliest. A European team of Bodenseewerk Geratetechnik and British Aerospace created BBG, a joint venture devoted to development and production of ASRAAM. The program is in jeopardy; reports are that delays will cause the missile to be bypassed in favor of a now-classified missile to equip the Advanced Tactical Fighter and replace the Sidewinder on already deployed aircraft. Such a development would be a setback to NATO defense cooperation. It may be necessary, however, as the venerable Sidewinder missile nears the end of its useful life in the 1990s.

NATO FRIGATE REPLACEMENT FOR THE 1990s (NFR-90)

France, Italy, Spain, West Germany, England, the United States, Canada, and the Netherlands are involved in the NFR-90 project to produce at least 50 general-purpose frigates with air defense capabilities tailored for the environment of the late 1990s. The NFR-90, currently in the project definition phase, is the largest joint weapons program in NATO history, with each ship expected to cost $230 million.

© 1988 Dataquest Incorporated July

NATO ANTI-AIR WARFARE SYSTEM (AAWS)

West Germany, England, the United States, Canada, Spain, and the Netherlands are involved in the concept exploration phase of the prospective NATO AAWS program. Italy and France may join at a later stage. The program is aimed at providing integrated late-1990 and 21st-century short-range defenses against aircraft and cruise missiles for the NFR-90 frigate and other ships of that size. Developmental costs for the AAWS are estimated at $900 million. The concept exploration phase, which began in October 1987, will last 18 months and will be followed by demonstration/validation, development, and production phases.

COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE (C3I) PROGRAMS

Constraints on defense resources in the European nations will place a premium on so-called force multipliers. Accordingly, spending on C3I is likely to increase over the next five years, despite the general pattern of level budgets. One industry study has predicted that Western European spending for C3I will increase by 23.6 percent between 1988 and 1992. A breakdown of this prognosis is given in Table 1.

Table 1

Forecast of National Expenditure on C3I (Millions of Dollars)

Year	France	Germany	Italy	England	NATO-wide	Other European Countries'	Total
1988	$ 880	735	315	760	271	403	$3,364
1992	$1,090	1,075	460	950	345	483	$4,403

Source: Defense News

West Germany, in particular, faced with a manpower shortage in the 1990s that will not only put pressure on its defense budget, but also will reduce the size of its army, has indicated that it will look to technology to compensate. Changes envisioned include increased reliance on microelectronics to provide deep reconnaissance, powerful command systems, accurate firepower at maximum range, and better coordination among these assets. Dennis Kloske, U.S. deputy undersecretary of defense for planning and resources, addressed an April conference of the Electronic Industries Association. Commenting on the field as a whole, he predicted that the next big electronics industry skirmish will be over the international C3I market, as the European defense industry invests heavily in command and control technology.

© 1988 Dataquest Incorporated July

Western Europe--Programs

The following specific C3I initiatives were launched in recent years:

- The European Data Distribution System (EDDS)
- The NATO Air Command and Control System (ACCS)
- RAMSES
- CATRIN
- SIACCON

European Data Distribution System (EDDS)

Nine Western European countries are planning a Europe-wide computerized data transfer network. Design of the EDDS is scheduled to begin in the summer of 1988. Implementation of the network is not expected until the late 1990s. The nine countries involved are Germany, Belgium, Denmark, France, Italy, the Netherlands, Norway, Spain, and England.

NATO Air Command and Control System (ACCS)

Generic system design of NATO's ACCS "Sigma Star" was to be finished by the end of 1987. When deployed (in the year 2000, at the earliest), it will integrate, process, and relay NATO air defense tracking and targeting information, providing an automated command and control system to support all European air operations. The ACCS consists of eight elements: AFATDS, ASAS, FAADC2I, CSSCS, MCS, MSE, and SINCGARS. The combined cost of these programs is $28 billion. ACCS funding will go from $4 billion in fiscal 1988 to $8 billion by fiscal 1992.

ACCS will interface with NATO command and control systems already under development: the NATO friend-or-foe identification system, the Multipurpose Information Distribution System (NATO's version of JTIDS class-2 terminals), and the Battlefield Information Collection and Exploitation System (BICES), which will link the battlefield intelligence systems of individual NATO countries and relay information to division commanders.

 © 1988 Dataquest Incorporated July

Western Europe--Programs

RAMSES

The French Ministry of Defense has formally accepted the initial components of a new command and control network that will link France's nuclear forces with government authorities. The RAMSES system was designed and will be produced by Thomson-CSF. It is scheduled to become fully operational in 1993.

CATRIN

A consortium of six major Italian firms was awarded a $650 million contract to design and develop CATRIN, an advanced network of sensors and communications gear for surveillance, targeting, fire control, and data management on the battlefield. Italtel, Telettra, and Marconi Italiana are responsible for the communications subsystem (SOTRIN), Agusta and Selenia for the air defense subsystem (SOATCC), and Aeritalia for the surveillance and target acquisition subsystem (SORAO).

SIACCON

The Italian army is drawing up plans for SIACCON, an automated command and control system. Although the program is still in its early stages, two Italian industry consortia have already been formed to bid for contracts. One group consists of Agusta, Honeywell Bull, Italtel, Selenia, SEPA, and Telettra, while the other includes Aeritalia, Marconi Italiana, and Olivetti. SIACCON will interface with several existing and planned C3I systems, the major example of which is the CATRIN integrated communications and information system.

SATELLITES

France, Italy, and Spain are teaming to work on the Helios military reconnaissance satellite program. The French share will be 70 percent, with 14.5 percent going to Italy and 6.5 percent to Spain. Plans call for two heliosynchronous satellites to be produced, with an option for a third. Helios is expected to enter service in 1993. Matra (France) is the prime contractor, with ground-based control and data processing stations to be manufactured by the French concerns, Aerospatiale, CNES, and SAT Control. The prime contractors for the Italian portion of the program are Aeritalia, Laben, and Selenia. The estimated cost of the entire Helios program is $1.33 billion, of which $456 million will be spent between 1988 and 1991.

Meanwhile, Italy will invest $637 million to launch SICRAL (satellite Italiano per comunicazione rapide e allarmi), its first military telecommunications satellite, by 1994. Research and development of the satellite, whose prime contractor is Selenio Spazio, will cost $159 million, while procurement and launch will run another $478 million.

© 1988 Dataquest Incorporated July

Western Europe--Programs

Table 2 summarizes European participation in the multinational programs discussed in this section.

Table 2

European Participation in Major Multilateral Defense Programs

Program	England	Germany	Netherlands	France	Spain	Italy
EFA	British Aero.	MBB			CASA	Aeritalia
Radar	Ferranti or Marconi	AEG			Inisel	FIAR
Franco-German Helicopter		MBB		Aerospatiale		
Tonal Helicopter	Westland		Fokker		CASA	Agusta
NH-90		MBB	Fokker	Aerospatiale		Agusta
Trigat	British Aero.	MBB		Aerospatiale		
MSOW	British Aero. or Hunting Eng.	MBB or Dornier			CASA or Sener	CASMU or Agusta
ASRAAM	British Aero.	Boden. Gerat.				
NFR-90	x	x	x	x	x	x
NATO AAWS	x	x	x	?	x	?
Helios				Matra	x	Aeritalia, Laben, and Selenia

Note: x denotes participation where contractor is not known;
? denotes country that may participate in the future.

Source: Defense Forecasts

© 1988 Dataquest Incorporated July

Western Europe--Programs

Table 3 presents the status of major European missile systems, and Table 4 documents aircraft programs.

Table 3

Status of Western European Missile Systems

System	Manufacturers: Prime	Manufacturers: Guidance	Status/Plans
Alarm	British Aerospace	Marconi	Enter British service 1990
ANS	Aerospatiale/ MBB	----	Development
AS30 Laser	Aerospatiale	Thomson-CSF	800 ordered for France, exports
ASMP	Aerospatiale	Thomson-CSF	Upgrade planned
ASR.1238	----	----	RFP, British RAF
ASRAAM	British Aerospace/ Bodenseewerk Geratetechnik	----	Fate uncertain; possible Sidewinder replacement
ASTER/SAAM	Aerospatiale	----	French naval use
Blowpipe/Javelin	Short Brothers	Short Brothers	British army, marines, export production
Crotale	Thomson-CSF/ Matra	Thomson-CSF	Upgrade planned
Eryx	Aerospatiale	----	French army, production by 1990
Exoat	Aerospatiale	EMD	Continued production
Hades	Aerospatiale	SFENA	Replace Pluton by 1992

(Continued)

© 1988 Dataquest Incorporated July

Table 3 (Continued)

Status of Western European Missile Systems

System	Manufacturers Prime	Manufacturers Guidance	Status/Plans
HOT	Euromissile	SAT/Eltro	Upgrade day/night launchers
Ikara Seris	British Aerospace Australia	I & C	Super Ikara in development
Kormoran 2	MBB	Thomson-CSF	Product contract expected
M4	Aerospatiale	SAGEM/EMD	Entering service
Magic	Matra	SAT	Magic 2--possible U.S. aircraft use
Mica	Matra	----	Under development
Milan	Euromissile	SAT/Eltro	Milan 2 in production
Mistral	Matra	SAT	Deliveries begin in 1988
Otomat upgrade	Matra/ OTO Milera	Thomson-CSF	French-Italian use, planned
Rapier/2000	British Aerospace	----	RAF and army use, popular export
RBS.15	Saab/Bofors	----	Swedish and Finnish naval use
RBS.56 Bill	Bofors	----	Swedish army use, U.S. evaluation
RBS.78 Rayrider	Bofors	----	Popular export, U.S. evaluation
Roland	Euromissile	SAGEM, SAT	In production
S3 SSBS	Aerospatiale	EMD-SATEM	Upgraded, S4 planned

(Continued)

© 1988 Dataquest Incorporated July

Table 3 (Continued)

Status of Western European Missile Systems

System	Manufacturers Prime	Guidance	Status/Plans
Sea Dart	British Aerospace	GE, Sperry	Royal naval Use
Sea Eagle	British Aerospace	Marconi	In service in Britain, India
Sea Skua	British Aerospace	Marconi	British service, export orders
Sea Wolf	British Aerospace	Marconi	British use, new versions ordered
Seacat	Short Brothers	Short Brothers	Export orders
Skyflash --	British Aerospace	Marconi	RAF and Swedish use, export orders
Starstreak	Starstreak	----	1990 production for Britain
Super 530D	Matra	ESD	In production
Swingfire	British Aerospace	----	Produced in Egypt
Trigat	Euromissile Dynamics		Contract awarded in June

Source: Aviation Week
Dataquest
July 1988

© 1988 Dataquest Incorporated July

Table 4

Status of Western European Aircraft

Aircraft	Manufacturer	Status
Tactical/Support		
Alpha Jet	Dassault-Breguet/Dornier	Cockpit, armament changes
AMX	Aeritalia/Embraer/Aermacchi	Production starts in 1988
C22J	Caproni	Production starts in 1988
C-101	CASA	150 ordered
EAP	British Aerospace	EFA test bed
Epsilon	Aerospatiale	171 ordered
EFA	4 Nations	In development
Harrier	British Aerospace	98 ordered; upgrades in progress
HS.1102 Hawk	British Aerospace	63 ordered; sub-assemblies for T-45
J35 Draken	Saab	84 ordered
JA37 Viggin	Saab	Winding down by 1990
JAS39 Gripen	Saab	35 ordered
Jaguar	Sepecat	Production continues in India
MB-339	Aermacchi	Upgraded version available
Mirage 3/5/50	Dassault-Breguet	Retrofit market
Mirage 2000	Dassault-Breguet	368 orders
Mirage F1	Dassault-Breguet	Winding down
Rafale	Dassault-Breguet	Estimated 330 to be built
S.211	Siai-Marchetti	In production
SF.260	Siai-Marchetti	In production
SF.600	Siai-Marchetti	Certified
Super Entendard	Dassault-Breguet	Available for license
Supersonic V/STOL	British Aerospace	Under study
Tornado	Panavia	235 to be built
Tucano T.MK	Short Brothers/Embraer	In production
Airlift		
Advanced Airlifter	NATO	C-130, Transall replacement study
C-23 Sherpa	Short Brothers	In production
C212	CASA	Upgraded
CN235	CASA/IPTN	In production
DO.228-100/200	Dornier	152 ordered, Indian production

(Continued)

 © 1988 Dataquest Incorporated July

Table 4 (Continued)

Status of Western European Aircraft

Aircraft	Manufacturer	Status
ASW Patrol		
ATL-2	Dassault-Breguet	In production
Helicopters		
A109	Agusta	In production
A129	Agusta	In production
ALH	MBB/Hindustan Aero.	In development
AS322	Aerospatiale	Upgrade defined
AS350	Aerospatiale	In production
AS355	Aerospatiale	In production
BK.117	MBB/Kawasaki	Production of 3/month
BO.105	MBB	Production of 3/month
BO.108	MBB	In development
EH-101	EH Industries	British, Italian, Canadian orders
Eurofar	Eureka Program	Studies proposed
Lynx	Westland	Upgrade available
NH-90	NATO	Definition
PAH-2/HAC-3/HAP	MBB/Aerospatiale	Definition
SA342	Aerospatiale	In production
SA365	Aerospatiale	In production
Sea King/Commands	Sikorsky/Westland	Phasing out by 1990

Source: Aviation Week
Dataquest
July 1988

© 1988 Dataquest Incorporated July

Other Nations Military Electronics Overview

OVERVIEW

The 12 nations outside of Europe with the largest volumes of military imports are listed in Table 1. Also included are data on the size of these nations' military exports where appropriate.

These countries generally are dependent on imports for all of their military equipment that incorporates advanced technologies, with only Israel, Japan, and South Korea being partial exceptions.

Israel has an advanced and expanding defense industry but a relatively small internal market. Israel's total 1988 to 1989 defense budget was $3.3 billion, of which $1.8 billion was provided by the United States. As a result, Israeli aerospace and electronics companies have been competing ferociously for shares of U.S. defense contracts, with some success. Israeli Aircraft Industries' (IAI) Elta division, for example, is marketing in the United States the integrated self-protection system it developed for the now-canceled Lavi fighter. IAI also signed a $158 million agreement with Lockheed Missiles & Space Co., Inc., for work on the Israeli Arrow antitactical ballistic missile, which is funded in part by the U.S. Strategic Defense Initiative (SDI) program. For many years, Israel has exported defense products covertly to countries such as South Africa, China, and Iran.

Table 1

Major Military Importers (Outside of Europe) of Interest to Defense Electronics Suppliers, 1986 (Millions of Dollars)

Country	Imports	Exports
Saudi Arabia	$2,900	0
Iraq	$4,900	0
India	$2,800	0
Iran	$1,800	0
Egypt	$ 825	$ 50
Australia	$ 800	$ 50
Japan	$ 675	$ 20
South Korea	$ 500	$ 30
Israel	$ 450	$ 20
Taiwan	$ 340	$ 0
Pakistan	$ 290	$ 30
China	$ 140	$1,100

Source: U.S. Arms Control and Disarmament Agency

© 1989 Dataquest Incorporated November

Other Nations Military Electronics Overview

South Korea's defense electronics industry is expected to improve steadily in sophistication and competitiveness. South Korea currently is seeking a coproduction deal with a foreign manufacturer for a new fighter aircraft—the FX—for its air force, primarily to obtain the know-how to develop its indigenous aerospace industry. The prime contractor, Samsung Aerospace Industry, anticipates eventual production of 120 aircraft. Japan's difficulty in persuading the Bush administration and Congress to permit its deal to coproduce the FSX fighter with General Dynamics has been cause for concern to South Korea, which has been looking at both the General Dynamics F-16 and the McDonnell Douglas F/A-18 as candidates for the FX model. The Panavia Tornado is the only non-U.S. candidate known to be under active consideration by South Korea.

Japan has a rapidly expanding defense electronics industry that is likely to be boosted by the development and production of the FSX fighter. Japan's fiscal 1989 defense budget totaled $30.9 billion, almost a 6 percent increase over its fiscal 1988 level. The increased strength of the yen and stable oil prices have allowed the Japanese Defense Agency to procure more advanced equipment than it had originally planned. Priorities in new procurement include electronic warfare platforms, aircraft, and missiles. Japan has not developed a significant military export market because of legislated controls. If such restrictions were lifted, Japan probably would be a significant competitor in global defense electronics markets.

Saudi Arabia consistently has ranked relatively high both in defense spending and military imports. Until recently, Saudi Arabia relied exclusively on U.S. manufacturers for high-technology armaments such as combat aircraft. Due to congressional restrictions, however, the U.S. share of the Saudi defense import market dropped from virtually 100 percent to approximately 50 percent. The Europeans quickly stepped in to fill the void: With its 1988 $18 billion arms deal with Saudi Arabia, the United Kingdom has moved into position to replace the United States as Saudi Arabia's primary defense supplier. Both the EFA Consortium and the French Rafale program are courting Saudi Arabia to join in development efforts for their respective aircraft.

Egypt, Iraq, and Iran all are heavily dependent on foreign imports for armaments and electronics. Egypt traditionally has relied on the United States and Iraq has imported military equipment primarily from the USSR and France. Eqypt and Iraq, however, have been engaged in efforts to codevelop armaments such as tanks and surface-to-surface missiles. The long-term success of these efforts remains to be seen.

India has been very active in building up a modern military force; it is seeking codevelopment projects and technology transfer deals for electronics components. Although India has relied largely on the USSR and the United Kingdom for defense imports in the past, the government in New Delhi has been looking elsewhere, in Europe and the United States, in recent years. Concern in the U.S. Congress and the Bush administration over the Indo-Pakistani competition, as well as the increasing visibility of Indian nuclear and missile programs, has led to careful scrutiny if not outright prohibition of certain transfers of U.S. electronics.

Other Nations Military Electronics Overview

China has a growing, but less sophisticated, arms industry than NATO countries. China's sizable export industry is dominated by low-technology, older weapons, although the transfer of CSS-2 medium-range ballistic missiles to Saudi Arabia is one notable exception. Taiwan also is developing its military electronics potential.

ISRAEL

Israel participates in many U.S. military electronics programs, from ballistic missile defense testbeds to command, control, and communications equipment and most recently, in the short-range UAV project. Israel has an infrastructure that includes avionics, electronic warfare, missile guidance, and communications.

Merkava Mark 3 Tank

Manufactured by Teledyne Continental, deliveries of the Merkava Mark 3 tank should begin in 1990. The Mark 3 will have special armor designed in replaceable modules, an all-electric turret traverse and gun elevation drives, and a neodymium-YAG laser rangefinder. The fire-control system was developed by Elop and Elbit; the advanced threat warning system, which detects a wide array of electromagnetic emissions, was developed by Amcoram. Each tank will cost approximately $2 million to develop.

F-16s

The Israeli government awarded a $94 million contract to Loral for the ALQ-178 electronic countermeasure system to be installed in Israeli F-16 aircraft. Elisra Electronics Systems is a subcontractor for Loral.

Phantom-2000

In April 1989, Israel accepted the first series-production Phantom-2000 from IAI. An upgrade of the F-4E aircraft, the Phantom-2000 includes high-power digital computers, high-resolution capability radar, head-up display, multifunction displays, an improved electronic warfare suite, and an airborne videotape recorder for recording flight performance. Norden supplied the radar; Elbit and Elisra are major subcontractors. Total cost of the program will be approximately $1.1 billion; 140 F-4E aircraft are scheduled to be upgraded during the next 10 years.

© 1989 Dataquest Incorporated November

Other Nations Military Electronics Overview

JAPAN

Unlike the United States, which faces a constrained defense budget, Japan will be able to procure almost all of the items the Japanese Defense Agency requested in fiscal year 1989 due to a 5.9 percent increase in the budget. Japan, like other U.S. allies, is moving gradually toward indigenous design of weapon systems, most notably in the FSX fighter aircraft development program. Japan may face greater difficulties than the European allies, however, in using U.S. military technology as a springboard for its own programs because of negative sentiments in the U.S. Congress over the trade deficit with Japan. Still, both the Aegis and FSX memoranda of understanding were successfully negotiated in 1988 and 1989.

Table 2 shows key items procured in the Japanese fiscal year 1989 budget.

Table 2

Key Japanese Defense Equipment Purchases 1989

Equipment Item	Amount
Ground Self-Defense Force	
Type 74 Main Battle Tank	56
Type 73 Armored Personnel Carrier	23
Improved HAWK SAMs	1 group
Stinger SAM	116 sets
SSM-1 surface-to-ship missile	16 sets
AH-1S antitank helicopter	9
OH-6D observation helicopter	11
HU-1H multipurpose helicopter	10
CH-47 transport helicopter	5
Maritime Self-Defense Force	
P-3C ASW patrol aircraft	10
SH-60J ASW helicopter	12
UH-60J multipurpose helicopter	3
Destroyer escort	2
Submarine	1
Air Self-Defense Force	
F-15J tactical fighter	11
CH-47 transport helicopter	2
T-4 intermediate trainer	20
E-2C Airborne early warning	3
Patriot missile	1 group
FSX fighter	R&D

Source: Defense News

© 1989 Dataquest Incorporated November

FSX

Mitsubishi Heavy Industries, the prime contractor for the FSX fighter, was awarded a $82 million contract in May 1989. The FSX has been the most highly visible Japanese procurement program in the United States. Based on the F-16, the FSX has been the subject of extensive negotiations between the U.S. and Japanese governments on issues such as workshares and technology transfers. Japan plans to procure between 130 and 170 FSX fighters. The entire program will cost close to $8 billion. The fiscal year 1989 Japanese defense budget funded the second year of FSX research at approximately $290 million.

General Dynamics is the major U.S. contractor in the FSX program and expects to receive about $375 million in contracts. The development cost of the FSX has been estimated at $1.2 billion; General Dynamics will receive between 35 and 40 percent of that total and the same percentage of the estimated $5 billion in production. General Dynamics will provide the engines and part of the fuselage and codevelop the wings and frame with Japan; Japan will provide the electronics and the missiles. More specifically, Japan, principally Mitsubishi, will develop the phased array radar, the electronic warfare suite, the inertial navigation system, and the fire-control computer.

Ships and Shipboard Electronics

In December 1988, Japan ordered its first Aegis destroyer at a price of $914 million. About one-half of that amount will be allocated for the Aegis air-defense system manufactured by General Electric. The Japanese Maritime Defense Forces received the Kurobe training support ship built by Nippon Kokan in early 1989, as well as AOE 423 Towada-class replenishment tankers built by Ishikawajima-Harima.

Missile Programs

The Technical Research and Development Institute of the Japan Defense Agency received $725 million in the fiscal year 1989 defense budget. Its research programs include developing a variety of new missiles such as a ship-to-ship version of the Type 88 cruise missile with Mitsubishi, an improved version of the Type 81 missile with Toshiba, and an air-to-air missile, the AAM-3, to replace the Sidewinder. Mitsubishi received a $47 million contract in early 1989 from the Institute to develop an air-to-ship weapon to replace the Type 80 (ASM-1) missile; it hopes to deliver prototypes by 1990.

Other missile programs include development of an antimissile missile with a 30 to 40 kilometer range and a maximum speed of Mach 2 or 3. The fiscal year 1989 defense budget included $40 million for missile research. In addition, Japan funded a $30 million study in fiscal year 1989 for the next-generation surface-to-air missile intended to replace the Patriot. The Japan Defense Agency is conducting the study in conjunction

© 1989 Dataquest Incorporated November

with Mitsubishi Electric, Mitsubishi Heavy Industries, Toshiba, and others. Initial research is expected to last three years; total cost of the program is estimated at $7.6 billion. Raytheon's Patriot will continue to be produced during the next 10 years in Japan under license. Japan recently ordered a Patriot Operator Tactics Trainer from Sanders Associates for $7 million. The trainer will allow simulation at the platoon and battalion levels.

SOUTH KOREA

The South Korean defense industry has made considerable strides in recent years, and the South Korean government is seeking greater self-sufficiency in military procurement. If economic growth continues at the same strong rate during the next 5 to 10 years, South Korea will be able to afford its ambitious procurement plans, which focus on maritime patrol aircraft, airborne early warning, electronic warfare, ground-based radars, and command, control, communications, and intelligence (C3I) systems.

The South Korean air force has a requirement for 120 new fighters before the end of the century. The inventory now comprises F-4, F-5 and F-16 C/D aircraft. The FX program will choose between licensed production of the F-16 or the F-18. At a price of between $3 billion and $4 billion, South Korea will buy 12 complete aircraft, kits for 36 aircraft, and will produce under license 72 aircraft. Negotiations have been under way since fall 1988; South Korea has not yet chosen the aircraft.

Samsung is the prime contractor in South Korea for the FX, but Daewoo and Korean Air also will receive a large portion of the work; airframe work will be divided evenly among the three companies. Lucky GoldStar and Litton-Korea will produce the avionics. Although the McDonnell Douglas F-18 is more expensive ($4 billion for 120) than the General Dynamics F-16 ($3 billion for 120), the F-18 is capable of carrying Harpoon and HARM missiles, and its two-engine configuration may be preferable for long-range operations over water. McDonnell Douglas also has offered an attractive industrial package. Both competitors have offered to modernize South Korea's F-4D and -E aircraft as part of the FX program. At a cost of between $2 million and $3 million, the avionics of the F-4 aricraft will be upgraded, including installation of a new radar, head-up display, and a mission computer. General Dynamics has teamed with Westinghouse and McDonnell Douglas has teamed with Hughes for the upgrade program.

Future aircraft programs include the FXX, an advanced-technology, multirole fighter, and the FXXX. South Korea plans to procure approximately 180 FXX aircraft between 1998 and 2003. General Dynamics has offered the Agile Falcon version of the F-16; McDonnell Douglas has offered the F/A-18 Hornet 2000 as a competitor. The FXXX aircraft is planned to be the first indigenous South Korean fighter, with development scheduled to begin in 2004.

 © 1989 Dataquest Incorporated November

The South Korean army began deliberations in July 1989 to choose a medium-utility helicopter and a light-utility helicopter. The final selections are expected at the end of 1989. The helicopters will augment South Korea's airlift capability.

The following competitors have lined up for the medium-utility helicopter: Aerospatiale, Bell Helicopter/Textron, Sikorsky, and Westland. Sikorsky has teamed with Korean Air to offer the UH-60 Black Hawk helicopter. Bell has teamed with Samsung to offer a heavy version of the 412 SP. Westland is offering the Lynx in a cooperative agreement with Hyundai Precision Industries; Aerospatiale will offer the Super Puma. The helicopters that are selected will be assembled in South Korea.

Daewoo Aerospace Industries and Sikorsky have offered the H-76 Eagle as a light-utility helicopter; Samsung Aerospace Industries and Bell Helicopter/Textron have proposed the 412 SP for light utility. A decision on the light-utility helicopter is expected after that of the medium-utility helicopter.

The South Korean navy and army have requirements for other helicopters as well. In mid-1989, the navy awarded a $200 million contract to Westland for 16 Super Lynx helicopters, and the army ordered 70 AH-1S Cobras from Bell Helicopter/Textron, 21 of which have been delivered. The army also requires an all-weather attack helicopter. McDonnell Douglas has proposed a version of the AH-64 Apache; however, the Westland Lynx and the Eurocopter PAH-2 also are being considered. A decision is expected by 1993.

TAIWAN

The largest procurement program in Taiwan is the Indigenous Defense Fighter, known as Ching Kuo, which is based on the F-16. The research and development (R&D) budget of the Ching Kuo originally was estimated at $1 billion, but it may be as much as $5 billion. Designed as an air-superiority fighter with a secondary antiship role, the Ching Kuo could provide subcontracts worth $27 billion.

The first prototype appeared in December 1988. The prime contractor is Taiwan's Aerospace Industry Development Center (AIDC). General Dynamics, which is assisting AIDC, received a contract for approximately $50 million for technical specifications of the aircraft. Garrett received a $150 million contract for work related to the engine. The Ching Kuo will install the GD-53 Golden Dragon radar, a multimode pulse-doppler fire-control radar based on the APG-67 developed by General Electric. Other elements include the following:

- Bendix/Lear Siegler—Fly-by-wire
- Elrop/Westinghouse—Head-up display
- Garrett—Engine
- Litton—Inertial navigation
- LSI (Smith)—Integrated avionics package

© 1989 Dataquest Incorporated November

Taiwan has not set a date yet for construction, which could begin as early as 1990. Approximately 250 Ching Kuo fighters will be procured at an initial rate of 15 per year, then ramping up to 30 per year. Approximately 40 to 50 of these will be used for training.

 © 1989 Dataquest Incorporated November

Rest of World—Business Overview and Forecast

SUMMARY

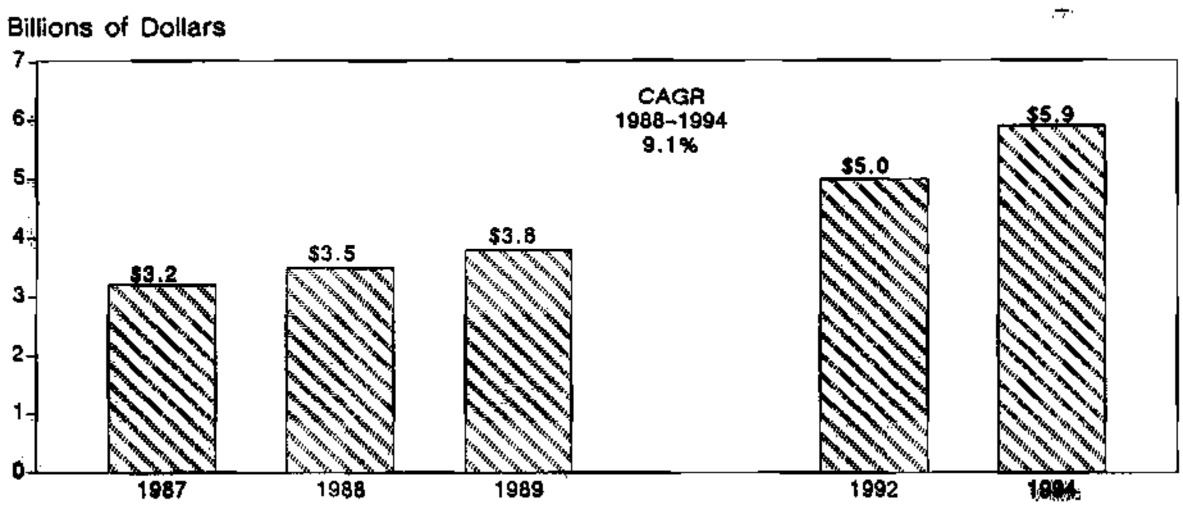
Rest of World (ROW) comprises the collection of non-NATO, non-Warsaw Pact countries. Those known to have significant military electronics production include the following:

- Japan
- Israel
- China
- South Korea
- Taiwan
- Singapore
- Brazil

ROW military electronics production in 1988 is estimated at $3.5 billion and is expected to grow to $5.9 billion by 1994, as shown in Figure 1.

Figure 1

ROW Military Electronic Equipment Production Forecast



Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Rest of World--Business Overview and Forecast

DEFENSE ELECTRONICS SPENDING

The majority of defense electronics spending in the ROW countries is driven by local defense requirements. The need for air, coastal, and sea lane defense is basic. Local wars, especially in the Middle East, provide further demand for electronic defense systems.

Total 1987 ROW defense spending is estimated at $250 billion. Of this amount, $6 billion is estimated to be the electronics content.

As in other countries, the principal ROW customers are the various defense ministries.

ELECTRONIC EQUIPMENT FORECAST

Overview

Local production of electronic systems in ROW is estimated to serve about half its needs. At $3.5 billion in 1988, military electronics production is expected to grow at 9.1 percent compound annual growth rate (CAGR), reaching $5.9 billion in 1994 (see Table 1). Figure 2 presents a breakout of ROW production by country. Japan and Israel are expected to remain the largest as they become more pervasive suppliers.

Table 1

ROW Military Electronic Equipment Production Forecast
1987 to 1994
(Millions of Dollars)

Equipment Category	1987	1988	1989	1992	1994	CAGR 1988-1994
Radar	$ 463	$ 495	$ 530	$ 646	$ 738	6.9%
Sonar	104	113	123	157	184	8.5%
Missile and Weapon	477	521	569	741	884	9.2%
Space	266	289	315	404	478	8.7%
Navigation	88	98	109	149	183	10.9%
Communication	344	382	424	580	695	10.5%
Electronic Warfare	237	262	290	391	476	10.4%
Reconnaissance	114	126	138	184	218	9.6%
Aircraft Systems	310	339	372	488	581	9.4%
Computer Systems	302	338	379	532	665	11.9%
Simulation and Training	39	43	47	62	75	10.0%
Miscellaneous Equipment	485	516	550	664	753	6.5%
Total*	$3,230	$3,524	$3,846	$4,998	$5,930	9.1%

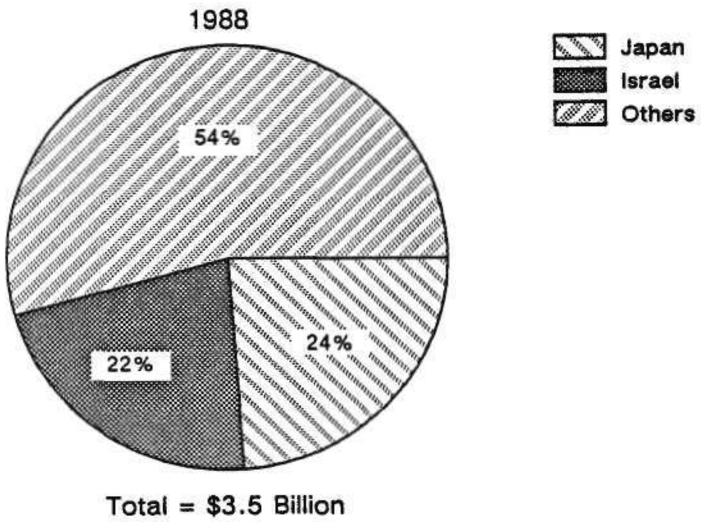
*Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Figure 2

Estimated ROW Military Electronics Production
by Country



Source: Dataquest
August 1988

Forecast Highlights

The following data are highlights of the production forecast presented in Table 1:

- The largest equipment categories in 1988 are as follows:
  - Missile and weapon—$521 million
  - Radar—$495 million
- The fastest CAGRs from 1988 through 1994 are as follows:
  - Computer systems—11.9%
  - Navigation—10.9%
  - Communication—10.5%

© 1988 Dataquest Incorporated August

Rest of World--Business Overview and Forecast

Forecast Assumptions

The following assumptions are drawn from the data presented in Table 1 and Figure 1:

- The basic infrastructure of communication, navigation, and command and control needs much more development.
- Local electronic content is increasing, as more systems are developed locally; licensing of U.S. and European systems is also increasing.
- Emphasis is on conventional defense systems, tactical missiles and aircraft, and patrol-oriented Navies.
- Space systems built by Japan, China, and India are for communication and intelligence.
- Continued emphasis is on locally developed electronic warfare systems, since these systems are difficult to secure from NATO countries.

REST OF WORLD PROGRAMS

Japan

Overview

Japan's fiscal 1988 defense budget is $28.5 billion. This exceeds, for the first time, the 1 percent of GNP limit imposed by its constitution. In recent years, Japan's spending has averaged 6 percent of growth, and it is expected to continue at this rate as Japan executes its defense buildup plan from 1986 through 1990. The current Liberal-Democrat-dominated government favors exceeding the 1 percent limit.

Military equipment procurement in Japan is governed by the Defense Agency and its mission-oriented Ground, Marine, and Air Self-Defense Forces. Procurement and research, development, testing and evaluation (RDT&E) are estimated at 30 percent of Japan's total budget, or about $8.6 billion, in 1988. The electronics content of defense purchases in 1988 is estimated at $2.0 billion. Domestic production of military electronics is estimated at $800 million. A large percentage of the domestically produced defense systems is licensed from the United States and employs enhancements, especially in the electronics. For many years, the bulk of the Japanese electronics firms has steered away from defense applications. However, as the local production grows, especially the production of missiles, more and more firms are attracted to participate.

 © 1988 Dataquest Incorporated August

Japanese advancements in gallium arsenide technology, integrated optoelectronics, and sensor systems are perhaps the best in the world. The United States and NATO are very much interested in their application to western defense systems. The Japanese also have proven to be adept in applying advanced commercial technology effectively to military systems. These facts will help shape the future of external business relationships with Japan.

Aircraft

Probably the most visible of the new Japanese defense programs is the FS-X close-support fighter. About 130 of the planes would be procured through 2001, with a total estimated value of $8.0 billion. After some controversy, the General Dynamics F-16 was selected as the platform for development of the FS-X. Japan plans to use domestically developed composite materials technology as well as a new fire control system, an active phased-array radar, and an integrated electronic warfare system to enhance the F-16. Further controversy surrounds whether or not General Dynamics, the United States, or NATO is allowed to have license to this new technology. Mitsubishi will be the prime contractor.

The significant airframe manufacturers are Fuji Heavy Industries, Kawasaki, and Mitsubishi. Mitsubishi manufactures the F-1 fighter, the F-15D and F-15DJ (12 on order), the F-4EJ (17 being upgraded), the T-2 trainer, the LR-1 reconnaissance craft, and the SH-60J (98 planned) and UH-60J helicopters. Mitsubishi Electric is a major manufacturer of avionics systems including flight control and electronic warfare systems.

Kawasaki licenses the P-3C from Lockheed for Anti Submarine Warfare (ASW) aircraft. Kawasaki built 40, and another 10 are on order. It also makes the new T-4 trainer, with total future procurement estimated at 150 to 200 aircraft. Fuji has the AH-1S anti-armor helicopter program (licensed from Bell) and manufactures drones.

Ishikawajima-Harima is the dominant aircraft engine manufacturer in Japan. Japan Aviation Electronics is a large subcontractor of navigation and flight control systems.

Ships

Hitachi, Ishikawajima-Harima, Mitsubishi, Mitsui, and Sumitomo are the principal surface ship manufacturers. Mitsubishi has the prime contract to build the Aegis air-defense vessel in Japan, with the first one to be ready in 1992. Four are planned, at $1.0 billion apiece. Mitsubishi Electric will provide the bulk of the on-board electronic systems. Japan builds three to four ships per year, on the average. Mitsubishi and Kawasaki are the principal submarine makers.

Missiles and Weapons

Japan licenses a variety of missile systems from U.S. manufacturers. The principal missile manufacturers are Kawasaki Heavy Industries, Mitsubishi Heavy Industries and Electric, and Toshiba. Kawasaki makes the KAM-3D and KAM-9 surface-to-surface missiles, and the Type-79 and Type-87 antitank missiles. Mitsubishi Heavy Industries

© 1988 Dataquest Incorporated August

makes the Hawk and Sparrow (licensed from Raytheon), the antiship SSM-1, and air-to-ship ASM-1. Mitsubishi Electric makes the Sidewinder air-to-air missile and the Patriot air defense system (a high-priority item with a $743 million budget for 1988). The Toshiba/Kawasaki team makes the Tan-SAM surface-to-air missile. Fujitsu, Japan Aviation Electronics, Mitsubishi, NEC Corporation, and Toshiba produce electronic missile guidance systems.

The success of the SSM-1 program has prompted the Defense Agency to investigate further domestic missile programs. One such example is the $65 million development program by Toshiba for a replacement for the Stinger portable air-defense missile. The upgrade is expected to have an improved infrared image-homing system. Some other developing missile programs include Mitsubishi's infrared-homing XAAM-3 to replace the Sidewinders and a Japanese version of the U.S. army's Multiple Launcher Rocket System.

Other Electronics

Other military electronic capabilities include night vision systems by Fujitsu, Mitsubishi Electric, and NEC. NEC and Mitsubishi Electric have established capabilities in supplying active phased-array radar systems.

Israel

In an effort to become self-reliant, Israel has developed an extensive infrastructure of military electronics design and production. Like Japanese electronics capability, Israel's electronics capability started by taking existing U.S. aircraft, in particular the F-4, and upgrading them with advanced avionics, radar, and electronic warfare systems to suit its own needs. Israel also has many original system designs including the Lavi fighter and its various subsystems, an array of remotely piloted vehicles (RPVs), and several missile systems including the Gabriel made by Israel Aircraft Industries (IAI).

Although the Lavi program was cancelled, its manufacturer, IAI, is marketing the electronics developed for the aircraft. It is also marketing a new aircraft called the Nammar, which will incorporate much of the Lavi electronic systems. Other military electronics companies include the following:

- Tadiran—Communications, electronic intelligence and RPVs
- Elisra Electronics—Electronic warfare, electronic intelligence, and radar
- Rafael Armament—Missile guidance and control, electronic warfare systems
- Elbit Computers—Electronic warfare and computing systems

Other Countries

NATO countries practice the extensive licensing of aircraft and missile systems know-how to dozens of other countries. In turn, those other countries with internal commercial electronics capabilities are utilizing that expertise to manufacture their own military electronics as well.

China is upgrading its aircraft and missile systems and is utilizing help from the United States, Europe, and Israel to do it. China currently manufactures many types of aircraft including the Jian Ji-7 and 8-2 based on the modified MIG-21.

Brazil is a manufacturer of substantial numbers of aircraft through Embraer (transports and trainers), Helibras (helicopters), and Avibras-Industrial Aerospacial (missiles).

Taiwan currently manufactures transport and trainer aircraft and is a manufacturer of electronic warfare systems. Singapore is in the aircraft upgrade business, including the upgrading of some electronic systems. Hindustan Aeronautics, Ltd., of India is a manufacturer of fighters, transports, and trainers, some of which are under license.

© 1988 Dataquest Incorporated August

(Page intentionally left blank)

 © 1988 Dataquest Incorporated August

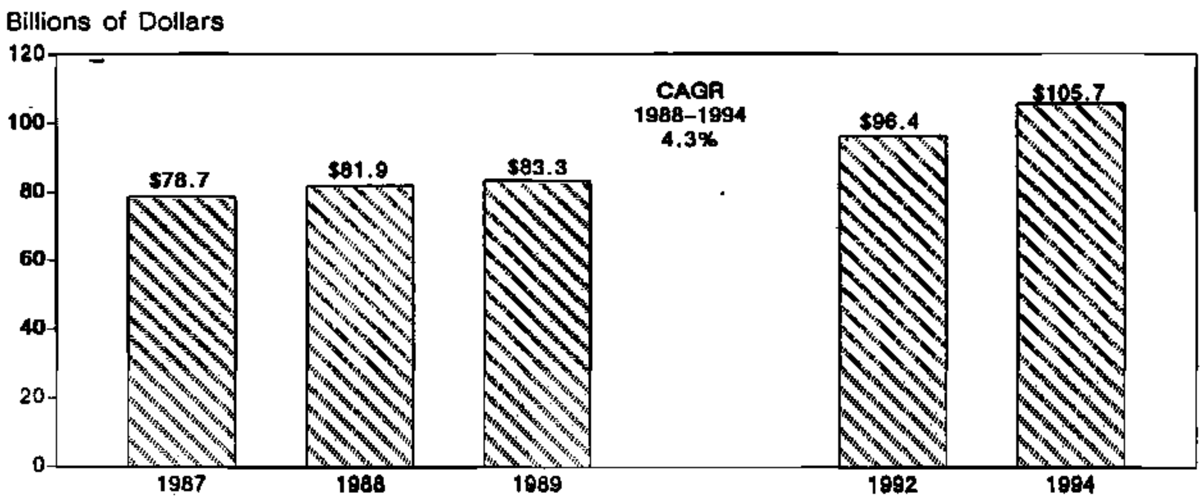
Worldwide Military Electronic Equipment Forecast

OVERVIEW

The worldwide (not including the Warsaw Pact member nations) military electronic equipment market is expected to grow from $81.9 billion in 1988 to $105.7 billion in 1994, a 4.3 percent compound annual growth rate (CAGR) (see Figure 1). The United States is expected to continue to dominate worldwide production, as it continues to emphasize the importance of military electronics, even in a era of declining budgets. Table 1 presents the forecast for this market, broken out by equipment category.

Figure 1

Worldwide Military Electronic Equipment Forecast



Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 1

**Estimated Worldwide Military Electronic Equipment Production
1987 to 1994
(Millions of Dollars)**

Equipment Category	1987	1988	1989	1992	1994	CAGR 1988-1994
Radar	$10,671	$11,034	$11,124	$12,402	$ 13,316	3.2%
Sonar	3,682	3,766	3,791	4,283	4,631	3.5%
Missile and Weapon	9,640	10,115	10,360	12,418	13,937	5.5%
Space	6,922	7,041	7,066	8,421	9,418	5.0%
Navigation	2,184	2,272	2,315	2,671	2,941	4.4%
Communication	7,170	7,562	7,801	9,160	10,095	4.9%
Electronic Warfare	5,173	5,461	5,604	6,609	7,292	4.9%
Reconnaissance	3,515	3,689	3,789	4,412	4,862	4.7%
Aircraft Systems	6,851	7,140	7,267	8,528	9,489	4.9%
Computer Systems	7,548	7,873	8,053	9,588	10,710	5.3%
Simulation and Training	973	1,029	1,062	1,299	1,474	6.2%
Miscellaneous Equipment	14,346	14,897	15,134	16,588	17,516	2.7%
Total*	$78,676	$81,879	$83,366	$96,379	$105,681	4.3%

*Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

FORECAST HIGHLIGHTS

The following data summarize the military electronic equipment forecast from 1987 through 1994:

- The largest equipment categories in 1988 are forecast, as follows:
  - Radar—$11.0 billion
  - Missile and Weapon—$10.1 billion
- The fastest CAGR from 1988 through 1994 is forecast, as follows:
  - Simulation and Training—6.2%
  - Missile and Weapon—5.5%
  - Computer Systems—5.3%

 © 1988 Dataquest Incorporated August

FORECAST ASSUMPTIONS

Certain assumptions can be drawn from the forecast data, as follows:

- Worldwide defense spending is leveling, but electronic content is increasing, as systems become more sophisticated.
- Expenditure on strategic and nuclear weapons systems are being reduced due to Intermediate Nuclear Forces (INF) and potential follow-up arms reduction treaties.
- Because of nuclear arms reduction, there will be further emphasis on conventional programs.
- Emphasis is on upgrading existing systems to complement development of new programs but to control overall costs.
- New generations of aircraft entering production by the mid-1990s include the Advanced Tactical Fighter (ATF), Advanced Tactical Aircraft (ATA), and the European Fighter Aircraft (EFA).
- A general leveling of ship and submarine building will prevail until the late 1990s.
- Future thrust areas will include the following:
  - Smart weapons—More autonomous, accurate, jamproof, target-discriminating missiles, bombs, and munitions
  - Command, Control, Communications and Intelligence (C3I)—Continued emphasis on improving passive information gathering, communications links, data intelligence extraction, and real-time decision support for tactical commanders
  - Stealth and antistealth techniques

GEOGRAPHIC TRENDS

Figure 2 presents the geographic view of worldwide military electronics production. The following is a summary of the data presented in Figure 2:

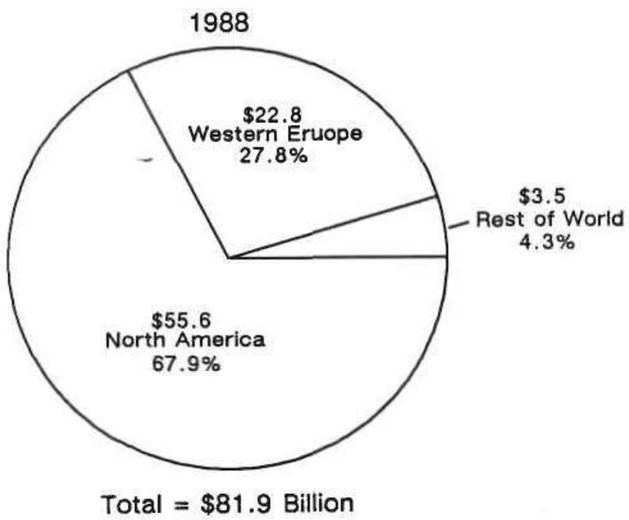
- U.S. production of $55.6 billion comprises 67.9 percent of the worldwide production in 1988. Its share will decline slightly to 66.1 percent by 1994, as European and the Rest of World manufacturers displace the U.S. in serving their own markets. U.S. production will exhibit a 3.9 percent CAGR, reaching $69.9 billion in 1994.

© 1988 Dataquest Incorporated August

- Western European production, at $22.8 billion in 1988, will compound at 4.6 percent through 1994, reaching $29.9 billion. Its share of the worldwide market will grow from 27.8 percent to 28.3 percent.
- Rest of World production, at $3.5 billion in 1988, will compound at 9.1 percent through 1994, reaching $5.9 billion. Its share of the worldwide market will increase from 4.3 percent to 5.6 percent.

Figure 2

Worldwide Military Electronics Production Forecast



Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

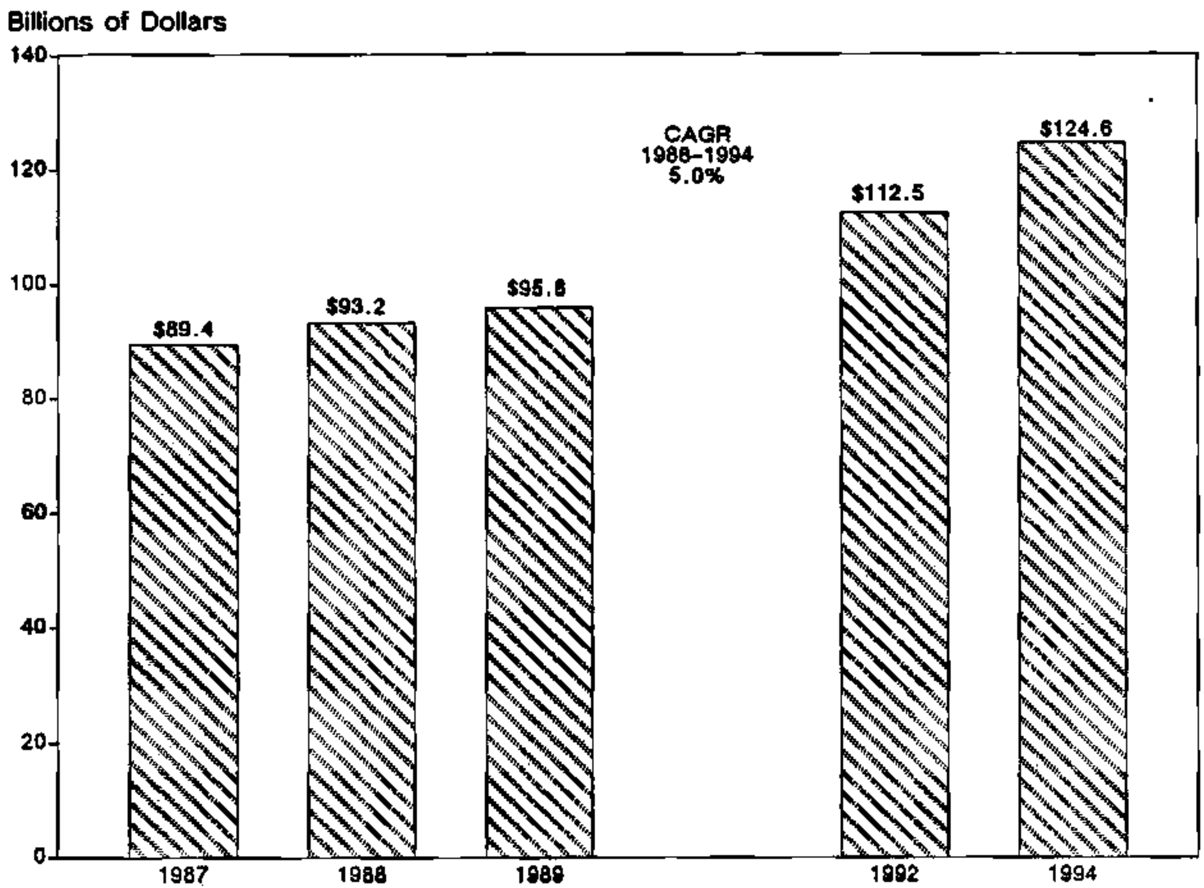
Military and Civil Aerospace Electronics Overview

SUMMARY

Figure 1 presents the forecast for worldwide military and civil aerospace electronic equipment production. At $89.4 billion in 1987, production is expected to grow 4.3 percent in 1988 and then grow at a 5.0 percent CAGR through 1994. The predominant trend is a leveling of worldwide defense spending from the buildup period earlier in the 1980s. Stable shipments of a new generation of electronics-rich commercial airliners, and recovering satellite construction, partially will offset the military leveling.

Figure 1

Estimated Military and Civil Aerospace Worldwide Electronics Production



Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

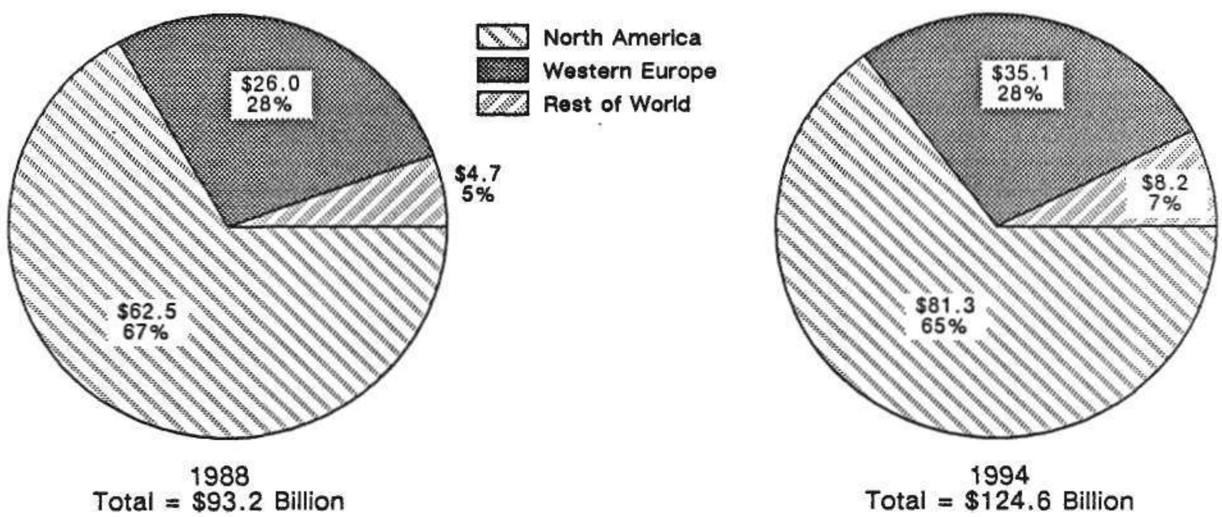
Military and Civil Aerospace Electronics Overview

In general, the electronic content of military equipment, civil space, and aviation systems is projected to continue increasing. Electronics allows more intelligence, precision, and capacity, as well as efficiency, to be incorporated into these systems. Therefore, the growth rates for electronics used in these systems will remain higher than the growth rate for the military and aerospace industries as a whole. This factor, especially as the military system industry restructures itself, will keep electronics a highly competitive area of growth.

The domination of world production by North American OEMs is yielding gradually to a greater presence from Western Europe and Japan (see Figure 2). As the United States places more pressure on other NATO countries and Japan to share common defense costs, an outcome will be an increasing share of electronics produced in those countries. Additionally, countries like Japan, China, and Brazil are growing infant aerospace industries and are predicted to be serving world markets, and their own, in increasing proportions.

Figure 2

Estimated Military and Civil Aerospace Geographic Electronics Production



Source: Dataquest August 1988

 © 1988 Dataquest Incorporated August

Military Market Overview

The use of electronics in military systems has grown rapidly over the past decade. As the need for more sophisticated and reliable systems arose, electronics stepped in as the primary means of achieving engineering goals. It is estimated that worldwide military electronics shipments grew at a 9 percent compound annual growth rate (CAGR) through the early 1980s, reaching a value of almost $80 billion in 1987. North America, principally the United States, is the primary producer of military electronics, accounting for 68 percent of the free-world total. Western Europe accounted for 28 percent, and the balance of the non-Warsaw Pact nations for 4 percent.

The next decade is predicted to witness less robust military electronics growth, as the market begins to mature and free-world defense spending levels. However, the worldwide market is expected to grow at a 4.3 percent CAGR, reaching $106 billion, as upgrade programs and new-generation aircraft and space systems are implemented.

The implication for military electronics OEMs and their suppliers is that growth will be more selective, and where growth occurs, it will be highly competitive.

NORTH AMERICA

North American production of military electronics is estimated at $55.6 billion in 1988 and is projected to grow at a 3.9 percent CAGR, reaching $69.9 billion in 1994. While the total U.S. defense budget will barely keep pace with inflation, the following factors will ensure faster rises in expenditure for defense electronics:

- The United States is depending on the capabilities of advanced electronics to multiply the effectiveness of its numerically smaller forces. New generations of aircraft, ships and submarines, space systems, and a variety of systems for land warfare are expected to be available in the 1990s. These new vehicles and systems will incorporate advanced sensors, signal processing, and data processing to permit each weapon system to be more flexible and effective.

- Although a tight defense budget may delay the introduction of these new systems, the armed forces will compensate by modernizing existing platforms with the more advanced systems now available.

- The proliferation of advanced military technologies in the third world means that the United States can no longer afford to maintain less than state-of-the-art equipment for contingencies anywhere.

© 1988 Dataquest Incorporated August

- Recognizing the increasing importance of defense electronics, the U.S. Department of Defense has been investing heavily in basic computing technologies and in the exploration of futuristic applications. Programs like MIMIC and VHSIC to develop advanced computing capabilities, as well as research programs in robotics; applications of artificial intelligence; and space-based, integrated intelligence and command systems for tactical operations are expected to proceed, despite pressures to constrain defense spending.

WESTERN EUROPE

The collective Western European production of military electronics is expected to grow from a 1988 level of $22.8 billion to $29.9 billion by 1994, a 4.6 percent CAGR. Growth in Europe is expected to be controlled, in spite of U.S pressure on Western European countries to share more of their own defense burden. Demand for European military electronic systems will be propelled by the same factors as those found in the United States.

REST OF WORLD

Of the remaining rest of world (ROW) nations, Japan and Israel are currently significant manufacturers and markets for military electronics. The former exports very few military electronics but produces extremely sophisticated systems for domestic consumption. Japan's defense spending is limited by law, but this restriction was loosened recently. Japan, like the European countries, is under increasing pressure to boost its economic and physical support of sea lane security in the Pacific and the Persian Gulf. Overall ROW electronics production is estimated at $3.5 billion in 1988 and is expected to grow at a 9.1 percent CAGR, reaching $5.9 billion in 1994.

Israel has developed an impressive defense electronics infrastructure in the past two decades. It has developed a strong export business and will be a formidable competitor for European and American firms.

Other countries such as China, India, Brazil, and South Korea have infant defense electronics markets and production capabilities, but they are expected to at least serve their own markets, in time.

© 1988 Dataquest Incorporated August

Political Environment

THE STRATEGIC VIEW

The most important determinant of the U.S. defense program in 1988 is neither the threat posed by Soviet military power nor U.S. alliance commitments; it is the federal budget deficit. Over the past several years, a bipartisan consensus has been forged in congress to the effect that the deficit poses the gravest threat to the nation's well-being. Moreover, cuts in the defense budget must play an equal part with reductions in civilian programs to bring about a balanced budget. Working through the Gramm-Rudman-Hollings amendment, the deficit-cutting spirit on Capitol Hill tolled the death knell for the Reagan military buildup, halting growth in defense spending. The "soft" foreign policy line pursued by Soviet leader Mikhail Gorbachev, bringing with it the possibility of far-reaching arms control agreements, supported congress' renewed appetite for defense cutbacks.

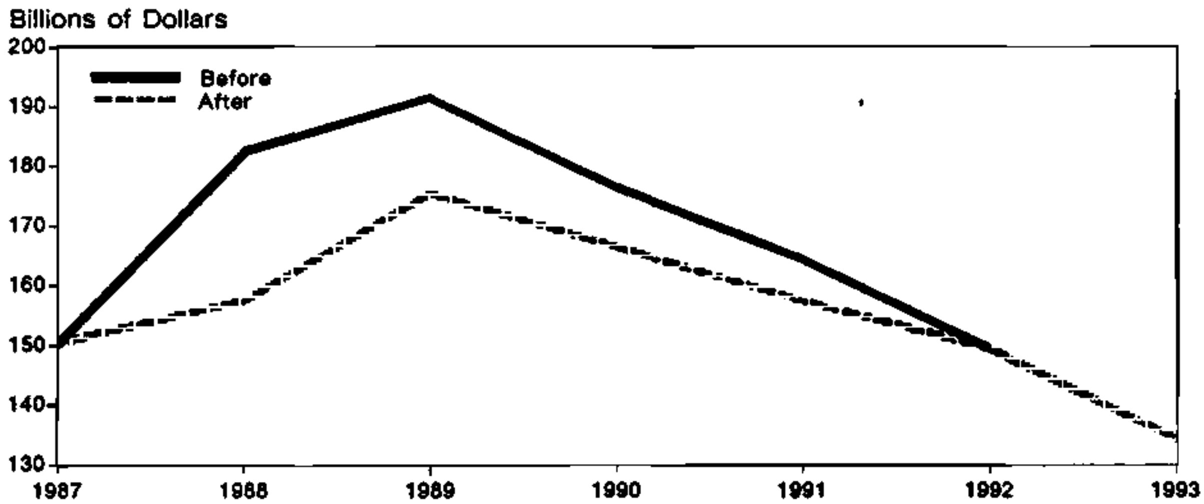
Concern about the deficit was strongly reinforced when the stock market crashed in October 1987. Two months later, the administration and congress reached a far-ranging compromise on fiscal policy, which incorporated somewhat more rapid progress toward lower deficits and, accordingly, further cuts in defense spending. As a result, the planned defense budget for fiscal 1989 was cut by $33 billion, about 10 percent. Rudely awakened from the fat years of the early 1980s, the military services were forced to make agonizing reappraisals of their goals and priorities. A further cut of $200 billion in the fiscal 1990 to 1994 defense program (roughly 12 percent) will be apportioned during the summer and fall.

Unless the next president is willing to accept the political stigma of raising taxes, even larger defense budget reductions may be necessary in the future. Although the December budget compromise improved the prospective deficit picture, it fell far short of what most leaders in the financial and business communities thought was necessary. Under current projections, the deficit will remain as high as $150 billion in fiscal 1992 (see Figure 1). A new debacle in the financial markets or other adverse economic news could lead to more heroic efforts to cut back federal spending. The share of any such reductions apportioned to defense will depend largely on three international factors: U.S./Soviet relations, developments in Europe, and events in such tumultuous regions as the Persian Gulf.

© 1988 Dataquest Incorporated August

Figure 1

Prospective Deficits before and after the December Budget Compromise
Baseline Deficit



Source: Congressional Budget Office
Dataquest
August 1988

U.S./Soviet Relations

Mr. Gorbachev has pursued a conciliatory foreign policy line for more than three years. It is having major effects on popular perceptions of the threat posed by the Soviet Union—in Europe, Japan, and the United States—and, thus, on support for defense spending. Mr. Gorbachev's willingness to compromise on long-standing Soviet positions in arms control negotiations—most importantly, a new willingness to accept intrusive measures of verification, including on-site inspections—has resulted in a treaty to abolish intermediate-range missiles. His tendency toward compromise has also raised the prospect of four additional, far-ranging agreements on other types of forces in the future (See Table 1). His conciliatory approach to international issues has also raised the possibility of peaceful solutions to several international conflicts, further eroding perceptions of the need for high levels of defense spending. The imminent withdrawal of Soviet forces from Afghanistan will further reinforce Mr. Gorbachev's image as a peacemaker.

Of course, one cannot be certain that the current Soviet line will persist. There have been signs that Mr. Gorbachev's internal position is shaky and some indicators of restiveness on the part of the Soviet military. International events might also slow or alter his policy. A blowup in Eastern Europe attributed to the more relaxed Soviet posture, for example, would alter Soviet policy profoundly, and the ensuing Soviet repression might reinvigorate public willingness in the west to support more ambitious defense spending objectives.

 © 1988 Dataquest Incorporated August

Political Environment

Table 1

Actual and Prospective Arms Control Agreements

Type	Key Features	Status
Intermediate Nuclear Forces	Totally eliminates land-based missiles with ranges between 500 and 5,500 kilometers	Completed
Strategic Nuclear and Space Forces	50 percent cuts in ICBMs, sea-based missiles, and long-range bombers	Near completion; feasible in one year
Chemical Weapons	Prohibits the production and use of all lethal chemical agents; requires destruction of existing stocks	In negotiation; feasible in several years
Conventional Forces in Europe	"Major" (25 percent) reductions in ground forces and removal of asymmetries between east and west	Talks will begin in 1988; agreement unlikely until 1990s
Nuclear Testing	Prohibits all nuclear tests	Talks on more limited agreements under way and feasible; comprehensive ban probably not in the cards

Source: Defense Forecasts

Still, the most likely scenario for the next five years would assume continued détente between the United States and the Soviet Union and progress in arms negotiations. In addition to ensuring that defense budget reductions motivated by economic considerations are feasible politically, this projection has important implications for the allocation of defense resources to different types of forces and weapons and to the electronics content of the budget. Most importantly, it means the continued erosion of support for nuclear weapon programs and greater emphasis on conventional forces. The agreements most likely to be concluded in the near term will pertain solely to nuclear forces. The emphasis on arms control also means greater spending for sophisticated intelligence systems; such pressures have already emerged from congressional hearings on the INF treaty.

© 1988 Dataquest Incorporated August

Political Environment

Continued U.S./Soviet détente means that the deployment of any strategic defense system is unlikely in the 1990s; the strategic defense initiative will most likely remain a $4 billion per year research program well into that decade. If there are any deployments of strategic defenses in this century, they likely will be constrained by the 1972 Antiballistic Missile (ABM) Treaty, meaning that they would include only small numbers of ground-based interceptors and radar. Even such a modest system would not enter production until the mid-1990s.

Greater reliance on conventional forces does not mean larger force levels; indeed, prospective budget cuts will enforce reductions in U.S. ground, air, and naval forces. Instead, the United States will seek to compensate with more capable weapons; the stress will be on exploiting technology, which means greater electronics content. Small arms aside, it is hard to think of a single modern weapon that does not contain microprocessors and other electronic devices. From the infantry soldier's radio backpack to modern warships, electronics are ubiquitous.

As a result of an initiative by Senator Sam Nunn (D-Ga), chairman of the Senate Armed Services Committee, and others, the defense department has undertaken the Balanced Technology Initiative to develop advanced technologies for conventional forces. The program received $200 million last year, with stress placed on developing smart weapons, armor/anti-armor technology, and surveillance, target acquisition, command and control, and battle management (see Table 2). Spending on these types of equipment can be expected to accelerate, particularly if further cuts are made in nuclear forces.

Table 2

Balanced Technology Initiative
Thrust Areas and Funding

Technology	Percentage of Total
Smart Weapons Technology	30%
RSTA/BMC3 Technology	24
Armor/Anti-Armor Technology	19
High-Power Microwaves	8
Special Technological Opportunities	19
Total	100%

Source: Congressional Testimony

© 1988 Dataquest Incorporated August

Political Environment

The European Situation

The shift in emphasis from nuclear to conventional forces will influence the posture of the armed forces in Europe most of all. The agreement to remove all intermediate-range missiles has caused considerable concern among some of NATO's military officials, with just-retired Supreme Allied Commander Bernard Rogers the most outspoken. During his eight years in office, Mr. Rogers pushed relentlessly for a number of development programs intended to provide the army with the technical capabilities necessary to implement its air/land battle doctrine, a tactical innovation intended to offset advances in Soviet capabilities for ground warfare. Many of these programs have lagged badly but will now receive greater impetus (See Table 3).

Table 3

Army Electronics Systems Necessary to Implement Air/Land Battle Doctrine

System	Current Status
Sensor/Surveillance	
Aquila Remotely Piloted Vehicle	Funding denied
Standoff Target Acquisition System	Cancelled
Precision Location and Strike System	Cancelled
Command, Control, and Communications	
Tactical Satellite	In development
All-Source Analysis System	In development
Single-Channel Ground and Airborne Radio System	Initial operating capacity slipped from 1985 to 1988
Multiple Subscriber Equipment	In planning
Platforms	
LHX Helicopter	Being restructured

Sources: Congressional Testimony
U.S. Department of Defense

© 1988 Dataquest Incorporated August

Political Environment

Talks between NATO and Warsaw Pact nations, intended to bring about major reductions in deployments of conventional forces in Europe, ironically will provide additional incentives for the modernization of NATO's conventional forces. Hopelessly outnumbered by Soviet armor, artillery, and other ground weapons, NATO will count on the leverage provided by its technical prowess to bring about asymmetrical reductions in ground forces. Robust development programs for conventional weapons are considered an essential, implicit trump in the NATO hand.

Congress is generally supportive of these modernization programs. Indeed, members of congress have taken the lead at times in urging a more rapid pace for some types of weapons and equipment. The Nunn Amendment is one congressionally pushed initiative. In December 1987, for example, Senator Dan Quayle proposed a package of U.S./European cooperative acquisition programs to upgrade NATO's conventional and remaining nuclear capabilities. Sen. Quayle estimated that the initiative would cost $75 billion over its 15-year lifetime. The specific weapons that Sen. Quayle would emphasize are listed below. While most of these weapons were already in NATO's plans, their inclusion in the Quayle initiative suggests a greater likelihood of their surviving future budget cutting.

The following weapon systems are included in the Quayle initiative:

- Improved conventional forward defenses:
  - Upgraded air defenses (Patriot)
  - Advanced artillery munitions and other fire support (ATM, MLRS, ATACMS, MSOW)
- Conventionally armed, long-range systems to disrupt second-echelon forces:
  - Cruise missiles
  - Aircraft-delivered munitions (Tacit Rainbow)
  - Advanced command/control and intelligence systems
  - Penetration aids
- Enhanced short-range nuclear systems:
  - Longer-range 155mm nuclear shell
  - Lance follow-on

© 1988 Dataquest Incorporated August

Political Environment

The major European powers are also seeking to modernize their conventional forces. They are constrained, however, by the small amounts of resources devoted to defense. Table 4 shows the relative size of European and U.S. defense budgets, as well as the burden of defense expressed as a share of GNP.

Table 4

1986 Defense Spending of Major NATO Members

Country	Total Budget (Billions of Dollars)	Percentage of GNP
United States	$281	6.8%
United Kingdom	$ 27	5.1%
France	$ 28	3.9%
West Germany	$ 28	3.1%
Italy	$ 13	2.2%

Source: U.S. Department of Defense

A tendency in recent years was toward closer cooperation in defense production, both among European manufacturers alone and, more recently, between the United States and European countries. As all nations' defense budgets remain constrained and the price of each item of equipment increases, the volume of potential sales for more and more types of equipment will become insufficient to sustain multiple manufacturers. The sharp third-world export market decline, which followed the drop in oil prices, has aggravated this trend. Increasingly, major development programs will be carried out by multinational teams, with cooperative arrangements established to ensure access to both European and American markets for the team winning procurement contracts.

Third-World Conflict

The final major geostrategic trend that will have a resounding impact on the U.S. defense budget is the turbulence in the third world, particularly in the arc from the Middle East through the Persian Gulf to Southern Asia, combined with the accelerating proliferation of weapons incorporating advanced technologies and the capabilities to produce some of those weapons in third-world nations. This factor, in fact, is probably the only one with the real potential to disrupt the downward trend in U.S. defense spending. A major escalation of fighting in the Persian Gulf, for example, or the eruption of a hot war in a second location, could break the consensus now supporting level defense budgets. (The current level of U.S. naval operations in the Persian Gulf, however, running at a cost of perhaps $200 million per year, requires only a cutback in other peacetime operations and training.)

© 1988 Dataquest Incorporated August

Political Environment

The potential of advanced munitions to enable a small nation to inflict serious damage on a much more powerful military force has been demonstrated repeatedly in recent years. The destruction of the British frigate Sheffield during the Falklands conflict and the successful Iraqi attack on the U.S. frigate Stark in 1987 are the most prominent examples. As a result, the United States can no longer plan to have two levels of forces, some with advanced technologies intended for major conflicts with the Soviet Union, and other, less capable forces for third-world conflicts. The most modern equipment is required virtually everywhere in the world.

Recent conflicts in the Persian Gulf demonstrate this particularly well. In various episodes during 1988, U.S. naval forces have used Harpoon antiship missiles, laser-guided weapons, and cluster munitions to attack Iranian forces. The latest surveillance and target acquisition systems have greatly aided the U.S. effort. The fact that some decisions on combat operations are being taken on a real-time basis in Washington by Secretary of Defense Frank Carlucci, and even by the president on one occasion, indicates the sophistication of the command and control systems now in use. For their part, American adversaries have fired Exocet air-to-surface missiles, Harpoon and Seacat antiship missiles, and Silkworm surface-to-surface missiles. Adversary aircraft have included both Soviet-built MiG-23s and U.S.-built F-14s.

The proliferation of capabilities to manufacture modern military equipment ensures that this trend toward advanced armaments in the third world will accelerate. In addition to the major European countries, Brazil manufactures and exports armored vehicles and aircraft; India produces a variety of military equipment; and both South and North Korea produce and export a variety of munitions and other equipment. Israel's military electronics industry is particularly advanced, and Israel is a major exporter to a number of countries, with China a particularly important customer.

Looking toward the longer term, a key development is the procreation of ballistic missiles. At least eight third-world nations now have programs to deploy short- or medium-range missiles in the 1990s. Some are variants of missiles purchased from the USSR, but many are indigenously designed spin-offs from civilian space programs. The proliferation of these weapons will place a premium on the development and widespread deployment of effective antitactical ballistic missile systems—programs now pursued vigorously by the United States, Western European nations, and Israel.

© 1988 Dataquest Incorporated August

Political Environment

BUDGET OUTLOOKS

Worldwide military expenditure is dominated by the defense budgets of the United States and the Soviet Union. Together, the two account for roughly 56 percent of the nearly $1 trillion expended by all nations for military purposes in 1987. Adding in the two superpowers' respective allies in Europe, NATO, and the Warsaw Pact accounted for about three-fourths of worldwide military expenditure (see Figure 2). Outside these two alliances, the largest military spenders are China ($26 billion), Saudi Arabia ($24 billion), Iraq ($16 billion), Japan ($13 billion), Iran ($12 billion), and Israel ($8 billion).

Figure 2

1987 Worldwide Defense Spending

Total = $1 Trillion

Source: Defense Forecasts
Dataquest
August 1988

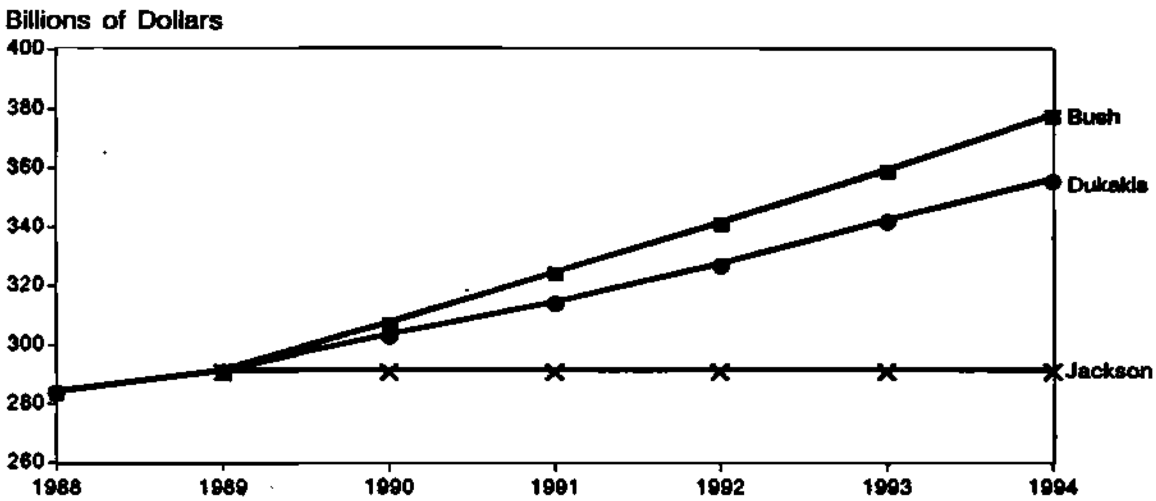
© 1988 Dataquest Incorporated August

United States

It is normally hazardous in an election year to project any aspect of government expenditure, particularly one as volatile and controversial as defense. This year, however, the task is relatively easy. There is nearly a consensus among the presidential candidates on the appropriate amounts to be spent on defense; the range of choice is small, as shown in Figure 3. In any event, congress would likely cut back George Bush's top line and build up Jesse Jackson's freeze proposal to something approximating the no-real-growth budget projected for Michael Dukakis. The real impact of the election will be seen in the apportionment of defense funds; the Bush or Dukakis administration could be expected to differ in the relative priorities that it would accord to various defense programs. The Strategic Defense Initiative is an obvious illustration.

Figure 3

Estimated Defense Budgets Under Alternative Administrations
Total Budget Authority



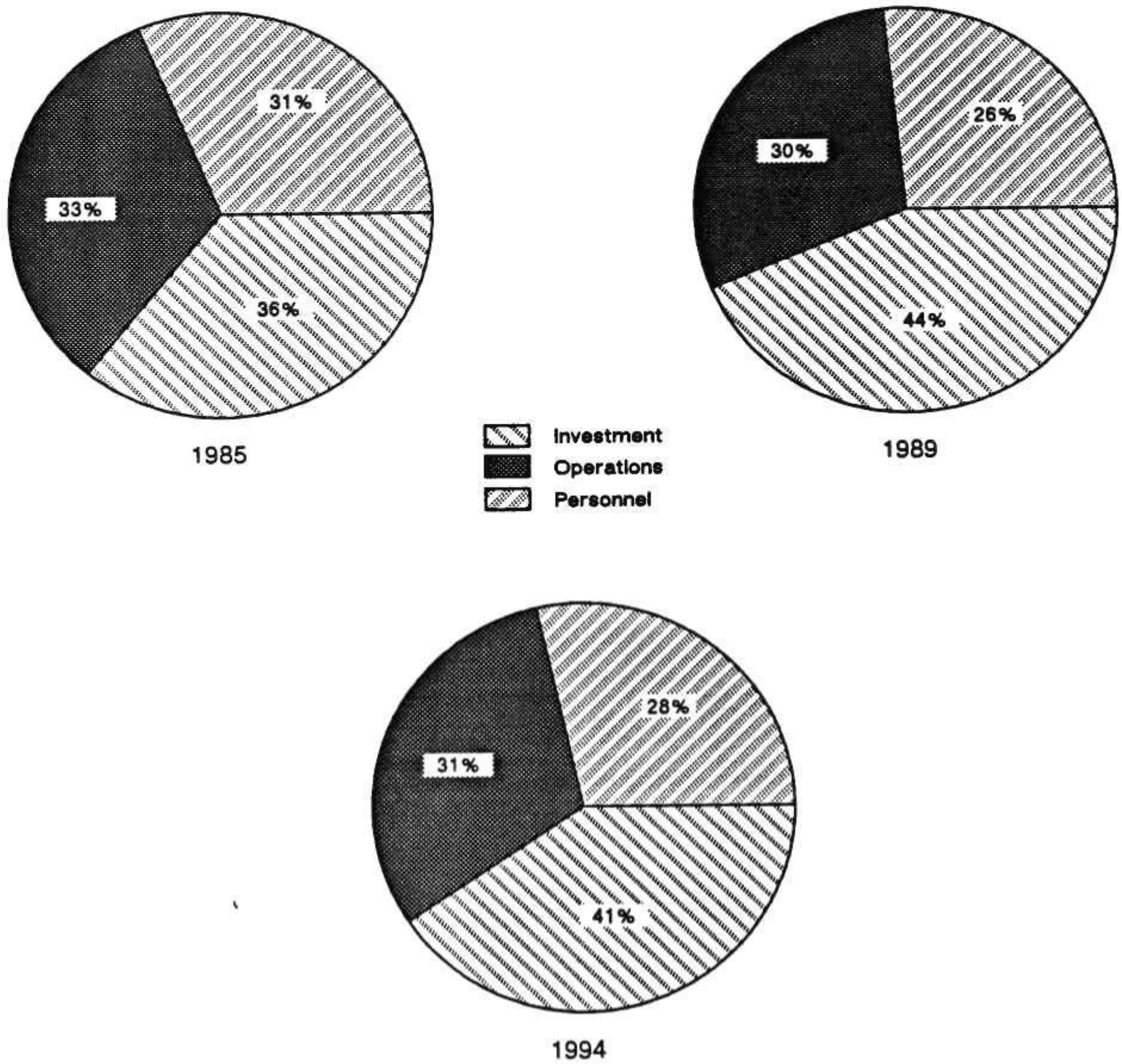
Source: Defense Forecasts
Dataquest
August 1988

The fiscal 1989 budget includes $291 billion for defense. Figure 4 shows how this amount is divided among the major appropriation categories: personnel, operations, and investment. For comparison, it also shows the apportionment in fiscal 1985, the height of the Reagan defense buildup, and our projection of the totals in fiscal 1994. Investment is projected to continue declining as a share of the defense budget. A small increase in procurement funding will be offset by a cut, in real terms, in defense research and development.

© 1988 Dataquest Incorporated August

Figure 4

Estimated Distribution of the U.S. Defense Budget by Type of Appropriation



Source: Defense Forecasts
Dataquest
August 1988

© 1988 Dataquest Incorporated August

Our projection of the defense budget by appropriation category is shown in Table 5. We project a 1 percent annual real growth.

Table 5

Future U.S. Defense Budgets by Appropriations Category
(Billions of Dollars)

	Actual	Requested	Projected				
	1988	1989	1990	1991	1992	1993	1994
Procurement	$ 81	$ 80	$ 83	$ 87	$ 91	$ 96	$101
R&D	37	38	39	38	38	39	40
Construction	8	9	9	10	10	11	11
Operations	81	86	91	97	103	109	116
Personnel	76	78	84	89	96	100	105
Total	$283	$291	$306	$321	$338	$355	$373

Source: Defense Forecasts

Funding for operations is projected to increase more rapidly than the overall budget to account for the higher operating tempos and greater readiness demanded by continuing turbulence in the third world. Although the military services may seek to cut operational budgets in order to preserve force levels, congress will act to protect them, and there will be some modest, further cuts in forces.

According to the defense department's most recent estimates, budgetary allocations for research and development will decline roughly 13 percent in real terms, reflecting the tendency to stretch out major modernization programs because of budgetary constraints. R&D spending will remain relatively high by historic standards, having increased by nearly 75 percent during the 1980s. Still, major new initiatives, and particularly the Strategic Defense Initiative, will feel the pinch.

The need to upgrade existing systems and the desire to maintain efficient production rates will cause some rise in procurement budgets. The very slight real increase anticipated, however, will enforce delays in the acquisition of certain weapons previously expected to begin entering the force structure in the mid-1990s. Procurement has already been hit hard by the defense cut-backs, dropping by more than one-fourth in real terms since fiscal 1985. The tendency has been to spread these reductions across the board, rather than to target individual types of weapons. Less visible items, such as munitions, spares, and communications equipment, that are procured in large numbers, have been particularly vulnerable. There is virtually no such "give" left within the procurement budget, however, and difficult choices will have to be made. Among the more likely big-ticket victims are both the M-X and Midgetman ICBMs, stretched-out procurement of Trident II missiles and B-2 Stealth bombers, further slowdowns in shipbuilding, and delays in the beginning of procurement of both air force and navy fighter aircraft and of the new army helicopter.

© 1988 Dataquest Incorporated August

Political Environment

Defense outlays lag budgetary appropriations by several years, depending upon the type of equipment being acquired. As a result, defense manufacturers generally have not yet experienced the effect of cutbacks in defense budgets. Outlay in fiscal 1989 will be nearly $20 billion greater than expenditure in fiscal 1986, for example, despite the fact that the defense budget in 1989 is only $10 billion larger than the fiscal 1986 total.

This delayed effect, reflecting the sharp growth in defense budgets in the early 1980s and mid-1980s, has just about run its course, however. Increasingly, federal outlays (and thus manufacturers' earnings) can be expected to conform more closely with changes in budget priorities. Major defense contractors are starting now to lay off employees and otherwise cut outlays. Changes in defense acquisition procedures and tax provisions, which have cut deeply into the profitability of the defense business, will add greater emphasis to manufacturers' efforts to constrain costs.

Canada

Canadian defense spending is estimated at $10.2 billion in 1988. The Canadian government has pledged to procure from 10 to 12 nuclear powered submarines for arctic defense. It estimates a 2 percent real growth in spending thorugh 1991.

Western Europe

The defense budget outlook for the major European countries resembles that of the United States, with level spending or even a slight decline, in real terms, the most likely scenario. The European defense electronics market is very small compared with its U.S. counterpart, however. To put the European market in perspective, the defense budgets of the four largest countries—Great Britain, France, Italy, and West Germany—totaled $96.9 billion in 1986, barely one-third the American figure for that year.

West Germany

In 1987, West Germany's total defense budget was $28.25 billion, of which $6.60 billion went to procurement. In a recent speech, Alfred Dregger, a leading defense spokesman for the conservative German government, indicated that German defense spending was likely to increase 2 to 3 percent per year. The Germans, moreover, face the prospect of a manpower shortage that will very likely drive up their personnel costs at the expense of weapons purchases.

United Kingdom

Plans for the British defense budget, $35.4 billion for 1987 and 1988, call for very modest growth over the next few years, forcing Prime Minister Margaret Thatcher to make difficult choices among currently planned weapon systems. Further, England is determined to modernize its nuclear forces, particularly through the acquisition of U.S. Trident II (D-5) submarine-launched ballistic missiles, even though this is forcing cuts in conventional plans. Specifications for the Royal Navy's most recently completed

© 1988 Dataquest Incorporated August

frigates have been downgraded, for example. Likewise, a British commitment to the NATO frigate program was delayed until the eleventh hour due to the Treasury's reservations. Most recently, long-standing British proposals to upgrade Lynx helicopters with improved radar have been cancelled to accommodate overall defense budget restrictions.

France

The French government has earmarked $79 billion for procurement between 1987 and 1991, of which two-thirds will go to conventional programs and one-third to nuclear programs. Total French procurement is slated to increase from $14.0 billion in 1987 to $17.7 billion in 1991, with $15.5 billion set for this year.

These budgetary developments will generate competing pressures on the military electronics market in Europe. On the one hand, purchases of new weapons will be limited. A corollary can be seen in the growing trend toward multicountry projects, which seek to avoid duplicative R&D and to take advantage of economies of scale in production. Such multinational projects are often threatened with collapse by disputes among the participants over capability and design options, however, and their successful completion is rarely certain. On the other hand, limited resources will lead the Europeans to upgrade the systems already deployed, adding more advanced electronics to squeeze greater capability from existing platforms. Likewise, force multipliers, such as reconnaissance aircraft and sophisticated communications systems, will be much in demand.

Corresponding to these competing pressures on electronics purchases, industry sources have been sending out contradictory signals about the future of the European electronics market. On the one hand, Italian defense electronics and communications firms are forecasting a sharp rise in sales, primarily domestic, through 1990. Some smaller companies expect to quadruple their military sales in that period, while other, larger firms are predicting increases of 30 to 40 percent. French Aerospace firms, on the other hand, having fared poorly in recent years, are not as sanguine about the future.

In the end, the future of European defense electronics will likely depend on the European manufacturers' ability to sell to the United States. European firms did begin to penetrate the American market seriously in the mid-1980s, the result of political pressures for greater collaboration across the Atlantic in defense procurement. A major and hotly contested U.S. Army contract for communications equipment was won by Thomson-CSF of France, for example. Given the intensifying protectionist sentiment in the United States, however, it is unclear whether or not this trend will be permitted to continue.

Other Nations

The ten nations outside of NATO and the Warsaw Pact with the largest military budgets are listed in Table 6. The table also includes data on these nations' military imports and exports.

Table 6

Major 1985 Defense Spenders Outside NATO and the Warsaw Pact Nations
(Millions of Dollars)

Country	Total Defense Budget	Military Exports	Military Imports
China	$24,000	$350	$ 110
Saudi Arabia	$22,200	0	$2,500
Iraq	$14,600	0	$2,100
Japan	$12,700	$ 90	$ 750
Iran	$11,300	0	$ 800
Israel	$ 7,210	$210	$ 750
India	$ 7,140	$ 5	$1,900
Romania	$ 5,350	$340	$ 20
North Korea	$ 5,200	$210	$ 300
Egypt	$ 5,120	$ 30	$1,100

Source: World Military Expenditures and Arms Transfers

Most of these countries remain dependent on imports for military equipment incorporating advanced electronics. Saudi Arabia, consistently the largest importer, depends primarily on American products, although congressional restrictions on sales of advanced U.S. aircraft have caused the Saudis to turn to Western European manufacturers, particularly in Britain. Iraq imports military equipment primarily from the Soviet Union and France; India, the third-largest importer, deals primarily with the Soviet Union and Britain; Egypt depends almost exclusively on the United States.

China, Israel, and Japan have rapidly growing defense industries. Japanese defense electronics are particularly sophisticated and are used increasingly to outfit domestically produced weapon platforms and to modify those purchased abroad. In 1987, for example, Japan agreed reluctantly—after extraordinary American pressures—to purchase its next fighter from General Dynamics, but quarreling over the manufacture of the aircraft's avionics and other subsystems continues still. Japanese military exports are small only because of tight legislative restrictions on foreign sales. If those restrictions were lifted, as many experts believe will be likely in the 1990s, sales of Japanese defense electronics could be expected to rise sharply.

© 1988 Dataquest Incorporated August

Political Environment

Israel has an extremely sophisticated and expanding defense industry. The figure for Israeli arms exports is probably understated, as exports to many nations, including China, South Africa, and Iran, have been kept secret. Israeli defense manufacturers are penetrating the U.S. market increasingly. Israeli companies have secured research contracts as part of the Strategic Defense Initiative, for example. In May 1988, an Israeli company—Tadiran—teamed with General Dynamics, and won a hard-fought competition to become the second source of Single-Channel Ground and Airborne Radio System (SINCGARS) equipment for the U.S. Army.

China's defense industries are not nearly as sophisticated as Israel's, but they are growing. Other nations that are not listed in Table 6 but have growing defense electronics manufacturing capabilities include Brazil, South Korea, and Taiwan.

© 1988 Dataquest Incorporated August

North America--Business Overview and Forecast

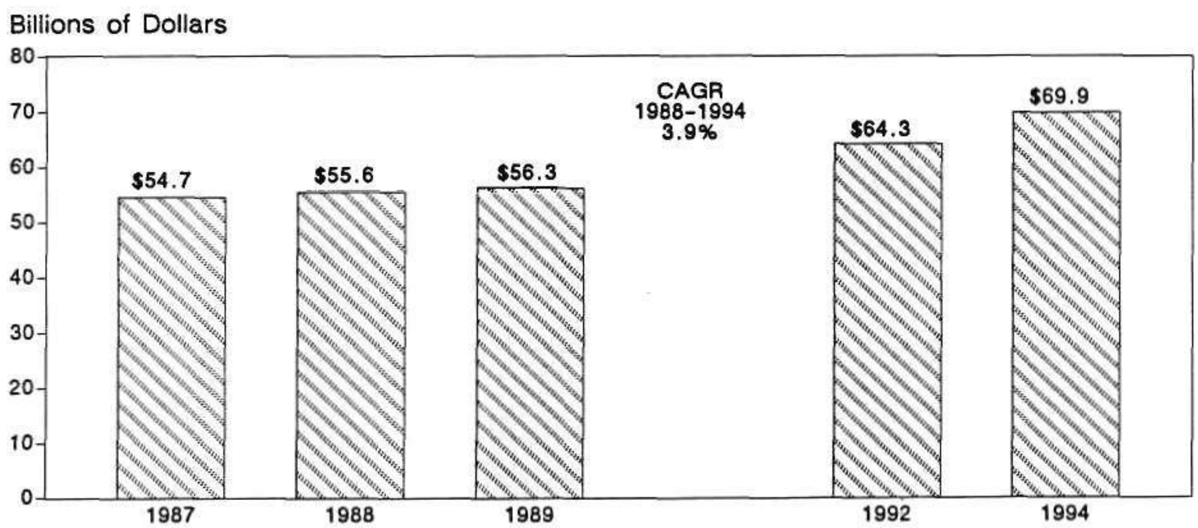
SUMMARY

The business picture for military electronics is less healthy than it was in the early 1980s, but plenty of opportunity remains for those OEMs and their suppliers that stick it out. As budget cuts enter their third year and outlays are flattening, shrinking and stretching backlogs are becoming a reality. Additionally, pressure by the U.S. government has been stepped up in the area of cost control. This factor will undoubtedly affect the bottom line as much as reduced budgets. Moreover, increased international production, flattened third-world oil revenue, Latin American credit holds, and continued restrictive technology export rules have ruled out exports as viable offsets to the declining budget.

North American production of military electronic equipment is expected to rise to $55.6 billion in 1988, a 1.6 percent increase over 1987 (see Figure 1). Production in 1989 is expected to grow 1.2 percent, reaching $56.3 billion. The 1988 through 1994 CAGR is expected to be 3.9 percent; production will reach $69.9 billion by 1994. Exports of defense electronics are expected to remain a constant share of production, at about 4.6 percent (see Figure 2).

Figure 1

Estimated North American Military Electronic Equipment Production (Billions of Dollars)

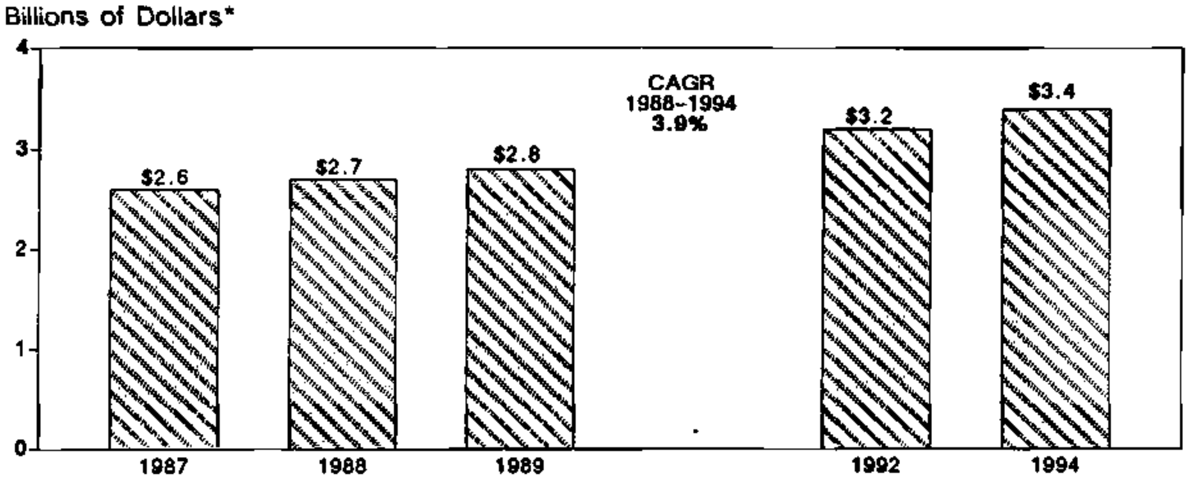


Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Figure 2

Estimated North American Military Electronic Equipment Exports
(Billions of Dollars)



*Includes electronics embedded into aircraft, missile systems, and other equipment

Source: Dataquest
August 1988

DEFENSE ELECTRONICS SPENDING

United States

Despite recent cuts in U.S. military spending plans, the electronics content of defense spending has been increasing steadily for years and now constitutes about 40 percent of total procurement and research and development funding, or about $46 billion in the current fiscal year. An additional $6 billion in spending for electronics is included in the operations budget, largely for parts and diagnostic devices for equipment maintenance and for some commercially available electronic products.

Growth in the electronics content of defense spending should continue through 1994, as follows:

- Accelerated proliferation of sophisticated military equipment by third-world nations places a greater premium on extending high-technology capabilities to all U.S. forces.

- Cuts in force levels necessitated by deficit targets mean greater emphasis on the capabilities of each weapon platform, as well as more stress on the surveillance, target acquisition, and command and control systems necessary to multiply the effectiveness of individual units.

© 1988 Dataquest Incorporated August

- Budgetary constraints mean efforts to extend the effective lifetimes of ships and aircraft through retrofits and upgrades of electronic systems.

- Constraints on operational funds mean greater reliance on simulators and other computerized training devices.

These factors should insure continued growth in budgetary appropriations and outlays for defense electronics during the early 1990s, despite the near-constant level of effort to contain overall defense spending. A breakdown of this spending by type of equipment is shown in Table 1. The aircraft systems segment provides the largest portion of the market, at about 30 percent. Particularly rapid growth will be seen in various surveillance, communications, and similar systems, however, which will account for about 25 percent of the market by the end of the forecast period.

Table 1

Projected Electronics Content of Defense Purchases
(Billions of Dollars)

Category	1988	1989	1990	1991	1992	1993	1994	CAGR 1988-1994
Procurement/R&D (Subtotal)	$46	$46	$48	$49	$52	$56	$57	3.6%
Aircraft Systems	$ 9	$ 9	$10	$10	$11	$12	$12	4.9%
Missiles	8	8	9	9	9	10	11	5.5%
Space Systems	6	6	6	6	7	8	8	4.9%
Shipboard Systems	5	5	5	5	5	5	5	0
Weapons	1	1	1	1	1	1	1	0
Vehicles	1	1	1	1	1	1	1	0
Communication and Electronics	9	11	11	12	13	14	14	7.6%
Other	6	5	5	5	5	5	5	(3.0%)
Operations and Maintenance	6	6	6	7	8	9	9	7.0%
Total	$52	$52	$54	$56	$60	$65	$66	4.1%

Note: Columns may not add to totals shown due to rounding.

Source: Defense Forecasts

In an atmosphere of defense budget austerity, the Pentagon will seek cost reductions through cancellation or stretching out of major programs. Business opportunities are presented by these events, however, as less sophisticated and less costly alternative systems are explored to fulfill urgent military requirements. Off-the-shelf commercial electronic items will become increasingly attractive for their lower cost and availability.

© 1988 Dataquest Incorporated August

Canada

The Canadian defense budget is expected to be $10.2 billion in 1988, up 4.5 percent from the 1987 spending level of $9.0 billion. The primary spending programs proposed in the near future for Canada include the following:

- $7 billion for 10 to 12 nuclear submarines for the 1990s
- $3.5 billion for 6 frigates
- $1.8 billion for EH Industries' Westland/Agusta EH-101 helicopters
- $1.0 billion for 300 battle tanks
- $350 million for 10 F/A-18s
- $300 million for 6 Lockheed CP-140s

PRINCIPAL PROGRAMS

The 25 major programs that will drive electronics purchases in North America are listed in Table 2.

Table 2

Key U.S. Defense Programs with High Electronics Content
(Millions of Dollars)

Program	FY 1988 Appropriation	FY 1989 Request	FY 1990-1994 Projection	Estimated Electronics Content
Strategic Defense Initiative (SDI)	$3,550	$4,550	$22,500	60%
National Aerospace Plane	$ 250	$ 350	$ 1,900	50%
MILSTAR Satellites	$ 200	$ 390	$ 7,200	65%
NAVSTAR Satellites and Receivers	$ 280	$ 280	$ 1,500	75%
B-2 Advanced Technology Bomber	$2,000	$3,000	$30,000	60%

(Continued)

 © 1988 Dataquest Incorporated August

Table 2 (Continued)

Key U.S. Defense Programs with High Electronics Content
(Millions of Dollars)

Program	FY 1988 Appropriation	FY 1989 Request	FY 1990-1994 Projection	Estimated Electronics Content
B-1B Avionics	$ 380	$ 250	$ 1,670	100%
Advanced Tactical Fighter (ATF)	$ 500	$ 700	$ 6,780	50%
Advanced Tactical Aircraft (ATA)	$ 700	$ 900	$ 7,000	50%
LHX Helicopter	$ 130	$ 180	$ 2,200	50%
Long-Range Antisubmarine Warfare (ASW) Aircraft	$ 2	$ 70	$ 800	70%
*Integrated Electronic Warfare System/Integrated Communication, Navigation, and Identification Avionics (INEWS/ICNIA)	$ 100	$ 130	$ 1,040	100%
*Mark XV Identification Friend or Foe (IFF) System	$ 50	$ 90	$ 1,040	100%
Low-Altitude Navigation and Targeting Infrared System for Night (LANTIRN)	$ 740	$ 690	$ 2,300	100%
Joint Surveillance Target Attack Radar System (JSTARS)	$ 350	$ 240	$ 1,550	50%
Advanced Tactical Air Reconnaissance System (ATARS)	$ 40	$ 60	$ 490	100%
Trident II Missile	$3,110	$2,450	$ 9,340	45%

(Continued)

© 1988 Dataquest Incorporated August

Table 2 (Continued)

Key U.S. Defense Programs with High Electronics Content
(Millions of Dollars)

Program	FY 1988 Appropriation	FY 1989 Request	FY 1990-1994 Projection	Estimated Electronics Content
Small ICBM (Midgetman)	$ 680	$ 200	$ 2,200	40%
MX ICBM (Peacemaker)	$ 910	$ 850	$ 2,400	40%
Advanced Medium-Range Air-to-Air Missile (AMRAAM)	$ 720	$ 900	$ 3,520	65%
Tacit Rainbow	$ 140	$ 210	$ 850	65%
Air Defense/Antitank System (ADATS)	$ 100	$ 160	$ 1,800	60%
*Airborne Self-Protection Jammer (ASPJ)	$ 250	$ 550	$ 1,900	100%
Mobile Subscriber Equipment (MSE)	$1,020	$1,000	$ 1,100	100%
Single-Channel Ground and Airborne Radio System (SINCGARS)	$ 20	$ 270	$ 1,200	100%
Very High-Speed Integrated Circuits (VHSICs)	$ 100	$ 40	0	N/A
Microwave/Millimeter Wave Integrated Circuits (MIMICs)	$ 50	$ 70	$ 400	N/A

*Common programs, included in other areas
N/A = Not Applicable

Source: Defense Forecasts

© 1988 Dataquest Incorporated August

BUSINESS ENVIRONMENT

It is an understatement to say that participation in the military electronics market will be tougher in the years to come. As worldwide and domestic demand for military electronics levels from years of aggressive growth, the industry will be undergoing a restructuring and a basic change in its modus operandi. Some of the basic changes facing industry participants include the following:

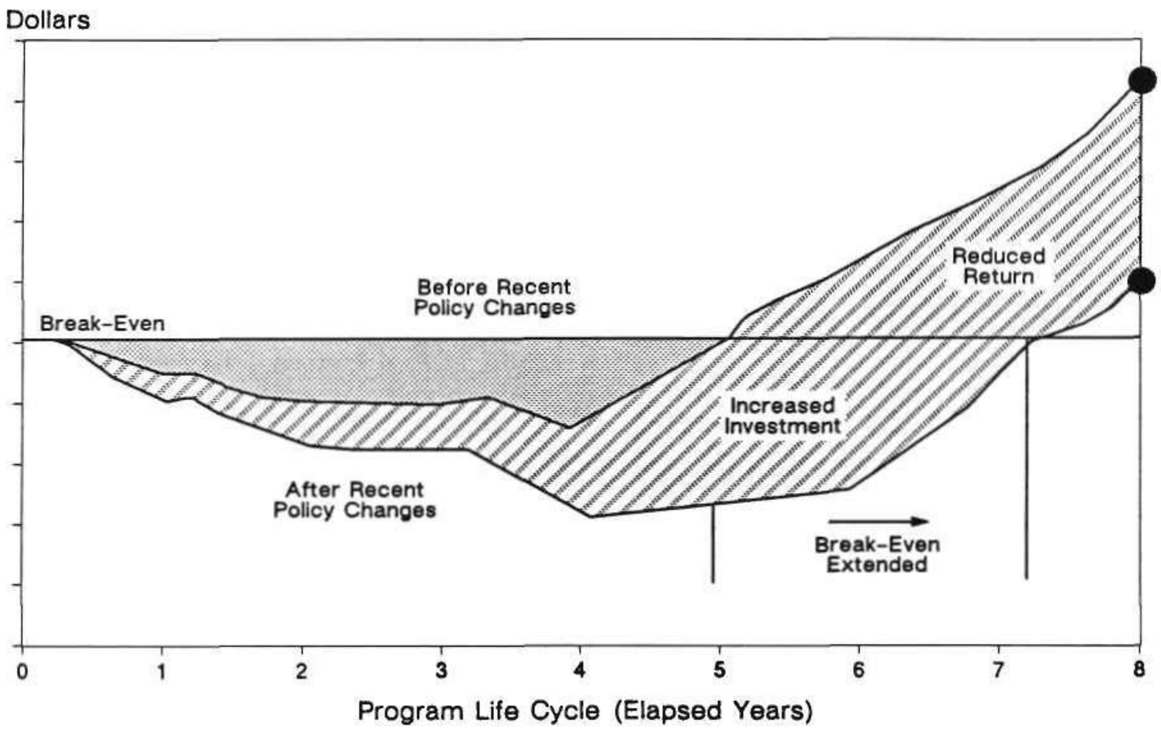
- Lower profit margins
- Higher risk—Cost sharing on overruns, fixed price contracts
- Emphasis on competition—Second sourcing, design competition, and recompetition
- Increased up-front investment burden
- Progress payments pushed out toward end of program
- Increased cost accounting justification and tax law changes
- Proliferation of teaming to share expertise and risk
- Internationalization—Sharing of burden and program participation
- Warranties—System performance liability
- Data rights—R&D is public domain
- Commercialization—Off-the-shelf procurement
- Relaxed export controls
- Fewer new program starts
- Growth in upgrade programs
- Further consolidation for survival

Figure 3 captures the essence of the impact of all these changes. The break-even point on a hypothetical program would stretch from 5 years to 8 years.

© 1988 Dataquest Incorporated August

Figure 3

"Now" versus "Then" Military Program Payback



Source: FEI

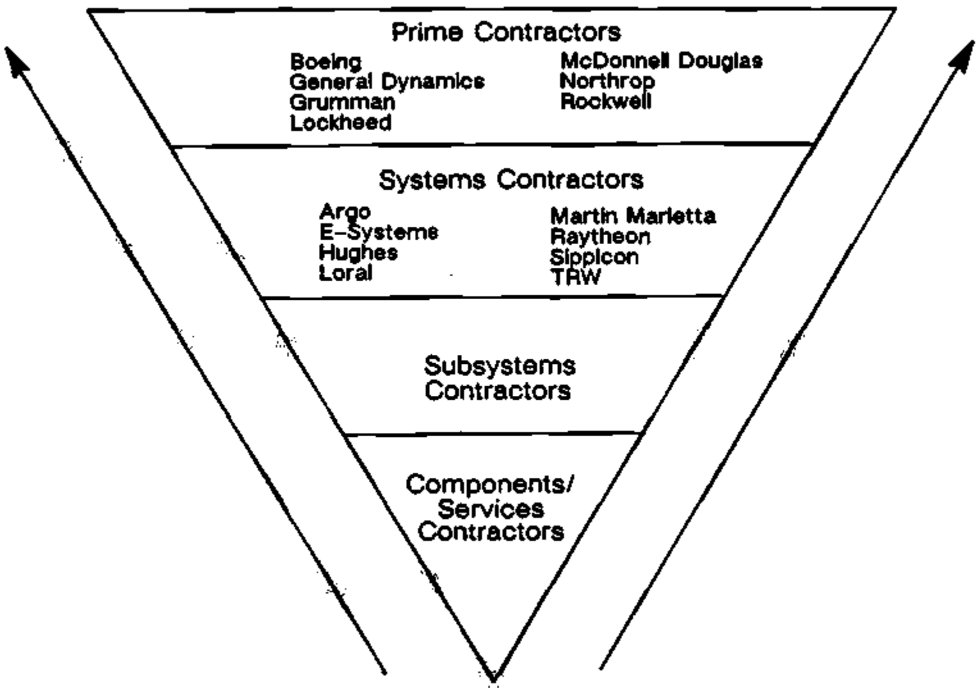
INDUSTRY STRUCTURE

Figure 4 presents the structure of the defense system industry. At the top are the prime contractors that coordinate the execution of an overall program with the various contracting bodies. These prime contractors are often the system integrators responsible for putting various subcontracted elements together and assuring that technical, cost, and scheduling goals are met. They are often suppliers of key systems and subsystems, as well as providers of the software and acceptance testing services.

Traditionally, the system and subsystem suppliers have been the principal purveyors of defense electronics to the prime contractors under sub- or direct contract; however, their domain is being overtaken somewhat by the larger prime contractors through outright acquisition. The prime motivation for this trend is the pursuit of better growth opportunities, especially in upgrade programs, as the large Reagan-era programs slow down through the early 1990s.

 © 1988 Dataquest Incorporated August

Figure 4
Defense Industry Hierarchy



Source: Security Pacific Bank
Dataquest
August 1988

ELECTRONIC EQUIPMENT FORECAST

Overview

North American production of military electronic equipment is expected to grow by 1.6 percent in 1988 and 1.2 percent in 1989. This growth reflects a trough in U.S. government defense outlays from accumulated budget cuts over the past three years. Production in 1988 is estimated at $55.6 billion and is expected to grow to $69.9 billion by 1994 (see Table 3).

 © 1988 Dataquest Incorporated August

Table 3

Estimated North American Military Electronic Equipment Production
1987 through 1994
(Millions of Dollars)

Category	1987	1988	1989	1992	1994	CAGR 1988-1994
Radar	$ 7,167	$ 7,203	$ 7,224	$ 8,010	$ 8,580	3.0%
Sonar	2,886	2,889	2,889	3,240	3,491	3.2%
Missile and Weapon	6,228	6,321	6,404	7,562	8,369	4.8%
Space	5,281	5,228	5,228	6,192	6,879	4.7%
Navigation	1,537	1,566	1,589	1,798	1,953	3.7%
Communication	4,616	4,750	4,878	5,680	6,202	4.5%
Electronic Warfare	3,413	3,518	3,596	4,222	4,637	4.7%
Reconnaissance	2,422	2,488	2,550	2,935	3,205	4.3%
Aircraft Systems	4,555	4,637	4,697	5,422	5.967	4.3%
Computer Systems	5,279	5,385	5,482	6,437	7,097	4.7%
Simulation and Training	671	695	715	863	970	5.7%
Miscellaneous Equipment	10,661	10,896	11,005	11,955	12,512	2.3%
Total	$54,717	$55,576	$56,257	$64,317	$69,861	3.9%

Source: Dataquest
August 1988

Forecast Highlights

The following are the prominent details of Dataquest's defense electronics forecast:

- Largest electronics categories in 1988:
  - Radar system--$7.2 billion
  - Missile and weapon—$6.3 billion
- Fastest-growing electronics categories, 1988 through 1994 CAGR:
  - Simulation and training—5.7 percent
  - Missile and weapon—4.8 percent

© 1988 Dataquest Incorporated August

Forecast Assumptions

Radar

The forecast drivers in the radar segment are as follows:

- Upgrades of aircraft including F-14, F-15, F-16, F-18, and P-3 with advanced smart, jamproof radar
- JSTARS radar based on E-8A electronic combat aircraft
- New aircraft systems including ATF, ATA, B-2, LHX, V-22, and C-17
- Upgrades of ground systems including early warning systems, such as over-the-horizon backscatter (OTH-B) and the Ballistic Missile Early Warning System (BMEWS), and air traffic control systems

One of the forecast risks in the radar segment is the prospect of new aircraft program slippages, but these could translate into better opportunities for upgrades.

Sonar

The forecast drivers in the sonar segment are as follows:

- Increasing emphasis on ASW as new, quieter Soviet submarines enter operation
- Upgrades of ship and helicopter systems, with better signal-processing capabilities

One of the forecast risks in the sonar segment is that navy shipbuilding plans are being slowed dramatically.

Missile and Weapon

The forecast drivers in the missile and weapon segment are as follows:

- Intermediate Nuclear Forces (INF) treaty driving emphasis on conventional weapons
- Upgraded guidance and control systems on tactical missiles to be jamproof and more sensitive to target signatures
- Replacement of older air-to-surface missiles
- Air defense systems to combat low-flying aircraft

© 1988 Dataquest Incorporated August

- Smart guided bombs, shells, munitions
- SDI-related research

One of the forecast risks in the missile and weapon segment is that INF and further strategic treaties might impact all aspects of strategic missiles.

Space Systems

The forecast drivers in the space systems segment are as follows:

- Increased emphasis on spaceborne surveillance to verify arms treaties
- MILSTAR and NAVSTAR implementation
- Launch vehicle problems creating big backlog
- Level SDI spending

One of the forecast risks in the space systems segment is that SDI could be used as a bargaining chip for future arms treaties.

Navigation

The forecast drivers in the navigation segment are as follows:

- Upgrades of navigational systems including the Global Positioning System (GPS) and LANTIRN
- ICNIA system for ATA, ATF, LHX
- GPS systems for ground and sea use

One of the forecast risks in the navigation segment is the potential for new aircraft production slippages.

Communication

The forecast drivers in the communications segment are as follows:

- SINCGARS implementation
- Mobile Subscriber Equipment (MSE) completion
- Air Command and Control System (ACCS) partial implementation
- Upgrades of various systems including Worldwide Military Command Control System (WWMCCS)

 © 1988 Dataquest Incorporated August

One of the forecast risks in the communications segment is that unit production schedules are slipping and easily might become budget-cutting items.

Electronic Warfare

The forecast drivers in the electronic warfare segment are as follows:

- ASPJ implementation on F-14, F-16, F/A-18, A-6E, EA-6B, and AV-8B aircraft
- INEWS for new aircraft
- Upgrade of airborne platform systems (e.g., F-4)
- Upgrade of ground and sea systems

One of the forecast risks in the electronic warfare segment is the potential for new aircraft production schedule slippages.

Reconnaissance

The forecast drivers in the reconnaissance segment are as follows:

- Increased need for improved passive intelligence gathering
- ATARS implementation
- Assorted classified programs

No forecast risks are apparent in the reconnaissance sector.

Aircraft Systems

The forecast drivers in the aircraft systems segment are as follows:

- Upgraded avionics on almost all aircraft including F-16, F-15, F-14, B-1B, and P-3
- New aircraft systems including ATA, ATF, B-2, LHX, V-22, and C-17

One of the forecast risks in the aircraft systems segment is that new aircraft production has slipped but can be traded for increased production of current aircraft.

© 1988 Dataquest Incorporated August

Computer Systems

The forecast drivers in the computer systems segment are as follows:

- Continued need for digitization of tactical systems
- R&D systems for SDI and other programs
- Information system upgrades and implementations of further Command, Control, Communications, and Intelligence Programs (C3I)
- Trend toward nondevelopmental items (NDI) or commercial systems

No forecast risks are apparent in the computer systems segment.

Simulation and Training

The forecast drivers in the simulation and training segment are as follows:

- Training for use of complicated advanced aircraft, EW systems, and other electronic equipment
- Maintenance training
- Battle scenario training because of reduced real-life exercises to minimize costs

One of the forecast risks in the simulation and training segment is the potential for higher growth, depending upon other cost cutting.

Miscellaneous Equipment

The forecast drivers in the miscellaneous equipment segment are as follows:

- "Black" program spending leveling
- Operation and maintenance emphasis in budget—for conventional warfare readiness

One of the forecast risks in the miscellaneous equipment segment is the Congressional and public attack on black programs.

© 1988 Dataquest Incorporated August

Civil Aviation

SUMMARY

Civil aviation's utilization of electronics is expected to continue expanding because it has gained acceptance as an important means of upgrading current systems to achieve efficiency and safety. Not only are electronic systems displacing nonelectronic equivalents on most aircraft, but they also are being used in new applications such as fly-by-wire flight controls and collision avoidance systems.

AIRCRAFT DEMAND

Table 1 and Figure 1 present the forecast for worldwide civil airliner deliveries. One of the key assumptions behind the forecast is an increase of 6 percent per year in passenger miles flown through the mid-1990s. Additionally, the International Airline Transport Association estimates that approximately one-half of the world's fleet of about 8,000 aircraft will need to be replaced by 1996. The recent occurrences of crashes and mishaps with older airliners are prompting the world's airlines to update their fleets. Figure 2 presents an age profile for U.S. airliners, defining the problem numerically.

Table 1

Estimated Worldwide Airliner Deliveries

Company/Aircraft	1987	1988	1989	1990	1991	1992	1993	Total 1989-1993
Boeing								
737	161	165	163	186	204	204	204	961
747	23	24	57	60	60	60	50	287
757	40	48	59	66	72	78	84	359
767	37	52	42	60	60	60	40	262
Subtotal	261	289	321	372	396	402	378	1,869
Percent of World	62.4%	56.3%	51.9%	53.3%	53.1%	53.0%	51.1%	
McDonnell Douglas								
MD-80/90	95	121	120	120	120	120	100	580
DC-10/MD-11	9	10	1	10	35	50	50	146
Subtotal	104	131	121	130	155	170	150	726
Percent of World	24.9%	25.5%	19.6%	18.6%	20.8%	22.4%	20.3%	
Airbus Industrie								
A300	11	17	25	20	15	10	10	80
A310	21	28	23	20	20	15	12	90
A320	0	16	65	84	84	84	84	401
A330	0	0	0	0	0	0	10	10
A340	0	0	0	0	0	12	30	42
Subtotal	32	61	113	124	119	121	146	623
Percent of World	7.7%	11.9%	18.3%	17.8%	16.0%	15.9%	19.7%	

(Continued)

©1989 Dataquest Incorporated December

Table 1 (Continued)

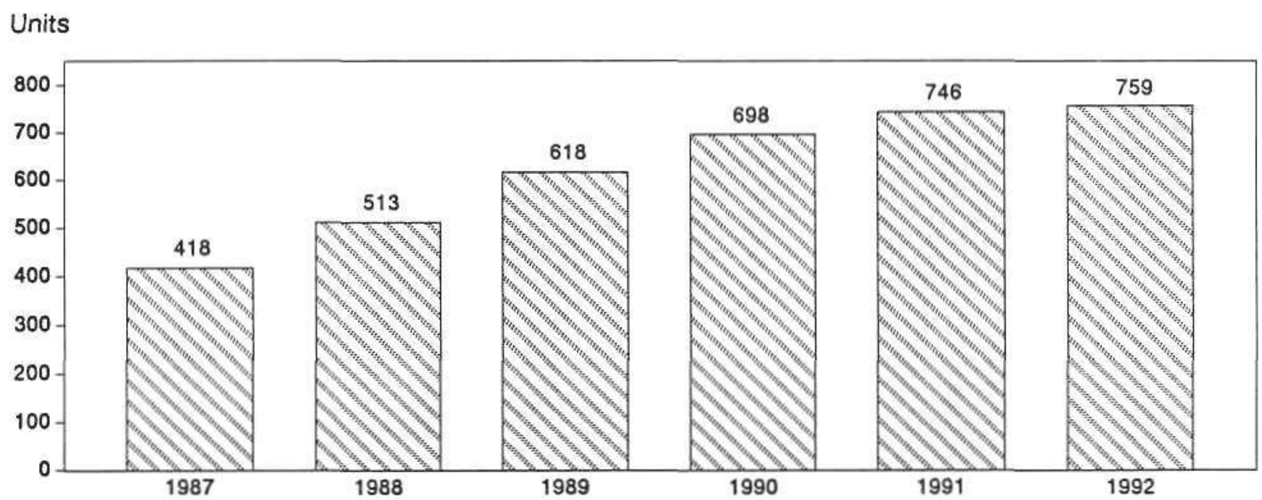
Estimated Worldwide Airliner Deliveries

Company/Aircraft	1987	1988	1989	1990	1991	1992	1993	Total 1989-1993
British Aerospace								
BAe 146	20	22	30	30	30	20	20	130
Percent of World	4.8%	4.3%	4.9%	4.3%	4.0%	2.6%	2.7%	
Fokker								
F-28	1	0	0	0	0	0	0	0
F-100	0	10	33	42	46	46	46	213
Subtotal	1	10	33	42	46	46	46	213
Percent of World	0.2%	1.9%	5.3%	6.0%	6.2%	6.1%	6.2%	
Total	418	513	618	698	746	759	740	3,561

Source: Prudential-Bache
Dataquest
December 1989

Figure 1

Worldwide Airliner Deliveries



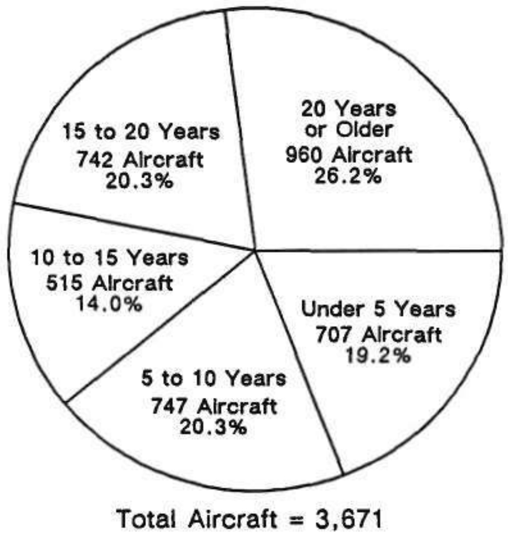
0005409-1

Source: Dataquest
December 1989

©1989 Dataquest Incorporated December

Figure 2

U.S. Commercial Airline Fleet



0005409-2

Source: Dataquest
December 1989

Boeing had an estimated 56 percent of the world airliner unit production in 1988. The Airbus Industrie consortium is expected to displace Boeing to some degree as its share of world production grows to 20 percent by 1993, roughly equal to the size of McDonnell Douglas.

Dataquest estimates that commercial airliners account for 75 percent of worldwide civil aircraft value, including general and business airliners and helicopters. Additionally, commercial airliners account for an estimated 90 percent of electronic consumption by the civil aviation industry.

ELECTRONIC APPLICATIONS

Driven by economics, competitive pressure, and safety consciousness, the civil aviation industry is incorporating more and more electronics into each new generation of aircraft. Two fundamental trends have developed in the application of electronics: the continued displacement of nonelectronic controls and the digitization of current analog controls. The latter factor is driven primarily by the application of bus-oriented computer architectures, which form the heart of the aircraft's control, data gathering, and data presentation capabilities.

The Electronic Cockpit

New generations of commercial transports are leading the way in state-of-the-art man/machine interface displays and controls. The employment of color and touch-sensitive CRTs, LCDs, and electrofluorescent displays is perhaps the most visible change. These items are displacing most of the electromechanical dials and indicators. In addition, they are tied directly

©1989 Dataquest Incorporated December

into computer systems and can be used in flexible, multiple-use ways to reduce the overall cockpit clutter and display more information than ever before.

A principal benefit of the advanced cockpits is that they allow for further automation of aircraft controls, and thus flight deck crews can be reduced from three to two people.

Electronic Flight Controls

As electronics has garnered a reputation for reliability, its application to aircraft control has grown rapidly. The new fly-by-wire systems are good examples of electronics use. A fly-by-wire system uses a predominance of electronic signals and actuators to manipulate control surfaces and to control engines, replacing hydraulics and mechanical links. These new systems have several benefits:

- They reduce aircraft weight and operating costs (fuel and maintenance).
- They are flexible because they are programmable.
- They provide real-time methods of gathering detailed information on the state of the aircraft's repair or function.

In addition, systems in development are employing fiber-optic data paths (known as fly-by-light) to further reduce weight and wiring and to improve on EMI/RFI problems.

Emerging transport aircraft architectures will employ a set of common computers known as line-replaceable units (LRUs). These LRUs will replace the multitude of analog/digital controllers and power supplies distributed around the aircraft. Boeing Commercial Airplanes has designed a fault-tolerant LRU system called the Integrated Avionics Computer System (IACS), to be used on future aircraft. Each LRU would have a core processor (an engineering version is currently based on four Intel 80960MC MPUs and eight 82965 Bus Extension Units) and a memory module (32KB of volatile and 128KB of nonvolatile memory). Each LRU would also have 10 to 12 I/O modules for analog interface with aircraft loads such as actuators for control surfaces. Inter-LRU data communication would occur with Boeing's version of the ARINC 629 standard known as DATAC. Crucial semiconductor technology identified for this architecture is smart power ASICs for the I/O modules, which require up to 28-volt operation; fault detection, isolation, and redundancy for the digital design; and bus ICs implementing the ARINC 629 standard.

Flight control equipment includes the following:

- Air data computers
- Flight instumentation and sensors
- Attitude controls
- Autopilots
- Engine controls
- An array of actuators and motors for the control surfaces, landing gear, and other devices

Some notable manufacturers of commercial aircraft flight controls include Allied-Signal Bendix, Canadian Marconi, Honeywell, Litton, Rockwell-Collins, and Smiths Industries.

 ©1989 Dataquest Incorporated December

Safety

With midair collisions still an unfortunate reality, the U.S. Federal Aviation Administration (FAA) is requiring that a version of the Traffic Alert and Collision Avoidance (TCAS) system be installed in all aircraft with more than 10 seats. TCAS is controlled by a microprocessor and is used in conjunction with aircraft transponders, which report an identifying code, altitude, and bearing. TCAS determines the threat posed by nearby aircraft and issues a voice order to the pilot if there is danger. Three versions of TCAS will be offered, depending on the size of aircraft. Bendix-King Avionics, Dalmo Victor, Foster Air Data Systems, and Rockwell International are considered to be the leading manufacturers of these systems. Assuming an average selling price of $100,000 and a potential market of 9,000 aircraft, the market over the next five years could approach $1 billion.

Because of severe thunderstorms, another safety system under consideration in the United States is the wind-shear controller. Honeywell Air Transport Systems has a version that uses a core MPU for governing input form sensors and initiating emergency commands to the aircraft flight controls during wind-shear conditions.

Other safety equipment includes ground-proximity warning systems, cockpit and flight data recorders, lightning-detection systems, and fire-protection equipment.

Ground-Based Systems

This category covers ground-based air traffic control radar, navigation, landing, and simulation and training systems. Upgrade programs by the FAA and other similar national agencies worldwide dominate equipment consumed in this category.

In the United States, the FAA has a large upgrade program under way called the National Airspace System Plan, with funding expected to continue at $2 billion per year for the next 10 years. At the heart of this program is an upgrade of air traffic control computers, software, and the various classes of radar. IBM received a $3.6 billion contract in 1988 to upgrade the computers and radar displays at U.S. air traffic control centers and airports. Raytheon and Sony have subcontracts with IBM for radar equipment and displays.

Also as part of NAS Plan, Westinghouse received two radar system awards in 1988 to upgrade aging systems currently in place. One is for $480 million to procure 137 of its ASR-9 systems for airports by 1992; the other is for $400 million for its long-range ARSR-4 system for intercity air traffic control centers. Both of these new radars are more sensitive and are capable of displaying weather formations, and they are more automated than existing systems. Another radar program is held by Unisys, which has a $450 million contract for the NEXRAD weather radar program, a joint program for the FAA and the National Oceanic and Atmospheric Administration (NOAA). The NEXRAD radar utilizes doppler technology for detecting, accurately and quickly, severe weather/wind storms.

In addition, an airport microwave landing system (MLS) upgrade to the instrument landing system (ILS) is under devlopment for the FAA. With a total production value of $1.1 billion, Hazeltine has an $89 million development contract for the system.

European and Asian countries, finding their air traffic control systems to be overtaxed and antiquated, also are planning upgrades. In Europe, members of the European Organization for the Safety of Air Navigation (Eurocontrol) have decided to install a centralized air traffic control

©1989 Dataquest Incorporated December

system in Brussels. The project, valued at $65 million and scheduled for completion in 1993, consists of developing a computer control center for coordinating traffic between European cities.

Training of pilots, air traffic control personnel, and aircraft maintenance crews is expected to require advanced training systems. As new flight controls, radar, and other equipment are introduced, new requirements for realistic trainers are needed to upgrade skills. High-resolution graphics, imagery-based graphic databases, and expert system-oriented software will be crucial to this technology.

Other Electronic Systems

Literally hundreds of electronic systems are on board most aircraft. In addition to the ones mentioned previously, the following typically are included:

- Assorted power supplies and batteries
- Antennas
- Audio systems
- Automatic direction finders
- Automatic landing systems
- Distress beacons
- Environment control
- Freight-handling systems
- Fuel-management systems
- Navigation-inertial, Loran, Omega, TACAN, VOR/ILS
- Radio communications equipment
- Sensors, pressure, and temperature systems
- Surveillance radar
- Weather/turbulence radar

INDUSTRY STRUCTURE

Like the military aviation industry, civil aviation has a distinct division of airframe integrators and system and subsystem providers. Electronic subsystems such as instruments and radios are very modular and are manufactured by several companies. Many companies produce both civilian and military versions of the same product.

Civil Space

SUMMARY

Opportunities for space-based and launch system electronics are driven by several nonmilitary government and private programs. Some of the programs are commercially oriented; some are national or international nonprofit services; and some are dedicated strictly to scientific research. The motivating factors behind these programs are as follows:

- Communications services
- Television broadcast services
- Microgravity manufacturing
- Meteorology
- Earth resource remote sensing
- Astronomical research
- Basic research—biological, chemical, and other scientific research
- Search and navigation
- Space exploration
- Space transportation and general-purpose platforms

SPACE STATION

Deemed the centerpiece of international space cooperation, and the crucial initial element for exploration of the solar system, the space station Freedom is perhaps the most important space program yet envisioned. In addition to its near-term uses for microgravity research and manufacture, earth resource and biosphere research, and astronomy, it has a role as a space-based manufacturing and assembly center for spacecraft. Because spacecraft could be assembled in orbit in microgravity, large vessels, which are necessary for long trips, could be put to use without the inefficient step of a surface launch. Long-range plans for these vessels include international projects such as establishing a manned moon base and a manned expedition to Mars.

© 1989 Dataquest Incorporated November

Designing, building, launching, assembling, and initial operation of Freedom is estimated to cost more than $30 billion during the next 15 years. The modularly designed station would be assembled via a series of 19 space shuttle flights through the 1995-to-1998 period. It will comprise two modules for habitation and a laboratory, four connecting nodes, and two attachable modules supplied by the European Space Agency (ESA) (Columbus Attached Laboratory) and National Space Development Agency (NASDA) of Japan (JEM, Japanese Experiment Module). Canada will be supplying the mobile servicing center. A free-flying, polar-orbiting satellite for earth resource observation, serviced at the space station, is proposed by the GE team and the ESA Columbus team. To address the concern of emergency escape, in October 1989, the National Aeronautical and Space Agency (NASA) issued a space-station crew emergency-return vehicle (CERV) RFP.

The governments of the United States, Canada, and Japan and the ESA will share in development of Freedom and its attached components. In December 1987, NASA awarded Phase 1 contracts to four major industry teams to begin development work on Freedom. Totaling more than $5 billion, the work was broken into four work packages, as presented in Table 1. Hampered by funding cuts during 1988 and 1989, 1990 NASA funding for the project is expected to be $1.8 billion—approximately $300 million less than its budget request.

Some results of lower-than-planned funding for Freedom are, among others, that its initial power capabilities might have to be cut from 75.0kW to 37.5kW, the crew size may be cut from eight to four, and communications will be based on UHF rather than S-band frequencies. Because of delays imposed by the cuts on the schedule for the attached modules, ESA has indicated that it might withdraw from the program if these cuts are pursued.

The competition for the Freedom contracts was intense, as much contractor up-front money was spent in preparing bids. This contractor "risk" spending is becoming typical of many of the large aerospace programs. The Electronics Industry Association (EIA) estimates that the electronic content of this project is in the 50 to 60 percent range. Dataquest estimates that the semiconductor usage for the entire program could be as much as $120 million.

© 1989 Dataquest Incorporated November

Table 1

Space Station Freedom Program Breakdown
U.S. Portion—Phase 1

Segment	Contractors	Dollar Amount
Work Package 1	Boeing Aerospace (Huntsville, Alabama)	$750 million
Manned Pressurized Modules		
Life Sciences Facilities	Lockheed Missiles & Space	
Habitation Design	Grumman Aerospace	
Software	TRW	
Payload Integration	Teledyne Brown Engineering	
Internal Communication	Harris Government Systems	
Work Package 2	McDonnell Douglas Astronautics	$1.9 billion
Truss Structure/Subsystems		
Manipulator Arm	Spar Aerospace/Astro Aerospace	
Data Management System	IBM Systems Integration Division	
Thermal Control System	Lockheed Missiles & Space	
Communications/Tracking	GE-RCA Communications Systems	
Attitude Control	Honeywell, Inc.	
Work Package 3	General Electric	$800 million
Free-Flying Platforms/ Telerobotic Servicer/Studies	TRW	
Work Package 4	Rockwell Rocketdyne	$1.6 billion
Power System		
Batteries/Component procurement	Ford Aerospace and Communications	
Power Conversion Units	Allied-Signal Fluid Systems	
Power Inverters	General Dynamics	
Photovotaic Wings	Lockheed Missiles & Space	
Solar Concentrators	Harris Government Systems	
Crew Emergency Return Vehicle (CERV) Proposal Teams	Lockheed/Boeing Rockwell/Honeywell/McDonnell Douglas TRW	TBD

Source: Dataquest
November 1989

© 1989 Dataquest Incorporated November

The Data Management System (DMS) for Freedom is being provided by IBM as principal contractor. It is a redundant and distributed architecture based on embedded Intel 80386 MPUs and general-purpose fixed and portable PS/2 Model 80 personal computers. The proposed data backbone of Freedom will be based on the fiber-optic FDDI standard operating at 100 Mbps with local data buses based on the MIL-STD-1553B standard. Computing line-replaceable units (LRUs) will be based on the Multibus II standard backplane. I/O cards in each LRU will control interfaces with sensors and effectors.

To account for possible differences between the ESA, NASDA, and NASA data communication standards (10 Mbps instead of 100 Mbps), gateway processors will interface the core station to the attached modules. Ada will be the standard high-level programming language for the station development. The power supply available to station LRUs will be 208 volts AC at 20 KHz. A proposed 256MB mass storage unit for distribution throughout the station is based on optical technology.

NORTH AMERICA

Overview

The North American civil space electronics market is driven principally by commercial communications satellite demand and projects sponsored by NASA. The largest single program in the 1990s will be the space station project, which currently is estimated to cost $30 billion over the next 15 years. Canada is in the process of forming a new space agency called the Canadian Space Agency. This agency budget is expected to be Can$200 million in 1990. In addition to its $1.2 billion participation in the space-station program for the Mobile Servicing System, Canada is managing the Radarsat program in conjunction with the United States. Table 2 summarizes the key North American space projects planned over the next several years.

 © 1989 Dataquest Incorporated November

Table 2

North American Civil Space Development Projects

Spacecraft	Contractor/ Sponsor	Launch Vehicle	Launch Purpose	Date
NASA Projects				
NOAA K, L, M	GE, Ford/NOAA, and NASA	Atlas E	Weather	1989, 1990, and 1991
GOES I, J, K, L, M	Ford, Hughes/NASA, JPL, and NOAA	Shuttle	Weather	1989 through 1992
GRO	TRW/NASA	Shuttle	Map gamma ray sources	1990
TDRSS E, F	TRW/NASA, DOD	Shuttle	Tracking/relay	1990, 1991
CRRES	Ball/NASA, DOD	Atlas Centaur	Radiation mapping	1990
UARS	GE/NASA	Shuttle	Stratosphere/mesosphere study	1991
ACTS	GE/NASA	Shuttle	Ka-band communication	1990
Mars Observer	GE/JPL	Shuttle	Mars orbiter	1992
Orbital Maneuvering Vehicle	TRW/NASA	Shuttle	Satellite retriever	1993
Tethered Satellite (TSS)	NASA/Italy(ASI)	Shuttle	Electricity Generation	1991
Ulysses	ESA/JPL	Shuttle	Solar system probe	1990
LAGEOS	Aeritalia/NASA	Shuttle	Tectonic study	1991
Wind	GE/NASA	TBD	Solar wind study	1992
EUVE	Fairchild/University of California	TBD	Ultraviolet survey	1991
EOS	Ball/NASA	TBD	Earth observed	TBD
Cassini	TBD, NASA/ESA	TBD	Saturn probe	TBD
Submillimeter Wave Astronomy Sat (SWAS)	Ball/Smithsonian	TBD	Astronomy	1994
Radarsat	Spar/Ball	TBD	Remote sensing	1994
CRAF	TBD	TBD	Comet study	1994
Advanced X-Ray Astrophysical Facility	TBD	TBD	Astronomy	TBD
Infrared Telescope	TBD	TBD	Astronomy	TBD
Commercial Projects				
American Satellite Company	GE/American Satellite Company	Shuttle	Communication	1990
RCA America	GE	Shuttle	Communication	1990
STC/DBS	GE/American Satellite Company	Ariane X	Direct broadcast	TBD
DBSC	Ford	Ariane X	Direct broadcast	1990
	Anik	Spar (Canada) Ariane 4	Communication	1990
Intelsat VII (Nine Satellites)	Ford, Alcatel, and Mitsubishi	TBD	Communication	1994
INMARSAT 2	GE, Marconi	Shuttle	Nav/Comm	1992
INMARSAT 3	RFP in by 2/90	TBD	Nav/Comm	1994
Telstar (x3)	GE	TBD	Communication	TBD

TBD = To be determined

Source: Dataquest
November 1989

© 1989 Dataquest Incorporated November

Civil Space

NASA

NASA's 1990 budget is expected to be approximately $12.3 billion when the U.S. Congress finishes its deliberations on the budget. This amount is up from $10.9 billion in 1989 and $9.6 billion in 1988. Benefiting partially from a cutback in Department of Defense (DOD) spending, NASA's budget is growing very rapidly compared with its pace of the previous 15 years. However, as this year's budgeting process has shown, the NASA budget still is subject to overall government spending leveling as imposed by the Gramm-Rudman legislation guidelines. Depending upon the priority NASA is able to garner, NASA's budget is projected to grow to somewhere between $27 billion and $55 billion by the year 2000. The lower number represents execution just on the existing programs, and the larger number includes funding for commencing the Mission to Planet Earth program, a manned moon-base program, and a mission to Mars.

The Bush administration has created the National Space Council, headed by Vice President Dan Quayle, to help coordinate U.S. policy in space. This body is expected to help set the vision and priorities of the combined U.S. space programs. Table 3 presents a breakdown of NASA's proposed 1990 budget of $13.3 billion.

Table 3

NASA 1990 Budget Proposal Breakdown
(Millions of Dollars)

Budget Element	Amount Budgeted
Research and Development	$ 5,800
Space Station	2,100
Space Transportation	600
Physics and Astronomy	900
Planetary Exploration	400
Earth Sciences	400
Other	1,400
Space Flight, Control, Communications	5,200
Construction	300
R&D Program Management	2,000
Inspector General	N/M
Total	$13,300

N/M = Not meaningful

Source: NASA

© 1989 Dataquest Incorporated November

Civil Space

The major growth in NASA's 1990 budget will be spending on the space station Freedom. However, because of Congressional cuts on the program, both initial crew size and power availability had to be cut in half. Key programs in NASA's future include the internationally supported Mission to Planet Earth program, which would cost $15 billion to $30 billion over the next 15 years for developing technology, instrumentation, and space observation platforms to research earth's growing atmospheric/environmental problems such as the ozone hole over the Antarctic. Other major long-range programs are a manned outpost on the moon and a manned international mission to Mars.

NASA is finding itself in a surge of activity as the Challenger disaster-caused backlog of spacecraft are launched. In 1989 and 1990 alone, the Magellan Venus probe, the Galileo Jupiter probe, and the Hubble space telescope will all be launched. This activity is helping the agency's image and has helped set loose (politically) a new set of programs, scheduled for the 1990s, to continue progress in planetary exploration and astronomy. These projects include the following:

- Comet rendezvous/asteroid flyby (CRAF) mission
- Cassini Saturn probe
- Advanced X-ray Astrophysical Facility
- Space Infrared Telescope Facility

NASA has two principle advanced-technology development umbrella programs to provide technology for future missions. One program, called the Civil Space Technology Initiative, was funded with $122 million in 1989 and has an objective of developing and filling technological gaps in propulsion, vehicle design, information systems, assembly, and control of large space structures, power systems, and robotics. The other program, called Pathfinder, was funded with $40 million in 1989, and its objective is development of technology to support the deep-space missions of the 21st century, including a mission to Mars.

In the space-transportation area, an important project is a cargo version of the space shuttle known as Shuttle-C. Designed for heavy lift missions and a targeted readiness in 1994, the Shuttle-C would utilize the newly developed advanced solid-rocket motors. With a possible program start in 1991, the current study/design contractors are Martin Marietta, Rockwell, and United Technologies.

NASA is planning to launch an estimated 35 missions over the next five years. Future nonshuttle commercial launches will be handled not by NASA, but instead by various commercial contractors. For a further discussion of NASA-related launch systems, refer to the U.S. Military Programs Space subsection.

Commercial North American Space Projects

Commercial space projects in the United States are dominated by communications satellites and launch services. Suffering from a glut in the mid-1980s, as of mid-1989, communications transponders are estimated to be 80 percent owned or leased out. Much

© 1989 Dataquest Incorporated November

of the other 20 percent comprises specialty channels or channels of aging spacecraft. The primary demand driver for communications satellites is for corporate voice and data services, with video conferencing gaining greater demand. The spread of very small aperture terminals (VSAT) for corporate communications is also helping accelerate demand for more transponders.

A typical communications satellite can have from 8 to 24 transponders that comprise 10 to 20 transmitters and 2 to 8 receivers operating in the C or Ku band, with 36-MHz channel bandwidth. New satellites will have higher-frequency S-band capability, allowing even greater channel multiplexing. Transmitters can comprise traveling wave tube (TWT) amplifiers that can handle up to 40 watts (TV broadcast) or solid-state amplifiers (based on gallium arsenide semiconductors) that can generate from 5 to 10 watts.

Addressing the economics of a commercial communications satellite, GTE's GSTAR IR is expected to cost $66 million for the spacecraft, $53 million for the launch, and $18 million for insurance, for a total of $137 million.

The successful August 1989 launch of a British TV satellite with a McDonnell Douglas Delta vehicle marks the entry of a U.S. company into the commercial launcher and launch service market. With a world commercial launch market estimated at 15 to 20 launches per year, the U.S. companies of General Dynamics (Atlas), Martin Marietta (Titan), McDonnell Douglas (Delta), and Orbital Sciences-Hercules (Pegasus) have their work cut out for them in competing with Arianespace, which has approximately one-half of the world market with nine launches planned for 1990.

A need for space platforms for remote sensing also is growing. The orbiting platforms gather geologic, biomass, and oceanic earth resource data, which are sold to research agencies or private organizations. Utilizing assorted visual and infrared sensors, including charge-coupled devices (CCD), these platforms are extremely electronics intensive. Following the lead set by the Lansat program, several countries—including France with the SPOT program, the U.S.S.R., and Japan—have entered the market for selling earth resource data. A company named Eosat manages the Lansat operation today; the Lansat 6 satellite is planned for 1991.

WESTERN EUROPE

Overview

Civil space activity in Western Europe is dominated by the European Space Agency and its associated activities. Born out of a need to build economy of scale, ESA is composed of and funded by various European governments and the Canadian government. Arianespace, a separate manufacturing and marketing organization, utilizes ESA-designed Ariane launch vehicles to provide launch services from its facility in Kourou, French Guiana.

© 1989 Dataquest Incorporated November

Independent of the ESA are ongoing projects with the national space agencies as well as several private ventures supplying, in particular, satellite communication and TV broadcast services.

ESA

Formed in 1980, ESA is chartered with peaceful applications of space research and technology development. Formed mostly of European countries wanting to pool their resources, ESA and the related Arianespace are chartered with making Europe a leader in world space technology, space-based research and service, and commercial launch services. ESA divides its efforts among space transportation, space stations and platforms, scientific research, telecommunications, earth observation, and microgravity research. The 1988 budget for ESA was 1,903 million accounting units (approximately $1.5 billion). Tables 4 and 5 present the participation percentages by member country and a breakdown of major element expenditure. Table 6 presents an overview of principal ESA development programs.

Table 4

ESA 1988 Funding Breakdown

Country	Participation
Austria	0.6%
Belgium	2.9
Canada	0.9
Denmark	0.7
Finland	0.1
France	21.5
West Germany	17.4
Ireland	0.1
Italy	10.6
Netherlands	2.0
Norway	0.6
Spain	2.6
Sweden	1.7
Switzerland	1.4
United Kingdom	6.2
Other Income	30.7
Total	100.0%

Source: ESA

© 1989 Dataquest Incorporated November

Table 5

ESA 1988 Expenditure

Expense Category	Percent of Expenses
Space Transportation Systems	32.3%
Space Station/Platforms	14.6
Telecommunications	13.4
Science	10.8
Earth Observation	9.4
Microgravity	2.4
Other/General	17.1
Total	100.0%

Source: ESA

Table 6

ESA Projects Planned or in Development

Project (Lead Contractor)	Description	Schedule
Science Program		
Ulysses (STAR/Dornier)	Solar system probe	Launch late 1990
Hubble Space Telescope (Lockheed/Perkin-Elmer)	Space-based telescope; NASA collaboration	Launch early 1990
Solar Terrestrial Science Program (STSP)	SOHO:Sun/solar wind study; Cluster:4 satellite earth plasma study; NASA collaboration	Awards 10/89; launch 1995
ISO (Aerospatiale)	Infrared space observatory	In development, launch 1993
Cassini-Titan Probe	Scientific probe to Saturn moon; NASA collaboration	Development to be determined, launch 1996
X-ray Multimirror Craft	X-ray astronomy; part of Horizon 2000 program	Development to be determined, launch 1998

(Continued)

© 1989 Dataquest Incorporated November

Table 6 (Continued)
ESA Projects Planned or in Development

Project (Lead Contractor)	Description	Schedule
Telecommunications Program		
Data-Relay Satellite	Communications relay	Awards January 1990; launch 1996
PSDE/SAT/AOT	Developmental communication satellites	In development through 1993
Earth Observation/ Microgravity Program		
ERS-1 (Dornier)	European all-weather remote sensing satellite	In development, launch 1992
Aristoteles (Dornier)	Earth gravity study	In development
Meteosat MOP 2, 3 (Aerospatiale)	Meteorlogical satellites	In development, launch 1990
Microgravity	IML 1, 2, 3 Missions	In development, launch 1990
Space Station/ Platforms Program		
Eureca (MBB/ERNO)	Recoverable unmanned satellite	In development, launch 1991
Columbus (British Aerospace)	Space-station module, free flyer, polar orbit platform	Phase 1 development through late 1990
Space Transportation		
Ariane 5 (SEP/ERNO/ Aerospatiale)	Next-generation launch vehicle	In development, launch 1995
Hermes (Aerospatiale)	Manned space plane	In development, launch 1999

Source: ESA

© 1989 Dataquest Incorporated November

Civil Space

Perhaps the highest visibility programs for ESA are the Hermes space plane, the Columbus space-station elements, and the Ariane launch system. The Hermes space plane will function similarly to the U.S. space shuttle. It will be launched from the Ariane 5 launch system and return to earth and land like a plane. Its missions will include servicing the Columbus manned free flyer, conducting space experiments, launching heavy payloads into geosynchronous orbit, and trips to the space station Freedom. Aerospatiale and Avions Marcel Dassault are prime contractors for the study and early development phase of Hermes.

The Columbus program includes a module attachable to the space station Freedom for space research, the man-tended free flyer (MTFF), and a polar orbiting platform for earth observation. British Aerospace is the prime contractor.

Arianespace, a private company, works in conjunction with ESA as it manufactures Ariane launch vehicles and provides commercial launch services. Arianespace is the largest commercial launch service provider in the world. It has at least nine launches scheduled for 1990 from the Kourou, French Guiana facility. The Ariane 4 is the current launch vehicle. With lift capacities of between 2,000kg and 4,200kg, 70 units are planned for production through 1998. The Ariane 5 is the next-generation launch vehicle and is capable of lifting the 21,000kg Hermes space plane into orbit. SEP of France is the primary Ariane propulsion contractor.

In addition to the headquarters in Paris, other important ESA locations include the principal R&D center ESTEC in Noordeijk, Netherlands, the space operations center ESOC in Darmstadt, West Germany, and the ESRIN center near Rome, which houses the information retrieval service and the Earthnet program office. ESA also has several ground tracking and communications station facilities around the world.

In 1988, a Microelectronics Technology Support Laboratory (MTSL) was established at University College of Cork, Ireland. This facility will have responsibility for qualification, selection, and monitoring of silicon, GaAs, and hybrid microelectronics. Semiconductor specifications are governed by the ESA 9000 standard for space environments. The MIL-STD-1750A ISA MPUs have been selected as the general data processors for the Columbus program. Based on CMOS silicon-on-sapphire (SOS) technology, a 3-mips implementation is under development. A quadredundant architecture based on the Inmos 32-bit Transputer also is under evaluation. For signal (video compression) processing applications, the Texas Instruments TMS 320C25 architecture has been evaluated for its SEU characteristics for use on Columbus and Hermes.

Harris Semiconductor has contributed LSI circuits to the design of the Advanced Guidance and Control Processor (AGCP) as part of the Modular Attitude and Control System (MACS). The processor is part of a prototype guidance, navigation, and control system for use on future ESA spacecraft. CMOS rad-hard, standard logic, ASICs, and SRAMs are other digital IC requirements being focused on.

© 1989 Dataquest Incorporated November

Other European Space Programs

Driven by commercial and national interests, several other projects are being conducted outside the direct purview of the ESA. Television broadcast capability and earth resource information services are two drivers of commercial demand for space hardware. National research and development for scientific purposes and eventual industrial application of space technology are other motivators. Some of these programs are sanctioned by the various national space agencies such as the National Space Research Center (CNES) of France and Italy's Agenzia Spaziale Italiana (ASI), and some are financed by private organizations such as Eutelsat.

Some prearranged consortiums develop standardized satellite architectures called buses. Two such consortiums are Satcom, led by Matra and British Aerospace, which supplies the Eurostar model, and Eurosatellite, led by MBB.

Table 7 lists other European space projects.

Table 7

Other European Space Programs in Development

Project (Lead Contractor)	Description	Schedule
France		
TOPEX/Poseidon (CNES/JPL)	Ocean observation	Launch 1991
SPOT 4 (CNES Matra/ Thomson/Enertec)	Commercial earth resource satellite service	Launch 1994
Telecom II	Communication services	Launch 1991
Italy		
SAX/SAX X (Selenia, Dornier)	X-ray satellite; synthetic aperture radar for shuttle	Launch 1992, 1993
Tethered Satellite (TSS)	Shuttle-based electricity experiment; NASA collaboration	Launch 1991
LAGEOS (Aeritalia)	Earth tectonic study	Launch 1991

(Continued)

© 1989 Dataquest Incorporated November

Table 7 (Continued)

Other European Space Programs in Development

Project (Lead Contractor)	Description	Schedule
West Germany		
ROSAT	X-ray telescope	Launch to be determined
Spacelab 2, 3	Material/life science; shuttle based	Launch 1992, 1993
Multinational		
Hispasat (Satcom: Matra/ British Aero.)	Two TV/communication satellites for Spain	Launch 1992
Locstar (Satcom: Matra/ British Aero.)	Radio location/messaging	Launch 1992
EUTELSAT 2 (Aerospatiale)	TV broadcast	Launch 1990
Amica (MBB/ERNO, GE, Matra, Aeritalia)	Retrievable commercial microgravity carrier	Launches 1992 through 1995

Source: Dataquest
November 1989

Alcatel Espace, in conjunction with Ford Aerospace and Mitsubishi, won a hard-fought battle for the International Telecommunications Satellite Organization (Intelsat) VII contract. Valued at $1 billion, the contract could involve as many as nine satellites, with deliveries through 1994. This contract, managed by the multinational Intelsat, is believed to be the single largest commercial satellite program in the world. If the contract falls through, Matra of France would be allowed a chance to manufacture the satellites.

JAPAN AND REST OF WORLD

Space electronics production outside of the United States, the U.S.S.R., and Europe is dominated by Japan as it continues a program to be self-reliant in space-based services and hardware including launch vehicles, satellites, and experimental facilities. Brazil, China, and India also have indigenous commercial launch capabilities and space hardware construction wherewithal, although they rely heavily on imported subsystems

 © 1989 Dataquest Incorporated November

and expertise. These countries have a growing desire to serve their own space hardware markets as well as to participate in global markets for launch services, communications services, and remote sensing. The path toward these goals is made easier as they capitalize on an already established electronics capability for consumer and industrial markets.

Japan

Japan has amassed tremendous capabilities in space hardware in recent years and has aggressive plans for the next decade. Japan's space activities include the following programs:

- Three new expendable boosters—H-I, M-3S-2, and H-II
- More than 10 advanced satellites
- Space platforms
- A space shuttle
- Participation in a U.S. shuttle mission
- Participation in the U.S./international space station
- Moon and Venus probes

Japan's space activities represent an increasing challenge to U.S. and European leadership in satellites, platforms, and launch services. However, the Japanese legislative body, the Diet, remains somewhat skeptical in its funding of space programs in light of the costs and intense competition for commercial projects.

Japan has two space agencies, NASDA and the Institute of Space and Astronautical Science (ISAS). Government funding for the overall Japanese space program was $1.1 billion (¥140 billion) in 1988 and is projected to grow to $2.4 billion (¥300 billion) by 1999. These agencies have been responsible for launching an average of one satellite per year since 1970. The Ministry of International Trade and Industry (MITI) serves to create competitive pressures by funding specific payloads.

Funding for 1989 was up ¥10 billion as the new ADEOS program was added. The ADEOS, scheduled for 1994 launch, is the advanced earth observation satellite and is Japan's precursor project for the international Mission to Planet Earth program being proposed by the United States. Another project in its early stages is the Hope spaceplane, targeted for availability in the mid-1990s and to be launched by the H-II booster. The H-II is Japan's emerging heavy-lift vehicle; Nissan is a prime H-II contributor. Nissan also is responsible for designing the various upper-stage and apogee kick motors used on Japanese spacecraft.

© 1989 Dataquest Incorporated November

Civil Space

Japan is preparing a massive facility at the Tanegashima space facility to support the new H-II booster launches, first scheduled for unmanned missions in 1992. The H-II booster will support manned launches by 1995. A summary of Japan's spacecraft, including launch dates, type of payload, and other pertinent data, is given in Table 8.

Table 8

Japanese Spacecraft in Development

Name	Type	Company	Comments	Launch Date
Geophysical Research	GEOTAIL	N/A	Space shuttle	1991
Solar Physics	HESP-1	N/A	ISAS-sponsored	1992
Solar Observer	Solar-A	N/A	ISAS-sponsored	1991
Broadcast Satellite #3A	BS-3A	NEC/GE	Color TV--3 channels	Mid-1990
Broadcast Satellite #3B	BS-3B	NEC/GE	Sister to BS-3A	Mid-1991
Earth Resources Satellite #1	ERS-1	NEC/Mitsubishi	Will carry synthetic aperture radar, visible and IR sensors	1991
Engineering Test Satellite #6	ETS-6	Mitsubishi	First H-II payload	1992
Moon Probe	MUSES-A	ISAS	M-3S-2 payload; seismic detection	1990
Space Flyer Unit		N/A	H-II payload; recoverable	1993
X-Ray Observer	Astro-D	ISAS	M-3S-2 payload	1993
Weather Satellite #5	GMS-5	NEC/Hughes	H-II payload	1994
Venus Probe		N/A	H-II payload; magneto-sphere probe	Mid-1990s
Japanese Experiment Module	JEM	NSDA	Space station module	Mid-1990s
Spaceplane	Hope	Mitsubishi	H-II payload	Mid-1990s
Earth Observation	ADEOS			1994

N/A = Not Available

Source: Dataquest
November 1989

© 1989 Dataquest Incorporated November

Rest of World

Perhaps the most interesting development outside of the first-world countries is the newly formed joint venture between Brazilian and Chinese business concerns to market launch services and tracking. Called INSCOM (for International Satellite Communications, Ltd.), the new enterprise couples the launch experience of China as represented by the China Great Wall Industry Corp. and the space tracking and marketing know-how of Avibras Aerospacial of Brazil. The concern will offer China's Long March and Brazil's Veiculo Landcador de Satellites (designed by Brazil's space agency Instituto de Pesquisas Espacias, or INPE) launch vehicles. Both countries have launch facilities, and Avibras has the expertise in earth station tracking. The Chinese government claims it has nine commercial launches scheduled through 1994. The Chinese government also plans to develop its own weather satellites in the next five years.

Israel Aircraft Industries has announced its leadership in a consortium to build the AMOS communication satellite for use primarily by the Israeli government. The Indian Space Research Organization (ISRO) is building the multipurpose INSAT-2A,B satellites for launch on ESA's Ariane 4 vehicles by 1991.

SPACE HARDWARE

Satellites, space stations, experimental facilities and equipment, probes, launch vehicles, upper stages, and launch and communication facilities all have a high electronics content. Commercial space hardware can average from 50 to 60 percent electronics content. A typical communications satellite contains $40 million worth of electronics, and its launch system contains another $12 million. Increasingly, this hardware is becoming standardized into modular LRUs and standard bus-oriented architectures.

Items such as guidance, navigation, and control (GNC) computers are becoming standard across many programs and are customized only with software, firmware, or through module (function circuit board) configurations. The electronic flight control systems often are at least quadredundant to prevent catastrophic failures. Following are examples of the type of electronic equipment that can be found in space systems:

- Standard Platform/Launch Vehicle Systems
  - Guidance, navigation, and control computers
  - Inertial navigation and Global Positioning System (GPS) units
  - Sensors—accelerometers, temperature, pressure, chemical
  - Main engine, maneuver, stabilization, and fuel controls
  - Destruction receiver

© 1989 Dataquest Incorporated November

- Distribution/multiplexing, relay boxes
- Power systems, solar panels, batteries, conditioning, and distribution
- Thermal management systems
- Flight transponders/telemetry units
- Displays (color CRT, LCD)
- Mission computers
- Radar and optoelectronic sensors
- Life support systems
- Data, video, voice communications

• Payload Systems
  - Transponders (C, Ku, Ka, S band)
  - Sensors and recorders—optical, IR, UV
  - Assorted experimental instrumentation

SPACE ELECTRONIC EQUIPMENT PRODUCERS

At least 100 companies worldwide specialize in the various electronic technologies associated with guidance, navigation, control, communication, power, sensors, and instrumentation. In addition, many national space agencies and universities design and manufacture scientific instrumentation, facilities, and test equipment. Principal systems integrators and space electronics producers include the following:

• North America
  - GM Hughes Space and Communications Group
  - TRW Space and Technology Group
  - GE Astro-Space Division
  - Ford Aerospace
  - Ball Aerospace Systems Division
  - Martin Marietta Aerospace/Missiles and Electronics Divisions
  - Jet Propulsion Laboratory (JPL)
  - Spar Aerospace
  - General Dynamics Space/Electronics Systems Divisions
  - Lockheed Missiles and Space

 © 1989 Dataquest Incorporated November

- Boeing Aerospace and Electronics
- Grumman Space Systems/Electronics Systems Divisions
- Rockwell Satellite and Space Electronics/Space Station/Space Transportation Systems Divisions

• Europe

- Aeritalia/Selenia Spazio (IRI)
- Aerospatiale Division Systemes Strategiques et Spatiaux
- Alcatel Espace
- British Aerospace Space Systems
- Dornier
- Marconi Space Systems
- Matra Espace/Fairchild Space
- Messerschmitt-Bolkow-Blohm (MBB) Space Systems Group
- Saab Space

• Japan

- Mitsubishi Electric
- NEC
- Toshiba
- Fujitsu

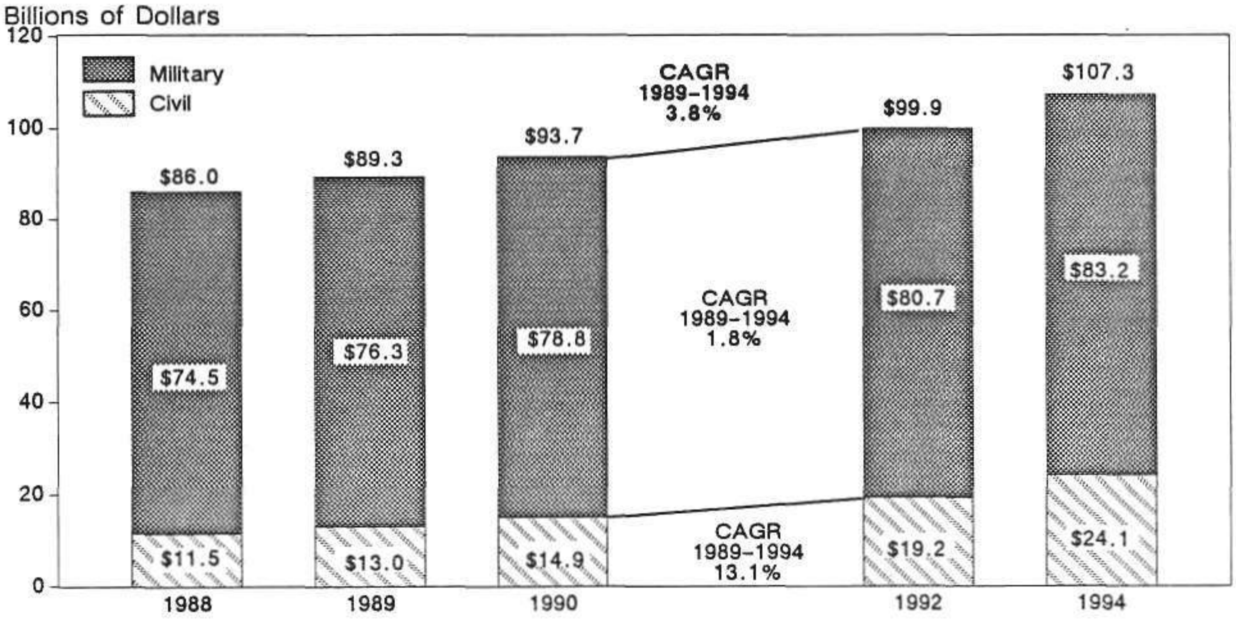
© 1989 Dataquest Incorporated November

Equipment Production Forecast

Figure 1 presents the overall worldwide military and aerospace electronics production forecast. Figure 2 details the geographical breakdown of production. Detailed forecasts by geographical area are listed in Tables 1 through 4.

Figure 1

Estimated Military and Civil Aerospace Worldwide Electronics Production

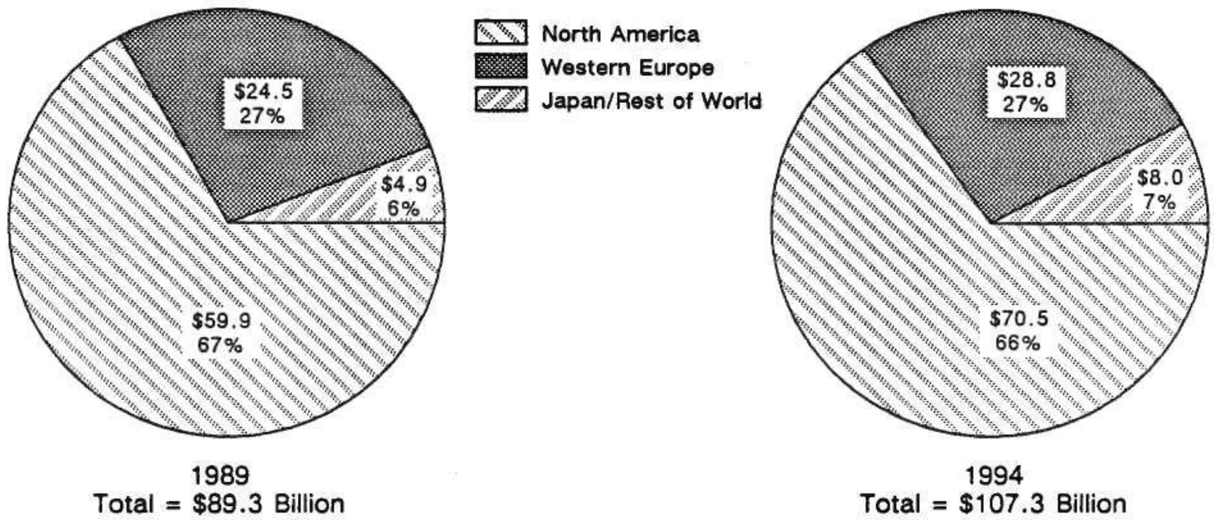


Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Figure 2

Estimated Military and Civil Aerospace Geographic Electronics Production



Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 1

Military/Aerospace Electronic Equipment Production Worldwide (Millions of Dollars)

	1987	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total	83,488	86,046	89,264	93,745	96,747	99,894	103,235	107,330	3.8%
Military	72,750	74,580	76,258	78,766	79,685	80,657	81,712	83,234	1.8%
Radar/Sonar	14,120	14,003	13,903	14,214	14,210	14,095	13,800	13,519	(0.6%)
Missile/Weapon	9,640	10,127	10,357	10,613	10,715	10,788	10,870	10,960	1.1%
Space	6,372	6,351	6,833	7,333	7,843	8,337	8,863	9,423	6.6%
Communication/Navigation	9,352	9,911	10,212	10,606	10,367	10,311	10,329	10,450	0.5%
Electronic Warfare	8,303	8,610	8,765	9,101	9,388	9,684	9,989	10,263	3.2%
Aircraft Systems	6,851	6,844	6,979	7,208	7,432	7,602	7,835	8,361	3.7%
Computer Systems	2,793	2,991	3,181	3,406	3,621	3,884	4,168	4,470	7.0%
Simulation	973	1,078	1,214	1,363	1,516	1,681	1,894	2,122	11.8%
Miscellaneous Equipment	14,346	14,665	14,814	14,924	14,594	14,274	13,965	13,666	(1.6%)
Civilian	10,738	11,466	13,006	14,979	17,063	19,237	21,523	24,096	13.1%
Radar	2,707	3,077	3,465	3,926	4,383	4,871	5,355	5,886	11.2%
Space	3,969	3,938	4,498	5,287	6,133	7,065	8,124	9,343	15.7%
Communication/Navigation	992	1,093	1,227	1,389	1,602	1,767	1,940	2,130	11.7%
Flight Systems	2,778	3,037	3,455	3,965	4,463	4,971	5,453	5,983	11.6%
Simulation	292	321	361	413	481	562	651	755	15.9%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 2

Military/Aerospace Electronic Equipment Production
North America
(Millions of Dollars)

	1987	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total	57,862	58,179	59,876	62,248	64,024	65,957	67,998	70,485	3.3%
Military	50,932	51,063	51,727	52,837	53,217	53,729	54,304	55,138	1.3%
Radar/Sonar	9,820	9,505	9,326	9,419	9,372	9,232	8,908	8,597	(1.6%)
Missile/Weapon	6,228	6,385	6,461	6,539	6,617	6,696	6,777	6,858	1.2%
Space	5,281	5,148	5,552	5,968	6,386	6,782	7,203	7,649	6.6%
Communication/Navigation	6,153	6,397	6,546	6,753	6,449	6,320	6,257	6,288	(0.8%)
Electronic Warfare	5,451	5,539	5,571	5,738	5,933	6,133	6,342	6,518	3.2%
Aircraft Systems	4,555	4,327	4,312	4,355	4,429	4,518	4,690	4,995	3.0%
Computer Systems	2,112	2,207	2,308	2,421	2,545	2,708	2,884	3,071	5.9%
Simulation	671	744	845	946	1,054	1,170	1,328	1,495	12.1%
Miscellaneous Equipment	10,661	10,811	10,806	10,698	10,430	10,170	9,915	9,668	(2.2%)
Civilian	6,930	7,116	8,149	9,411	10,807	12,228	13,694	15,347	13.5%
Radar	1,590	1,825	2,080	2,355	2,645	2,949	3,228	3,533	11.2%
Space	2,693	2,470	2,818	3,330	3,865	4,456	5,145	5,941	16.1%
Communication/Navigation	663	713	808	910	1,074	1,185	1,298	1,422	12.0%
Flight Systems	1,783	1,892	2,198	2,536	2,892	3,245	3,559	3,903	12.2%
Simulation	201	216	245	280	331	393	464	548	17.5%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 3

Military/Aerospace Electronic Equipment Production
Europe
(Millions of Dollars)

	1987	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total	21,576	23,432	24,494	26,096	26,762	27,358	27,984	28,846	3.3%
Military	18,800	20,237	20,957	22,042	22,242	22,333	22,419	22,682	1.6%
Radar/Sonar	3,733	3,904	3,945	4,123	4,123	4,102	4,081	4,061	0.6%
Missile/Weapon	2,935	3,221	3,327	3,453	3,419	3,351	3,284	3,218	(0.7%)
Space	825	914	966	1,021	1,082	1,147	1,216	1,289	5.9%
Communication/Navigation	2,767	3,034	3,133	3,258	3,258	3,258	3,258	3,258	0.8%
Electronic Warfare	2,501	2,683	2,766	2,890	2,934	2,978	3,023	3,068	2.1%
Aircraft Systems	1,986	2,178	2,295	2,444	2,554	2,592	2,605	2,775	3.9%
Computer Systems	590	674	745	838	909	987	1,071	1,162	9.3%
Simulation	263	291	322	365	406	450	500	555	11.5%
Miscellaneous Equipment	3,200	3,338	3,458	3,648	3,557	3,468	3,381	3,297	(1.0%)
Civilian	2,776	3,195	3,537	4,055	4,520	5,024	5,565	6,164	11.8%
Radar	786	884	977	1,119	1,236	1,366	1,510	1,669	11.3%
Space	811	940	1,056	1,220	1,397	1,585	1,781	2,000	13.6%
Communication/Navigation	283	330	363	416	458	503	554	609	10.9%
Flight Systems	819	951	1,042	1,187	1,300	1,425	1,561	1,711	10.4%
Simulation	77	90	99	113	129	145	159	175	12.1%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 4

Military/Aerospace Electronic Equipment Production
Japan/Rest of World
(Millions of Dollars)

	1987	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total	4,050	4,435	4,894	5,401	5,962	6,579	7,253	7,999	10.3%
Military	3,018	3,280	3,574	3,887	4,226	4,594	4,989	5,414	8.7%
Radar/Sonar	567	594	632	672	715	761	810	862	6.4%
Missile/Weapon	477	521	569	621	679	741	809	884	9.2%
Space	266	289	315	343	374	408	445	485	9.0%
Communication/Navigation	432	480	533	594	660	733	814	904	11.1%
Electronic Warfare	351	388	428	472	521	573	624	678	9.6%
Aircraft Systems	310	339	372	408	448	492	539	592	9.7%
Computer Systems	91	110	128	146	167	189	213	237	13.1%
Simulation	39	43	47	51	56	61	66	72	8.8%
Miscellaneous Equipment	485	516	550	578	606	637	669	702	5.0%
Civilian	1,032	1,155	1,320	1,514	1,736	1,984	2,264	2,585	14.4%
Radar	331	368	408	452	502	556	616	683	10.9%
Space	465	528	624	737	872	1024	1198	1402	17.6%
Communication/Navigation	46	50	56	63	70	79	88	99	12.0%
Flight Systems	176	194	215	242	271	301	333	369	11.4%
Simulation	14	15	17	19	22	25	28	32	13.3%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Semiconductor Markets

The following is a list of the material in this section:

- Semiconductor Markets Forecast
- Standard Logic
- ASICs
- Microcomponents
- Memory
- Analog
- Discrete Semiconductors
- Optoelectronics
- Radiation Tolerance

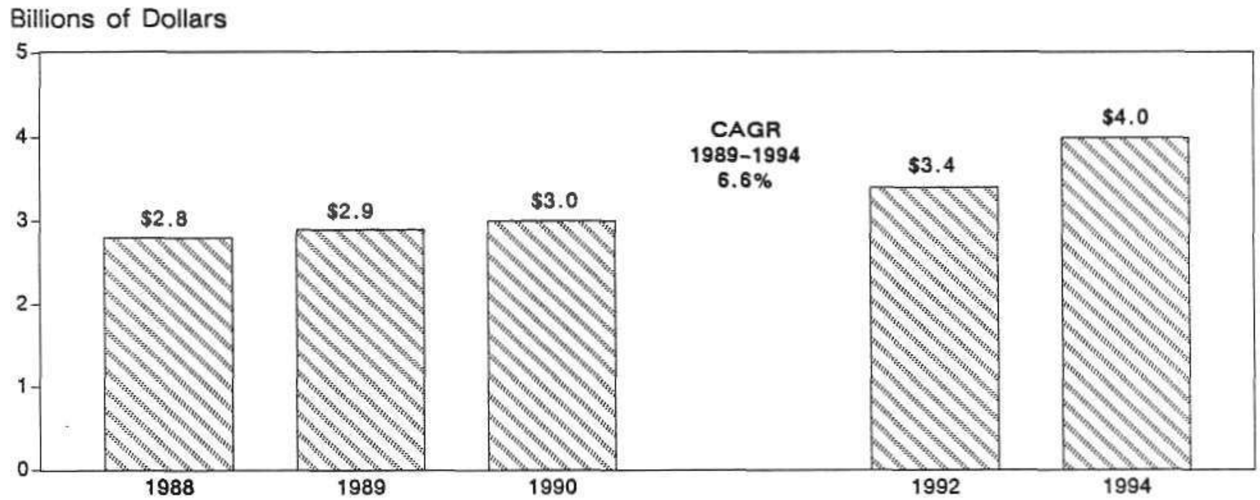
© 1990 Dataquest Incorporated September

Semiconductor Markets—Forecasts

Figures 1 and 2 and Tables 1 through 14 detail Dataquest's semiconductor consumption forecast for military and civilian areospace applications for various geographic areas. Tables 15 and 16 detail North American semiconductor consumption by specification, and Tables 17 and 18 provide European specification and country detail.

Figure 1

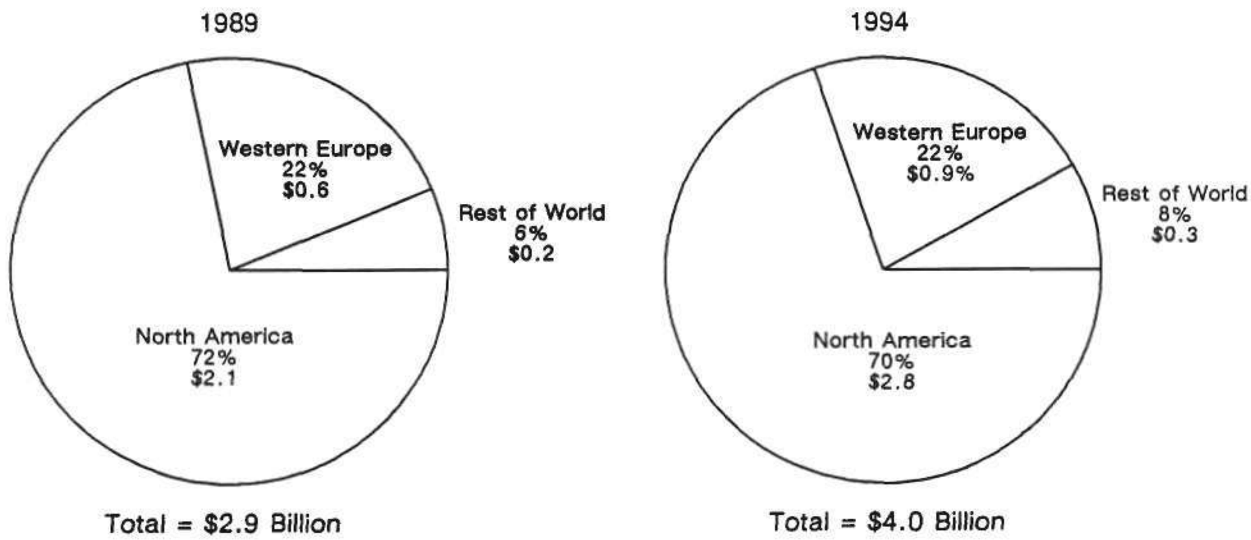
Estimated Worldwide Military/Aerospace Semiconductor Consumption



Source: Dataquest (July 1990)

Figure 2

Estimated Geographic Military/Aerospace Semiconductor Consumption



Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 1

Estimated Worldwide Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	2,775.5	2,873.7	3,023.3	3,191.3	3,410.8	3,669.5	3,964.3	6.6%
IC	2,190.0	2,301.6	2,436.4	2,584.3	2,778.0	3,007.4	3,271.7	7.3%
Digital Bipolar	574.4	554.2	527.9	489.1	455.6	425.4	395.6	(6.5%)
Memory	96.2	85.4	75.2	65.9	58.3	52.9	48.5	(10.7%)
Microcomponent	59.1	58.6	60.1	60.2	60.1	60.1	60.3	0.6%
Logic	419.0	410.2	392.7	363.0	337.2	312.4	286.8	(6.9%)
Standard (S/MSI)	259.5	234.5	227.2	211.5	194.1	177.4	157.5	(7.7%)
ASIC	159.5	175.7	165.4	151.5	143.1	134.9	129.3	(5.9%)
Digital MOS	1,037.2	1,176.0	1,314.7	1,470.7	1,658.9	1,865.8	2,092.2	12.2%
Memory	385.1	448.2	496.9	554.4	623.8	698.9	778.3	11.7%
Microcomponent	246.5	269.7	302.9	339.7	382.0	431.6	489.1	12.6%
MOS Logic	405.5	458.1	515.0	576.5	653.1	735.3	824.7	12.5%
Standard (S/MSI)	88.0	92.3	96.2	98.3	100.6	103.2	107.7	3.1%
ASIC	317.5	365.8	418.8	478.2	552.5	632.1	717.0	14.4%
Analog	578.5	571.4	593.7	624.5	663.6	716.2	783.9	6.5%
Discrete	478.9	469.0	480.9	498.0	517.9	538.2	558.8	3.6%
Optoelectronic	106.6	103.1	106.0	109.0	114.9	123.9	133.8	5.3%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 2

Estimated North American Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	2,000.2	2,058.6	2,135.1	2,235.5	2,379.3	2,554.1	2,756.1	6.0%
IC	1,585.1	1,651.0	1,721.4	1,808.0	1,933.1	2,086.2	2,265.8	6.5%
Digital Bipolar	432.0	419.5	396.7	365.0	337.1	312.8	288.4	(7.2%)
Memory	74.6	64.1	55.8	48.8	42.9	38.7	35.4	(11.2%)
Microcomponent	40.4	39.5	40.6	41.4	42.0	42.8	43.6	2.0%
Logic	317.0	315.9	300.3	274.8	252.1	231.3	209.4	(7.9%)
Standard (S/MSI)	189.8	174.1	171.0	160.2	146.9	134.7	118.6	(7.4%)
ASIC	127.2	141.8	129.3	114.5	105.2	96.7	90.8	(8.5%)
Digital MOS	756.1	845.1	929.7	1,028.9	1,155.4	1,295.7	1,449.2	11.4%
Memory	288.3	326.9	357.3	395.5	442.8	494.1	548.4	10.9%
Microcomponent	175.8	191.9	213.2	237.9	268.4	304.1	345.8	12.5%
MOS Logic	292.0	326.3	359.2	395.5	444.2	497.4	555.0	11.2%
Standard (S/MSI)	56.2	58.4	60.9	62.2	63.6	64.9	67.5	3.0%
ASIC	235.8	267.9	298.2	333.3	380.6	432.6	487.4	12.7%
Analog	397.0	386.4	395.1	414.2	440.6	477.8	528.2	6.5%
Discrete	341.0	335.3	340.6	352.7	367.0	381.8	396.7	3.4%
Optoelectronic	74.1	72.3	73.0	74.8	79.2	86.0	93.6	5.3%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 3

Estimated North American Military/Aerospace Logic Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Logic	609.0	642.2	659.5	670.2	696.3	728.8	764.4	3.5%
Bipolar Logic	317.0	315.9	300.3	274.8	252.1	231.3	209.4	(7.9%)
Standard (S/MSI)	189.8	174.1	171.0	160.2	146.9	134.7	118.6	(7.4%)
TTL	167.2	151.7	148.7	138.6	126.1	114.9	100.3	(7.9%)
LS/S	91.2	79.7	79.7	72.9	63.4	55.2	46.1	(10.4%)
FAST/AS/ALS	30.3	29.8	29.7	29.8	29.9	29.9	28.0	(1.2%)
Standard	40.4	37.8	35.5	32.5	29.7	27.2	24.0	(8.7%)
Other	5.3	4.4	3.8	3.4	2.9	2.6	2.2	(12.8%)
ECL	17.8	17.8	17.9	17.4	16.8	15.9	14.7	(3.7%)
Other	4.8	4.6	4.4	4.2	4.0	3.8	3.6	(4.7%)
ASIC	127.2	141.8	129.3	114.5	105.2	96.7	90.8	(8.5%)
Gate Array	50.8	53.4	55.3	50.6	48.0	48.0	48.5	(1.9%)
Cell-Based IC	2.8	3.9	5.7	8.0	10.8	14.6	19.0	37.3%
Prog. Logic	27.5	26.1	24.6	23.1	21.7	20.0	18.4	(6.8%)
Full Custom	46.1	58.4	43.8	32.9	24.6	14.0	4.9	(39.0%)
MOS Logic	292.0	326.3	359.2	395.5	444.2	497.4	555.0	11.2%
Standard (S/MSI)	56.2	58.4	60.9	62.2	63.6	64.9	67.5	3.0%
HC/HCT	18.2	17.1	17.2	16.6	15.8	14.4	13.2	(5.1%)
AC/ACT/FCT	17.4	21.4	24.3	26.1	27.5	28.4	28.4	5.8%
4000/54C	13.4	11.9	10.5	9.3	8.2	7.3	6.4	(11.5%)
GaAs	2.7	3.2	3.7	4.2	5.0	5.7	7.1	17.2%
Other	4.5	4.8	5.3	6.0	7.1	9.1	12.5	20.9%
ASIC	235.8	267.9	298.2	333.3	380.6	432.6	487.4	12.7%
Gate Array	134.7	150.1	164.4	179.2	199.8	224.7	251.7	10.9%
Cell-Based IC	44.8	51.8	59.6	71.5	87.2	102.9	119.9	18.3%
Prog. Logic	22.5	35.4	45.0	53.3	61.5	69.2	76.1	16.6%
Full Custom	24.8	19.1	15.3	12.2	9.8	7.8	6.3	(20.0%)
GaAs	9.0	11.5	14.1	17.2	22.3	27.9	33.5	23.8%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 4

Estimated North American Military/Aerospace Microcomponent Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Microcomponent	216.2	231.5	253.9	279.3	310.4	346.9	389.4	11.0%
Bipolar Microcomponent	40.4	39.5	40.6	41.4	42.0	42.8	43.6	2.0%
MPU/Bit Slice	23.4	22.1	22.1	21.7	21.1	20.6	20.1	(1.9%)
Peripheral	17.0	17.4	18.5	19.7	20.9	22.2	23.5	6.2%
MOS Microcomponent	175.8	191.9	213.2	237.9	268.4	304.1	345.8	12.5%
MPU	59.3	57.6	58.6	60.6	65.5	73.5	84.6	8.0%
8-Bit	26.1	20.6	17.5	14.9	12.7	10.9	9.3	(14.7%)
16-Bit	29.6	31.8	34.3	36.9	39.1	40.0	39.2	4.3%
32-Bit	3.6	5.2	6.8	8.8	13.7	22.6	36.1	47.2%
MCU	17.8	19.5	21.1	22.9	25.1	27.7	31.6	10.1%
4-Bit	1.2	1.1	1.0	0.9	0.9	0.8	0.7	(8.0%)
8-Bit	16.1	17.5	18.8	20.0	20.9	21.1	21.2	3.9%
16-Bit	0.5	0.9	1.3	2.0	3.3	5.8	9.6	60.7%
DSP MPU	6.6	9.7	12.1	15.2	18.9	24.6	32.0	27.0%
MPR	90.2	102.5	117.9	134.7	152.9	170.6	187.2	12.8%
System Support	30.4	31.9	33.5	35.7	38.7	41.6	44.7	7.0%
Communication	28.5	31.1	35.0	39.3	44.6	50.7	57.5	13.1%
Other/Graphics	31.3	39.5	49.4	59.7	69.6	78.3	85.0	16.6%
GaAs	1.9	2.6	3.5	4.5	5.9	7.7	10.4	32.0%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 5

Estimated North American Military/Aerospace Memory Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Memory	362.9	391.0	413.0	444.3	485.7	532.8	583.8	8.3%
Bipolar Memory	74.6	64.1	55.8	48.8	42.9	38.7	35.4	(11.2%)
RAM	17.6	14.9	13.5	12.4	11.6	10.9	10.3	(7.1%)
TTL	14.1	11.3	9.8	8.6	7.5	6.6	5.8	(12.4%)
ECL	3.5	3.6	3.7	3.8	4.0	4.2	4.5	4.5%
PROM/ROM	49.5	42.1	35.8	30.4	25.9	22.8	20.5	(13.4%)
Other	7.5	7.1	6.5	6.0	5.5	5.1	4.7	(8.1%)
MOS Memory	288.3	326.9	357.3	395.5	442.8	494.1	548.4	10.9%
DRAM	27.5	33.5	38.0	43.0	48.6	54.9	62.0	13.1%
SRAM	130.2	151.0	165.3	184.4	209.2	234.4	257.8	11.3%
EPROM	40.0	41.1	42.9	44.9	46.5	47.8	49.3	3.7%
ROM/PROM	18.5	21.9	24.7	27.4	30.1	32.8	35.3	10.0%
EE/Nonvol.	55.4	58.2	61.7	67.6	76.0	85.1	94.5	10.2%
Flash	0.1	0.3	0.6	1.1	2.1	4.8	10.4	103.2%
Other/FIFO	15.1	18.8	21.3	24.0	26.2	28.5	31.1	10.6%
GaAs	1.5	2.1	2.6	3.3	4.1	5.7	8.0	30.8%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 6

Estimated North American Military/Aerospace Analog/Discrete/Optoelectronic Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Analog	397.0	386.4	395.1	414.2	440.6	477.8	528.2	6.5%
Amplifier	114.5	104.2	101.1	101.6	105.6	109.9	114.0	1.8%
Comparator	19.4	18.5	18.2	18.7	19.3	20.0	20.8	2.3%
Voltage Reg./Ref.	20.6	19.4	19.3	19.8	20.5	21.3	22.1	2.6%
Interface	42.9	40.7	40.7	41.7	43.2	44.8	46.5	2.7%
Data Conversion	92.3	91.0	92.1	95.3	98.7	103.6	108.8	3.6%
Other/Power	75.1	73.5	74.6	77.2	80.3	84.7	89.8	4.1%
GaAs	32.2	39.1	49.1	59.9	73.0	93.5	126.2	26.4%
Discrete	341.0	335.3	340.6	352.7	367.0	381.8	396.7	3.4%
Sm. Sig. Diode	50.3	47.5	47.5	48.0	48.7	49.4	50.2	1.1%
Sm. Sig. Transistor	96.8	84.6	80.8	80.8	82.0	83.2	84.9	0.1%
Rectifier	36.8	37.2	37.7	39.1	40.8	42.8	45.0	3.9%
Power MOSFET	35.2	41.0	45.3	50.5	55.8	60.7	65.2	9.7%
Power Bipolar Trans.	40.1	37.5	35.8	34.2	32.6	31.2	29.8	(4.5%)
GaAs	69.8	75.2	80.8	87.1	93.7	100.7	107.5	7.4%
Other	12.0	12.3	12.7	13.0	13.4	13.8	14.2	2.8%
Optoelectronic	74.1	72.3	73.0	74.8	79.2	86.0	93.6	5.3%
LED Lamps/Displays	17.2	15.7	15.3	15.3	15.8	16.2	16.7	1.3%
Coupler/Isoltr./ Intrptr.	15.8	14.5	14.2	14.2	14.7	15.2	15.8	1.7%
Emitter/Detect/Other	41.1	42.1	43.6	45.3	48.7	54.6	61.1	7.7%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 7

Military/Aerospace North American GaAs Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
GaAs	180.8	196.9	218.6	242.9	274.8	318.3	376.5	13.8%
Standard Logic	2.7	3.2	3.7	4.2	5.0	5.7	7.1	17.2%
ASIC	9.0	11.5	14.1	17.2	22.3	27.9	33.5	23.8%
Microdevice	1.9	2.6	3.5	4.5	5.9	7.7	10.4	32.0%
Memory	1.5	2.1	2.6	3.3	4.1	5.7	8.0	30.8%
Analog	32.2	39.1	49.1	59.9	73.0	93.5	126.2	26.4%
Discrete	69.8	75.2	80.8	87.1	93.7	100.7	107.5	7.4%
Optoelectronic	63.7	63.2	64.8	66.7	70.7	77.0	83.9	5.8%

Source: Dataquest (July 1990)

Table 8

Estimated European Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	632.9	647.1	695.8	733.9	776.8	826.2	881.5	6.4%
IC	484.4	506.4	548.2	581.9	619.7	663.5	713.0	7.1%
Digital Bipolar	116.9	108.3	105.5	99.5	95.3	91.5	88.1	(4.0%)
Memory	16.2	15.6	14.2	12.3	10.9	10.0	9.2	(10.0%)
Microcomponent	16.5	16.9	17.1	16.5	15.8	15.3	14.8	(2.7%)
Logic	84.1	75.8	74.2	70.7	68.6	66.2	64.1	(3.3%)
Standard (S/MSI)	54.4	45.0	41.6	37.6	34.9	32.3	30.0	(7.8%)
ASIC	29.7	30.7	32.6	33.2	33.7	33.9	34.2	2.1%
Digital MOS	224.8	256.0	292.3	326.1	361.8	400.4	443.1	11.6%
Memory	72.7	87.7	100.1	111.5	124.1	138.0	153.5	11.9%
Microcomponent	58.6	63.4	71.3	79.3	87.8	97.7	109.1	11.5%
MOS Logic	93.4	105.0	120.9	135.3	149.8	164.7	180.5	11.4%
Standard (S/MSI)	23.9	24.8	25.2	25.0	24.7	24.8	25.6	0.6%
ASIC	69.5	80.2	95.8	110.2	125.1	139.9	154.9	14.1%
Analog	142.8	142.1	150.4	156.3	162.7	171.5	181.8	5.1%
Discrete	118.9	113.4	118.5	122.0	125.8	129.7	133.7	3.3%
Optoelectronic	29.6	27.3	29.1	30.1	31.2	33.0	34.8	5.0%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 9

Estimated European Military/Aerospace Logic Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Logic	177.5	180.8	195.2	206.0	218.4	230.9	244.7	6.2%
Bipolar Logic	84.1	75.8	74.2	70.7	68.6	66.2	64.1	(3.3%)
Standard (S/MSI)	54.4	45.0	41.6	37.6	34.9	32.3	30.0	(7.8%)
TTL	48.0	38.5	34.9	30.9	28.4	26.2	24.2	(8.9%)
LS/S	28.1	22.0	19.0	16.1	14.5	13.1	11.9	(11.6%)
FAST/AS/ALS	14.2	12.0	11.6	11.1	10.6	10.1	9.6	(4.3%)
Standard	3.8	2.9	2.7	2.5	2.3	2.1	1.9	(7.4%)
Other	1.9	1.7	1.5	1.3	1.1	0.9	0.8	(13.6%)
ECL	4.6	4.8	5.0	5.0	4.9	4.7	4.4	(1.6%)
Other	1.8	1.7	1.7	1.6	1.5	1.4	1.3	(5.2%)
ASIC	29.7	30.7	32.6	33.2	33.7	33.9	34.2	2.1%
Gate Array	14.2	14.8	15.6	15.7	15.7	15.0	14.2	(0.8%)
Cell-Based IC	2.1	3.1	4.2	5.5	6.8	8.5	10.2	26.9%
Prog. Logic	8.1	7.8	8.1	7.7	7.3	6.9	6.6	(3.4%)
Full Custom	5.3	5.0	4.8	4.3	3.9	3.5	3.1	(9.0%)
MOS Logic	93.4	105.0	120.9	135.3	149.8	164.7	180.5	11.4%
Standard (S/MSI)	23.9	24.8	25.2	25.0	24.7	24.8	25.6	0.6%
HC/HCT	10.2	9.8	9.3	8.4	7.5	6.8	6.1	(9.0%)
AC/ACT/FCT	4.5	6.4	7.6	8.5	8.9	9.4	9.8	9.0%
4000/54C	5.7	4.9	4.3	3.8	3.4	3.0	2.7	(11.5%)
GaAs	1.1	1.3	1.5	1.7	1.9	2.2	2.5	13.8%
Other	2.4	2.4	2.5	2.6	3.0	3.5	4.5	13.4%
ASIC	69.5	80.2	95.8	110.2	125.1	139.9	154.9	14.1%
Gate Array	36.2	41.5	48.8	54.9	61.4	67.6	74.0	12.3%
Cell-Based IC	16.6	23.2	30.0	35.6	40.9	46.7	52.7	17.9%
Prog. Logic	3.4	4.9	6.8	9.1	11.4	13.7	16.2	27.0%
Full Custom	10.5	7.0	5.6	5.0	4.5	3.8	2.8	(16.7%)
GaAs	2.8	3.6	4.6	5.6	6.8	8.1	9.3	20.8%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 10

Estimated European Military/Aerospace Microcomponent Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Microcomponent	75.2	80.3	88.4	95.8	103.6	113.0	123.9	9.1%
Bipolar Microcomponent	16.5	16.9	17.1	16.5	15.8	15.3	14.8	(2.7%)
MPU/Bit Slice	11.9	11.9	11.7	10.8	9.9	9.0	8.3	(7.0%)
Peripheral	4.6	5.0	5.5	5.7	6.0	6.2	6.5	5.3%
MOS Microcomponent	58.6	63.4	71.3	79.3	87.8	97.7	109.1	11.5%
MPU	14.7	14.6	15.8	17.2	19.2	22.5	26.8	12.9%
8-Bit	3.1	2.2	1.9	1.7	1.5	1.3	1.3	(10.0%)
16-Bit	10.3	10.5	11.3	12.0	12.7	13.4	13.8	5.6%
32-Bit	1.3	1.9	2.6	3.5	5.0	7.8	11.7	43.8%
MCU	7.7	8.0	8.8	9.4	10.1	10.8	11.5	7.5%
4-Bit	0.4	0.3	0.3	0.2	0.2	0.2	0.2	(10.5%)
8-Bit	6.7	6.9	7.5	7.9	8.4	8.9	9.4	6.4%
16-Bit	0.6	0.8	1.0	1.2	1.5	1.7	1.9	18.7%
DSP MPU	3.8	4.2	5.8	6.8	7.8	9.1	10.6	20.4%
MPR	31.6	35.6	39.7	44.6	49.1	53.6	58.3	10.4%
System Support	10.3	10.5	11.3	12.0	12.8	13.6	14.5	6.7%
Communication	9.8	10.8	12.2	13.6	15.1	16.7	18.2	11.0%
Other/Graphics	11.5	14.3	16.2	18.9	21.2	23.3	25.6	12.4%
GaAs	0.8	1.0	1.2	1.4	1.5	1.7	1.9	14.0%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 11

Estimated European Military/Aerospace Memory Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Memory	88.9	103.3	114.3	123.8	135.0	148.0	162.7	9.5%
Bipolar Memory	16.2	15.6	14.2	12.3	10.9	10.0	9.2	(10.0%)
RAM	3.9	3.6	3.5	3.3	3.1	2.9	2.7	(5.9%)
TTL	2.8	2.5	2.3	2.0	1.8	1.6	1.4	(10.5%)
ECL	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.9%
PROM/ROM	9.9	9.8	8.5	6.9	5.9	5.3	4.8	(13.5%)
Other	2.4	2.2	2.2	2.1	2.0	1.9	1.8	(4.0%)
MOS Memory	72.7	87.7	100.1	111.5	124.1	138.0	153.5	11.9%
DRAM	7.9	9.9	11.7	13.2	14.8	16.6	18.5	13.4%
SRAM	33.5	41.8	48.3	54.3	61.1	68.7	77.3	13.1%
EPROM	10.4	11.0	11.8	12.3	12.7	12.7	12.2	2.1%
ROM/PROM	4.8	5.8	6.7	7.3	8.0	8.6	9.3	9.9%
EE/Nonvol.	11.5	13.6	14.9	16.7	18.6	20.5	22.1	10.2%
Flash	0	0.1	0.2	0.4	0.7	1.6	3.5	103.2%
Other/FIFO	4.1	4.7	5.5	6.0	6.6	7.3	8.1	11.4%
GaAs	0.5	0.7	1.0	1.2	1.6	2.0	2.4	27.1%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 12

Estimated European Military/Aerospace Analog/Discrete/Optoelectronic Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Analog	142.8	142.1	150.4	156.3	162.7	171.5	181.8	5.1%
Amplifier	40.3	39.2	40.6	41.2	41.8	42.4	43.1	1.9%
Comparator	7.0	6.8	7.0	7.2	7.3	7.4	7.5	2.0%
Voltage Reg./Ref.	8.2	8.0	8.2	8.4	8.5	8.6	8.8	1.8%
Interface	16.4	16.3	16.9	17.2	17.4	17.7	18.0	2.1%
Data Conversion	32.9	32.3	33.9	35.1	36.4	37.6	39.0	3.8%
Other/Power	27.4	27.0	28.5	29.8	31.1	32.5	34.0	4.7%
GaAs	10.6	12.5	15.3	17.5	20.2	25.2	31.5	20.3%
Discrete	118.9	113.4	118.5	122.0	125.8	129.7	133.7	3.3%
Sm. Sig. Diode	18.6	17.6	18.3	18.5	18.7	18.9	19.1	1.7%
Sm. Sig. Transistor	31.3	28.3	29.4	29.4	29.7	30.0	30.3	1.4%
Rectifier	12.8	12.2	12.9	13.3	13.8	14.3	14.8	3.9%
Power MOSFET	12.3	12.4	13.3	14.7	16.1	17.5	18.8	8.6%
Power Bipolar Trans.	14.4	13.2	13.0	12.5	12.0	11.5	11.0	(3.6%)
GaAs	25.3	25.6	27.4	29.3	31.2	33.1	35.1	6.5%
Other	4.2	4.1	4.2	4.3	4.5	4.6	4.7	2.8%
Optoelectronic	29.6	27.3	29.1	30.1	31.2	33.0	34.8	5.0%
LED Lamps/Displays	6.8	6.1	6.5	6.6	6.7	6.9	7.0	2.8%
Coupler/Isoltr./ Intrptr.	6.2	5.5	5.8	6.0	6.1	6.3	6.4	3.1%
Emitter/Detect/Other	16.6	15.7	16.8	17.5	18.4	19.8	21.4	6.4%

Source: Dataquest (July 1990)

Table 13

Military/Aerospace European GaAs Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
GaAs	59.5	65.8	73.8	81.4	89.7	100.7	113.2	11.5%
Standard Logic	1.1	1.3	1.5	1.7	1.9	2.2	2.5	13.8%
ASIC	2.8	3.6	4.6	5.6	6.8	8.1	9.3	20.8%
Microdevice	0.8	1.0	1.2	1.4	1.5	1.7	1.9	14.0%
Memory	0.5	0.7	1.0	1.2	1.6	2.0	2.4	27.1%
Analog	10.6	12.5	15.3	17.5	20.2	25.2	31.5	20.3%
Discrete	25.3	25.6	27.4	29.3	31.2	33.1	35.1	6.5%
Optoelectronic	18.4	21.1	22.9	24.6	26.5	28.4	30.6	7.7%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 14

Estimated Japan/Rest of World Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	142.4	167.9	192.4	221.9	254.7	289.2	326.6	14.2%
IC	120.5	144.1	166.7	194.4	225.2	257.7	292.9	15.2%
Digital Bipolar	25.5	26.4	25.7	24.7	23.2	21.1	19.1	(6.3%)
Memory	5.4	5.7	5.3	4.9	4.5	4.2	3.9	(7.5%)
Microcomponent	2.2	2.2	2.3	2.3	2.2	2.1	2.0	(2.1%)
Logic	17.9	18.5	18.1	17.5	16.5	14.8	13.2	(6.5%)
Standard (S/MSI)	15.3	15.4	14.6	13.7	12.3	10.5	8.9	(10.4%)
ASIC	2.6	3.1	3.5	3.8	4.1	4.3	4.3	7.0%
Digital MOS	56.3	74.8	92.7	115.7	141.8	169.7	199.9	21.7%
Memory	24.1	33.6	39.5	47.4	56.9	66.8	76.5	17.9%
Microcomponent	12.1	14.4	18.4	22.5	25.9	29.7	34.2	18.9%
MOS Logic	20.1	26.8	34.8	45.8	59.1	73.2	89.2	27.2%
Standard (S/MSI)	7.9	9.1	10.1	11.1	12.2	13.4	14.6	9.9%
ASIC	12.2	17.7	24.8	34.7	46.8	59.7	74.6	33.4%
Analog	38.7	42.9	48.3	54.1	60.3	66.9	73.9	11.5%
Discrete	19.0	20.3	21.8	23.4	25.0	26.7	28.4	7.0%
Optoelectronic	2.9	3.5	3.8	4.1	4.5	4.9	5.3	8.6%

Source: Dataquest (July 1990)

Table 15

Military/Aerospace IC Consumption by Specification North America 1989 (Millions of Dollars)

	JAN	883/SCD SMD	Custom* Space	Commercial	Total
IC	144.9	1,148.4	206.1	151.5	1,651.0
Digital Bipolar	75.5	253.8	67.1	23.1	419.5
Digital MOS	21.1	633.8	88.7	101.4	845.1
Analog	48.3	260.8	50.2	27.0	386.4

*Includes custom rad-hard/tolerant specification shipments
Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 16

Military/Aerospace IC Consumption by Specification
North America 1994
(Millions of Dollars)

	JAN/QML	883/SCD SMD	Custom* Space	Commercial	Total
IC	226.6	1,481.7	332.2	225.3	2,265.8
Digital Bipolar	66.3	168.7	38.9	14.4	288.4
Digital MOS	94.2	956.5	224.6	173.9	1,449.2
Analog	66.0	356.5	68.7	37.0	528.2

*Includes custom rad-hard/tolerant specification shipments
Source: Dataquest (July 1990)

Table 17

European Military/Aerospace Semiconductor Consumption
by Specification

	1990	1994
BS/CECC/ESA	22%	24%
US Spec.	49	41
Mil. Temp/Other	29	35
Total	100%	100%

Source: Dataquest (July 1990)

Table 18

European Military/Aerospace Semiconductor Consumption
by Country

	1990
United Kingdom	28%
France	30
West Germany	15
Italy	12
Scandinavia	7
Rest of Europe	8
Total	100%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 2

Estimated North American Military/Aerospace Semiconductor Consumption
(Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
Total Semiconductor	$1,975.6	$2,036.0	$2,149.5	$2,496.6	$2,957.3	7.8%
IC	$1,565.9	$1,629.5	$1,724.1	$2,030.8	$2,448.8	8.5%
Digital Bipolar	408.8	371.5	353.0	333.2	327.7	(2.5%)
Memory	68.5	56.6	48.3	38.1	34.4	(9.5%)
Microcomponent	41.1	41.4	43.0	47.0	51.9	4.6%
Logic	299.2	273.5	261.7	248.0	241.4	(2.5%)
Standard (S/MSI)	200.0	174.7	160.6	140.0	123.8	(6.7%)
ASIC	99.2	98.8	101.1	108.0	117.6	3.5%
Digital MOS	754.9	843.5	938.0	1,193.9	1,507.4	12.3%
Memory	279.2	309.2	341.8	428.9	528.8	11.3%
Microcomponent	171.7	194.6	221.4	289.2	369.1	13.7%
MOS Logic	304.0	339.7	374.7	475.9	609.5	12.4%
Standard (S/MSI)	56.2	58.5	61.3	64.4	68.1	3.1%
ASIC	247.8	281.2	313.4	411.5	541.4	14.0%
Analog	402.2	414.5	433.1	503.7	613.8	8.2%
Discrete	$ 338.2	$ 330.9	$ 345.2	$ 375.6	$ 406.9	4.2%
Optoelectronic	$ 71.4	$ 75.6	$ 80.2	$ 90.2	$ 101.6	6.1%

Source: Dataquest
October 1989

©1989 Dataquest Incorporated October

Table 3

Estimated North American Military/Aerospace Logic Consumption (Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
Total Logic	$603.2	$613.2	$636.4	$724.0	$850.9	6.8%
Bipolar Logic	$299.2	$273.5	$261.7	$248.0	$241.4	(2.5%)
Standard (S/MSI)	200.0	174.7	160.6	140.0	123.8	(6.7%)
TTL	176.5	151.4	137.5	118.4	104.7	(7.1%)
LS/S	95.3	77.7	67.6	53.5	43.8	(10.8%)
FAST/AS/ALS	34.2	29.9	29.0	29.3	28.7	(0.8%)
Standard	41.5	39.0	36.7	32.4	29.7	(5.3%)
Other	5.5	4.8	4.2	3.2	2.5	(12.6%)
ECL	18.1	18.1	18.2	17.1	15.0	(3.7%)
Other	5.4	5.2	4.9	4.5	4.1	(4.5%)
ASIC	99.2	98.8 118.4	101.1	108.0	117.6	3.5%
Gate Array	42.2 61.2	43.3 63.0	46.5	53.1	59.6 41	6.6%
Cell-Based IC	2.8	4.1	5.9	11.3	19.8	37.3%
Prog. Logic	27.5	26.1	24.6	21.7	18.4	(6.8%)
Full Custom	26.7	25.4	24.2	21.9	19.8	(4.8%)
MOS Logic	$304.0	$339.7	$374.7	$475.9	$609.5	12.4%
Standard (S/MSI)	56.2	58.5	61.3	64.4	68.1	3.1%
HC/HCT	18.2	17.5	17.6	16.1	13.5	(5.1%)
AC/ACT/FCT	17.4	20.9	23.7	26.9	27.7	5.8%
4000/54C	13.4	11.9	10.5	8.2	6.4	(11.5%)
GaAs	2.7	3.4	4.2	6.1	8.6	20.0%
Other	4.5	4.8	5.3	7.1	11.9	19.8%
ASIC	247.8	281.2 304.5	313.4	411.5	541.4	14.0%
Gate Array	134.7 ~~157.5~~	152.1 ~~174.0~~	190.6	231.6	256.1 291.8	10.9%
Cell-Based	35.5	61.1 ~~43.1~~	50.5	88.0	79 ~~143.0~~	27.1%
Prog. Logic	20.3	29.4	37.4	51.2	60.8	15.6%
Full Custom	25.5	22.3	19.3	13.3	4.5	(27.3%)
GaAs	9.0	12.3	15.6	27.5	41.2	27.4%

Source: Dataquest October 1989

GaAs 12.3 41.2

29.7

BiCMOS GA 1.0 1.2 1.5

396.8

725.0

©1989 Dataquest Incorporated October

Table 4

Estimated North American Military/Aerospace Microcomponent Consumption
(Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
Total Microcomponent	$212.8	$236.0	$264.4	$336.2	$421.0	12.3%
Bipolar Microcomponent	$ 41.1	$ 41.4	$ 43.0	$ 47.0	$ 51.9	4.6%
MPU/Bit Slice	23.4	22.1	22.1	22.6	23.2	1.0%
Peripheral	17.7	19.3	20.9	24.5	28.6	8.2%
MOS Microcomponent	$171.7	$194.6	$221.4	$289.2	$369.1	13.7%
MPU	58.5	58.1	60.7	74.0	98.6	11.2%
8-Bit	26.1	20.6	17.5	12.9	11.4	(11.2%)
16-Bit	28.8	32.3	36.0	43.8	45.8	7.3%
32-Bit	3.6	5.2	7.2	17.2	41.4	51.3%
MCU	18.1	19.5	21.0	25.2	29.7	8.8%
4-Bit	1.5	1.5	1.4	1.3	1.2	(5.0%)
8-Bit	16.1	17.3	18.6	20.6	21.0	3.9%
16-Bit	0.5	0.7	1.1	3.2	7.6	60.0%
DSP MPU	7.5	12.4	17.9	30.3	42.0	27.7%
MPR	85.7	101.8	118.0	153.5	187.7	13.0%
System Support	29.4	31.7	34.2	40.1	46.3	7.9%
Communication	27.4	31.1	35.0	44.6	57.5	13.1%
Other/Graphics	28.9	39.0	48.8	68.7	83.9	16.6%
GaAs	1.9	2.8	3.7	6.3	11.1	32.0%

Source: Dataquest
October 1989

©1989 Dataquest Incorporated October

Table 5

Estimated North American Military/Aerospace Memory Consumption (Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
Total Memory	$347.7	$365.8	$390.1	$467.0	$563.2	9.0%
Bipolar Memory	$ 68.5	$ 56.6	$ 48.3	$ 38.1	$ 34.4	(9.5%)
RAM	17.2	15.0	13.7	12.3	11.2	(5.7%)
TTL	13.7	11.4	10.0	8.2	6.8	(10.0%)
ECL	3.5	3.6	3.7	4.0	4.5	4.5%
PROM/ROM	43.5	33.9	27.1	18.8	16.6	(13.3%)
Other	7.8	7.7	7.5	7.0	6.6	(2.9%)
MOS Memory	$279.2	$309.2	$341.8	$428.9	$528.8	11.3%
DRAM	23.4	26.8	30.6	40.1	51.7	14.1%
SRAM	125.3	141.0	158.4	203.2	250.4	12.2%
EPROM	40.0	40.8	42.6	49.1	55.4	6.3%
ROM/PROM	18.5	21.0	23.7	28.9	33.9	10.0%
EE/Nonvol	55.4	60.1	63.7	78.5	101.6	11.1%
Other/FIFO	15.1	17.4	19.7	24.1	27.9	10.0%
GaAs	1.5	2.2	3.0	4.9	8.0	29.6%

Source: Dataquest
October 1989

©1989 Dataquest Incorporated October

Table 6

Estimated North American Military/Aerospace Analog/Discrete/Optoelectronic Consumption
(Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
Analog	$402.2	$414.5	$433.1	$503.7	$613.8	8.2%
Amplifier	112.3	112.9	113.6	120.9	128.2	2.6%
Comparator	19.4	19.4	20.1	21.6	23.1	3.6%
Voltage Reg./Ref.	20.6	19.9	20.2	21.4	23.1	3.0%
Interface	42.9	42.3	42.3	45.1	49.1	3.0%
Data Conversion	91.2	92.6	94.9	110.7	123.7	6.0%
Other/Power	75.1	76.0	77.5	83.4	93.3	4.2%
GaAs	40.7	51.5	64.6	100.6	173.3	27.5%
Discrete	$338.2	$330.9	$345.2	$375.6	$406.9	4.2%
Sm Sig Diode	49.9	50.8	51.8	54.0	56.1	2.0%
Sm Sig Transistor	95.8	76.7	78.0	80.9	83.8	1.8%
Rectifier	36.8	37.2	37.7	40.8	45.0	3.9%
Power MOSFET	35.2	41.1	47.1	58.6	68.4	10.7%
Power Bipolar Trans.	39.7	37.5	35.8	32.9	30.3	(4.2%)
GaAs	68.9	75.3	82.1	95.1	109.1	7.7%
Other	12.0	12.3	12.7	13.4	14.2	2.8%
Optoelectronic	$ 71.4	$ 75.6	$ 80.2	$ 90.2	$101.6	6.1%
LED Lamps/Displays	17.2	17.7	18.2	19.2	20.3	2.8%
Coupler/Isoltr/Intrptr	15.8	16.4	17.0	18.3	19.7	3.7%
Emitter/Detect/Other	38.4	41.5	45.0	52.6	61.6	8.2%

Source: Dataquest
October 1989

©1989 Dataquest Incorporated October

Table 7

Military/Aerospace North American GaAs Consumption
(Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
GaAs	$188.4	$215.7	$246.5	$324.6	$447.8	15.7%
Standard Logic	2.7	3.4	4.2	6.1	8.6	20.0%
ASIC	9.0	12.3	15.6	27.5	41.2	27.4%
Microdevice	1.9	2.8	3.7	6.3	11.1	32.0%
Memory	1.5	2.2	3.0	4.9	8.0	29.6%
Analog	40.7	51.5	64.6	100.6	173.3	27.5%
Discrete	68.9	75.3	82.1	95.1	109.1	7.7%
Optoelectronic	63.7	68.3	73.2	84.1	96.6	7.2%

Source: Dataquest
October 1989

Table 8

Estimated European Military/Aerospace Semiconductor Consumption
(Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
Total Semiconductor	$636.2	$672.0	$719.7	$831.9	$967.2	7.6%
IC	$491.4	$522.0	$562.4	$660.0	$780.0	8.4%
Digital Bipolar	116.6	106.8	101.3	97.9	100.4	(1.2%)
Memory	16.2	14.3	12.4	9.9	9.0	(9.0%)
Microcomponent	16.5	16.9	16.8	16.0	15.5	(1.8%)
Logic	83.8	75.5	72.1	72.0	76.0	0.1%
Standard (S/MSI)	54.4	44.8	39.5	34.1	30.7	(7.3%)
ASIC	29.4	30.7	32.6	37.9	45.3	8.1%
Digital MOS	230.8	266.1	303.1	380.2	470.7	12.1%
Memory	72.3	82.0	92.2	117.6	147.9	12.5%
Microcomponent	61.2	73.0	84.4	105,1	128.3	11.9%
MOS Logic	97.2	111.0	126.5	157.5	194.5	11.9%
Standard (S/MSI)	25.7	26.1	26.6	26.4	28.1	1.5%
ASIC	71.5	84.9	99.9	131.1	166.4	14.4%
Analog	144.1	149.2	158.0	181.9	208.8	7.0%
Discrete	$117.9	$121.5	$127.0	$137.9	$148.8	4.1%
Optoelectronic	$ 26.9	$ 28.5	$ 30.2	$ 34.0	$ 38.4	6.1%

Source: Dataquest
October 1989

©1989 Dataquest Incorporated October

Table 9

Estimated European Military/Aerospace Logic Consumption
(Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
Total Logic	$181.1	$186.5	$198.7	$229.5	$270.5	7.7%
Bipolar Logic	$ 83.8	$ 75.5	$ 72.1	$ 72.0	$ 76.0	0.1%
Standard (S/MSI)	54.4	44.8	39.5	34.1	30.7	(7.3%)
TTL	48.0	38.3	32.9	27.0	23.1	(9.6%)
LS/S	28.1	21.8	17.7	13.5	11.1	(12.7%)
FAST/AS/ALS	14.2	12.0	11.0	10.0	9.1	(5.3%)
Standard	3.8	2.9	2.7	2.4	2.1	(6.0%)
Other	1.9	1.7	1.5	1.1	0.9	(12.6%)
ECL	4.6	4.8	5.0	5.6	6.2	5.2%
Other	1.8	1.7	1.6	1.5	1.4	(4.5%)
ASIC	29.4	30.7	32.6	37.9	45.3	8.1%
Gate Array	14.2	14.8	15.5	17.1	18.7	4.8%
Cell-Based	2.1	3.1	4.5	8.7	15.2	37.3%
Prog. Logic	7.8	7.8	7.9	8.1	7.8	0.1%
Full Custom	5.3	5.0	4.7	4.1	3.6	(6.5%)
MOS Logic	$ 97.2	$111.0	$126.5	$157.5	$194.5	11.9%
Standard (S/MSI)	25.7	26.1	26.6	26.4	28.1	1.5%
HC/HCT	10.6	9.9	9.1	6.9	5.4	(11.3%)
AC/ACT/FCT	5.1	6.7	8.4	10.1	11.5	11.3%
4000/54C	5.9	5.0	4.4	3.5	2.7	(11.5%)
GaAs	1.3	1.5	1.8	2.3	3.1	15.0%
Other	2.8	2.9	3.0	3.6	5.4	13.4%
ASIC	71.5	84.9	99.9	131.1	166.4	14.4%
Gate Array	36.6	42.3	48.8	62.9	77.5	12.9%
Cell-Based	17.4	23.7	30.2	41.5	55.8	18.7%
Prog. Logic	3.4	4.8	6.4	11.1	17.5	29.3%
Full Custom	11.1	10.0	9.2	7.6	4.7	(14.0%)
GaAs	3.0	4.1	5.2	8.0	10.8	21.5%

Source: Dataquest
October 1989

©1989 Dataquest Incorporated October

Table 10

Estimated European Military/Aerospace Microcomponent Consumption
(Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
Total Microcomponent	$77.8	$90.0	$101.2	$121.1	$143.8	9.8%
Bipolar Microcomponent	$16.5	$16.9	$ 16.8	$ 16.0	$ 15.5	(1.8%)
MPU/Bit Slice	11.9	11.9	11.3	9.6	8.0	(7.6%)
Peripheral	4.6	5.0	5.5	6.4	7.5	8.2%
MOS Microcomponent	$61.2	$73.0	$ 84.4	$105.1	$128.3	11.9%
MPU	14.8	16.4	18.5	22.9	28.5	11.6%
8-Bit	3.1	2.7	2.4	1.9	1.6	(10.0%)
16-Bit	10.4	11.3	12.1	13.8	15.5	6.6%
32-Bit	1.3	2.4	4.0	7.2	11.3	36.3%
MCU	7.5	8.2	9.0	10.3	11.6	7.1%
4-Bit	0.4	0.4	0.3	0.3	0.2	(10.5%)
8-Bit	6.5	7.0	7.5	8.3	9.0	5.1%
16-Bit	0.6	0.9	1.1	1.8	2.4	22.7%
DSP MPU	3.8	7.0	9.7	13.1	17.8	20.4%
MPR	34.3	40.1	45.7	56.8	67.7	11.0%
System Support	14.0	14.8	15.7	18.1	20.8	7.0%
Communication	9.5	10.8	12.2	15.2	18.5	11.4%
Other/Graphics	10.8	14.6	17.8	23.5	28.4	14.3%
GaAs	0.8	1.2	1.5	2.0	2.7	17.3%

Source: Dataquest
October 1989

©1989 Dataquest Incorporated October

Table 11

Estimated European Military/Aerospace Memory Consumption
(Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
Total Memory	$88.5	$96.3	$104.6	$127.6	$156.9	10.2%
Bipolar Memory	$16.2	$14.3	$ 12.4	$ 9.9	$ 9.0	(9.0%)
RAM	3.9	3.5	3.3	2.9	2.6	(5.9%)
TTL	2.8	2.4	2.1	1.7	1.4	(10.1%)
ECL	1.1	1.1	1.2	1.2	1.2	1.1%
PROM/ROM	9.4	7.9	6.4	4.4	3.9	(13.3%)
Other	2.9	2.9	2.8	2.6	2.5	(2.9%)
MOS Memory	$72.3	$82.0	$ 92.2	$117.6	$147.9	12.5%
DRAM	7.9	9.5	10.7	13.4	16.9	12.2%
SRAM	33.1	37.6	42.8	56.1	73.0	14.2%
EPROM	10.4	10.7	11.2	12.8	14.4	6.2%
ROM/PROM	4.8	5.4	6.1	7.5	8.8	10.0%
EE/Nonvol	11.5	13.6	15.3	20.1	25.2	13.1%
Other/FIFO	4.1	4.5	5.0	6.0	7.0	9.3%
GaAs	0.5	0.7	1.0	1.7	2.7	30.0%

Source: Dataquest
October 1989

©1989 Dataquest Incorporated October

Table 12

Estimated European Military/Aerospace Analog/Discrete/Optoelectronic Consumption (Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
Analog	$144.1	$149.2	$158.0	$181.9	$208.8	7.0%
Amplifier	40.3	40.5	41.1	43.3	45.7	2.4%
Comparator	7.1	7.1	7.4	7.9	8.5	3.6%
Voltage Reg./Ref.	8.2	7.9	7.9	8.2	8.6	1.8%
Interface	16.5	16.5	16.9	18.4	20.0	3.9%
Data Conversion	32.2	33.7	35.5	40.2	45.6	6.2%
Other/Power	25.2	25.6	27.5	32.4	38.2	8.3%
GaAs	14.6	17.8	21.7	31.4	42.2	18.9%
Discrete	$117.9	$121.5	$127.0	$137.9	$148.8	4.1%
Sm Sig Diode	18.4	18.7	19.1	19.8	20.6	1.9%
Sm Sig Transistor	31.0	29.9	30.5	31.6	32.7	1.8%
Rectifier	12.8	13.4	14.0	15.1	16.2	3.9%
Power MOSFET	12.3	14.4	16.4	20.4	23.9	10.7%
Power Bipolar Trans.	14.2	13.4	12.8	11.8	10.8	(4.2%)
GaAs	25.0	27.3	29.8	34.5	39.6	7.7%
Other	4.2	4.3	4.4	4.7	4.9	2.8%
Optoelectronic	$ 26.9	$ 28.5	$ 30.2	$ 34.0	$ 38.4	6.1%
LED Lamps/Displays	6.4	6.6	6.8	7.2	7.6	2.9%
Coupler/Isoltr/ Intrptr	6.0	6.2	6.4	7.0	7.5	3.9%
Emitter/Detect/Other	14.5	15.7	17.0	19.9	23.3	8.2%

Source: Dataquest
October 1989

©1989 Dataquest Incorporated October

Table 13

Military/Aerospace European GaAs Consumption
(Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
GaAs	$63.4	$72.2	$81.9	$103.9	$128.7	12.3%
Standard Logic	1.3	1.5	1.8	2.3	3.1	15.0%
ASIC	3.0	4.1	5.2	8.0	10.8	21.5%
Microdevice	0.8	1.2	1.5	2.0	2.7	17.3%
Memory	0.5	0.7	1.0	1.7	2.7	30.0%
Analog	14.6	17.8	21.7	31.4	42.2	18.9%
Discrete	25.0	27.3	29.8	34.5	39.6	7.7%
Optoelectronic	18.2	19.5	20.9	24.0	27.6	7.2%

Source: Dataquest
October 1989

Table 14

Estimated Japan/Rest of World Military/Aerospace Semiconductor Consumption
(Millions of Dollars)

	1988	1989	1990	1992	1994	CAGR 1989-1994
Total Semiconductor	$159.7	$183.2	$208.0	$264.5	$328.6	12.4%
IC	$131.1	$152.0	$174.4	$225.8	$284.5	13.4%
Digital Bipolar	30.8	31.2	30.6	27.9	23.3	(5.7%)
Memory	6.7	6.3	6.0	5.4	4.9	(5.0%)
Microcomponent	2.9	3.1	3.3	3.1	2.8	(2.1%)
Logic	21.2	21.8	21.4	19.4	15.6	(6.4%)
Standard (S/MSI)	18.1	18.1	17.2	14.5	10.5	(10.4%)
ASIC	3.1	3.7	4.2	4.9	5.2	7.0%
Digital MOS	51.6	66.0	82.1	121.0	166.8	20.4%
Memory	21.4	26.8	32.1	44.5	58.6	17.0%
Microcomponent	12.9	17.4	22.3	31.3	41.4	18.9%
MOS Logic	17.3	21.8	27.7	45.2	66.8	25.1%
Standard (S/MSI)	8.9	9.7	10.7	13.0	15.5	9.9%
ASIC	8.4	12.2	17.1	32.2	51.4	33.4%
Analog	48.7	54.8	61.6	77.0	94.4	11.5%
Discrete	$ 25.8	$ 28.0	$ 30.1	$ 34.5	$ 39.2	7.0%
Optoelectronic	$ 2.8	$ 3.2	$ 3.5	$ 4.2	$ 4.9	8.8%

Source: Dataquest
October 1989

©1989 Dataquest Incorporated October

Table 15

Military/Aerospace IC Consumption by Specification North America 1988
(Millions of Dollars)

	JAN/QML	883/SMD	Custom* Space	Other Custom	Commercial	Total
IC	$180.8	$627.1	$202.6	$453.9	$101.4	$1,565.9
Digital Bipolar	81.8	179.9	89.9	36.8	20.4	408.8
Digital MOS	22.6	294.4	60.4	324.6	52.8	754.9
Analog	76.4	152.8	52.3	92.5	28.2	402.2

*Includes custom rad-hard/tolerant specification shipments

Source: Dataquest
October 1989

Table 16

Military/Aerospace IC Consumption by Specification North America 1992
(Millions of Dollars)

	JAN/QML	883/SMD	Custom* Space	Other Custom	Commercial	Total
IC	$235.4	$890.1	$299.3	$453.5	$152.5	$2,030.8
Digital Bipolar	80.0	153.3	56.6	26.7	16.7	333.2
Digital MOS	59.7	525.3	167.1	346.2	95.5	1,193.9
Analog	95.7	211.6	75.6	80.6	40.3	503.7

*Includes custom rad-hard/tolerant specification shipments

Source: Dataquest
October 1989

©1989 Dataquest Incorporated October

Semiconductor Markets—Forecast

OVERVIEW

Consumption of semiconductors in the military and aerospace industry is expected to be somewhat moderate, as overall electronic systems growth levels from a period of rapid growth in the early 1980s. However, like electronic system penetration of hardware, semiconductor usage will continue to be more pervasive within those electronic systems. The net result is that worldwide semiconductor consumption, as shown in Figure 1, is expected to rise from the 1988 level of $2.8 billion to $4.9 billion by 1994, reflecting a 9.6 percent compound annual growth rate (CAGR).

The military/aerospace semiconductor segment experienced slow growth in 1987, when prices collapsed in the standard logic and linear commodity areas and contract auditing in the United States slowed procurement. In 1988, the industry is witnessing a return to stability and is expected to grow by 9.3 percent worldwide, 7.4 percent in North America, and 14.6 percent in Western Europe. Western European growth in local currencies in 1988 is expected to be 6.9 percent. Worldwide growth is expected to be 9.3 percent in 1989, with 9.2 percent in North America, 9.0 percent in Western Europe, and 13.6 percent in Rest of World.

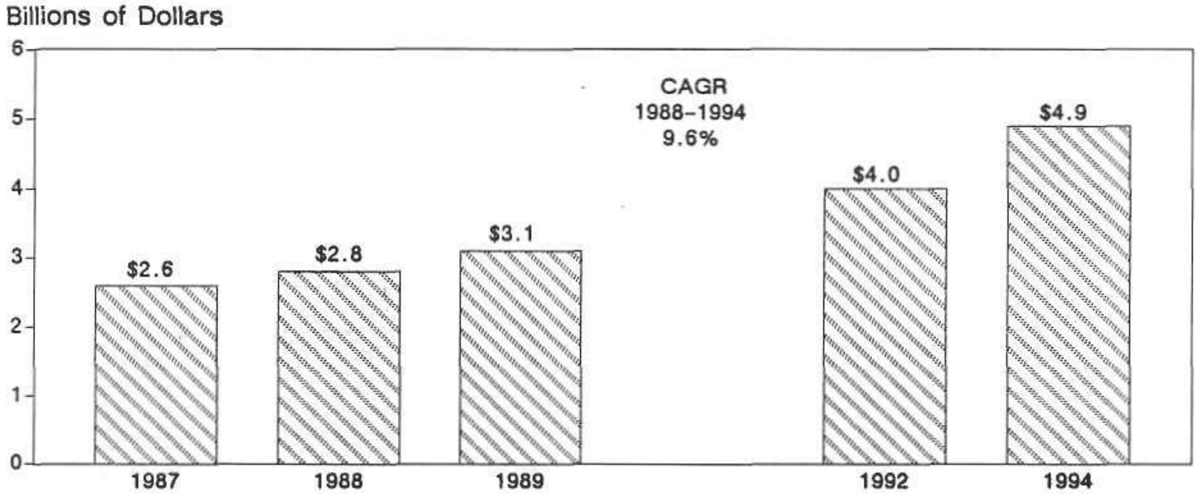
North America is expected to continue to dominate worldwide military/aerospace semiconductor usage through 1994, maintaining 71 percent of the total usage. Rest of World consumption is expected to rise from 5 to 6 percent, and Western European usage will decline from 24 to 23 percent (see Figure 2).

Tables 1 through 16 present the detailed semiconductor product forecast. Refer to the individual semiconductor product sections and the "System Semiconductor Utilization" section for forecast assumptions.

© 1988 Dataquest Incorporated August

Figure 1

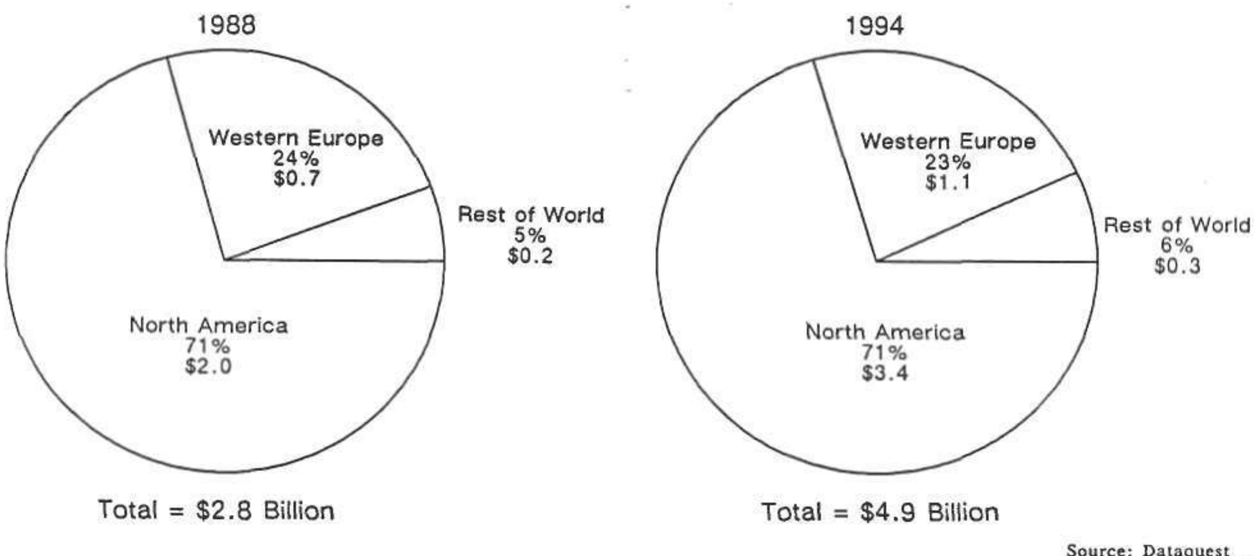
Estimated Worldwide Military/Aerospace Semiconductor Consumption



Source: Dataquest
August 1988

Figure 2

Estimated Geographic Military/Aerospace Semiconductor Consumption



Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Semiconductor Markets--Forecast

Table 1

Estimated Worldwide Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Total Semiconductor	$2,565.9	$2,806.6	$3,069.9	$4,019.5	$4,860.9	9.6%
IC	$2,094.4	$2,302.8	$2,536.9	$3,398.5	$4,160.8	10.4%
Bipolar Digital	672.1	680.2	691.8	764.7	822.6	3.2%
Memory	121.7	115.8	112.4	105.2	96.6	(3.0%)
Microcomponent	87.1	94.6	102.2	128.6	151.3	8.1%
Logic	463.2	469.8	477.3	530.8	574.8	3.4%
Standard (S/MSI*)	330.1	325.7	321.4	327.8	327.9	0.1%
ASIC	133.1	144.0	155.9	203.0	246.9	9.4%
MOS Digital	911.5	1,066.6	1,244.8	1,863.0	2,417.8	14.6%
Memory	302.9	346.7	399.1	593.0	750.6	13.7%
Microcomponent	225.0	266.9	315.8	506.7	699.8	17.4%
Logic	383.5	453.0	529.9	763.3	967.3	13.5%
Standard (S/MSI)	83.0	93.6	104.4	146.4	177.8	11.3%
ASIC	300.5	359.4	425.4	616.8	789.5	14.0%
Analog	510.8	555.9	600.3	770.9	920.4	8.8%
Discrete	$ 380.0	$ 406.2	$ 430.0	$ 498.6	$ 560.8	5.5%
Optoelectronic	$ 91.6	$ 97.6	$ 103.0	$ 122.3	$ 139.2	6.1%

*Small- and medium-scale integration standard logic.
Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 2

Estimated North American Military/Aerospace Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Total Semiconductor	$1,848.3	$1,985.7	$2,167.6	$2,842.6	$3,439.1	9.6%
IC	$1,532.9	$1,654.3	$1,815.3	$2,428.5	$2,967.7	10.2%
Bipolar Digital	501.0	496.7	504.1	552.7	590.2	2.9%
Memory	95.4	89.3	87.0	80.9	73.8	(3.1%)
Microcomponent	66.9	71.7	77.7	97.6	114.2	8.1%
Logic	338.7	335.7	339.4	374.3	402.3	3.1%
Standard (S/MSI)	236.8	228.5	223.9	225.2	221.0	(0.6%)
ASIC	101.9	107.2	115.4	149.1	181.3	9.2%
MOS Digital	656.3	754.0	878.3	1,317.9	1,712.1	14.6%
Memory	66.5	78.2	89.8	135.3	173.6	14.2%
Microcomponent	165.1	192.1	225.2	366.5	513.4	17.8%
Logic	275.2	317.7	373.6	538.7	680.8	13.5%
Standard (S/MSI)	54.2	61.0	70.3	99.4	118.5	11.7%
ASIC	221.0	256.8	303.3	439.3	562.3	14.0%
Analog	375.6	403.5	433.0	557.9	665.3	8.7%
Discrete	$ 245.9	$ 258.5	$ 275.8	$ 323.1	$ 368.4	6.1%
Optoelectronic	$ 69.5	$ 73.0	$ 76.5	$ 91.0	$ 103.0	5.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

 © 1988 Dataquest Incorporated August

Table 3

Estimated North American Military/Aerospace Logic Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Total Logic	$613.9	$653.4	$713.0	$912.8	$1,083.1	8.8%
Bipolar Logic	$338.7	$335.7	$339.4	$374.3	$ 402.3	3.1%
Standard (S/MSI)	236.8	228.5	223.9	225.2	221.0	(0.6%)
TTL	215.4	206.7	201.5	200.4	194.4	(1.0%)
LS	108.1	100.0	94.2	83.1	72.3	(5.3%)
FAST	48.8	50.5	52.9	66.4	74.2	6.6%
AS	7.2	7.1	7.0	6.7	6.5	(1.6%)
ALS	12.9	13.5	14.2	17.8	19.9	6.7%
S	13.0	11.9	10.8	8.0	6.5	(9.6%)
Standard	13.3	12.0	11.1	9.4	8.3	(6.0%)
Other	12.1	11.7	11.3	8.9	6.8	(8.6%)
ECL	15.6	16.2	17.1	20.3	22.5	5.6%
Other	5.8	5.6	5.3	4.5	4.1	(5.1%)
ASIC	101.9	107.2	115.4	149.1	181.3	9.2%
Gate Array	66.0	69.1	73.5	93.6	112.8	8.5%
ECL	47.8	53.3	60.1	85.0	106.5	12.2%
Other	18.2	15.8	13.4	8.5	6.3	(14.2%)
Cell-Based IC	1.5	1.9	2.6	7.4	13.0	37.8%
Programmable Logic	27.5	29.6	33.0	42.9	50.7	9.4%
Full-Custom	6.9	6.6	6.3	5.3	4.8	(5.2%)
MOS Logic	$275.2	$317.7	$373.6	$538.6	$ 680.7	13.5%
Standard (S/MSI)	54.2	61.0	70.3	99.4	118.5	11.7%
HC/HCT	22.7	23.1	23.4	23.4	21.5	(1.2%)
AC/ACT/FCT	5.6	10.9	18.0	37.3	51.1	29.4%
4000/54C	13.4	13.2	13.0	11.5	9.0	(6.2%)
BICMOS	0.1	0.3	0.7	3.9	6.7	69.4%
GaAs	2.6	3.6	5.1	10.8	16.4	28.7%
Other	9.8	9.9	10.2	12.4	13.8	5.7%

Note: Columns may not add to totals shown because of rounding.

(Continued)

© 1988 Dataquest Incorporated August

Table 3 (Continued)

Estimated North American Military/Aerospace Logic Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
ASIC	221.0	256.8	303.3	439.2	562.3	14.0%
Gate Array	160.8	182.2	209.7	288.6	354.1	11.7%
CMOS	160.4	180.5	202.3	269.0	325.2	10.3%
BICMOS	0.4	1.7	7.4	19.6	29.0	60.4%
Cell-Based	28.9	36.0	44.8	77.9	106.9	19.9%
Programmable Logic	7.2	10.0	13.4	23.7	33.5	22.2%
Full-Custom	18.9	18.9	19.2	20.5	21.6	2.2%
GaAs	5.2	9.7	16.2	28.5	46.2	29.7%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 4

Estimated North American Military/Aerospace Microcomponent Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Total Microcomponent	$232.0	$263.7	$302.9	$464.0	$627.5	15.5%
Bipolar Microcomponent	$ 66.9	$ 71.7	$ 77.7	$ 97.6	$114.2	8.1%
MPU/Bit-Slice	50.5	53.9	57.9	71.4	82.8	7.4%
Peripheral	16.4	17.7	19.8	26.1	31.4	10.0%
MOS Microcomponent	$165.1	$192.1	$225.2	$366.5	$513.4	17.8%
MPU	22.4	25.3	29.1	46.2	60.8	15.7%
8-Bit	5.5	5.5	5.6	5.6	5.4	(0.3%)
16-Bit	13.5	14.6	16.7	27.1	35.1	15.7%
32-Bit	3.4	5.2	6.8	13.5	20.4	25.6%
MCU	20.5	23.4	27.0	37.9	47.7	12.6%
4-Bit	1.9	1.9	2.0	2.0	2.0	0.9%
8-Bit	17.5	19.3	21.3	28.0	33.3	9.5%
16-Bit	1.1	2.1	3.7	7.9	12.4	33.9%
DSP MPU	22.4	29.9	38.2	81.7	133.2	28.3%
MPR	97.9	110.3	125.5	186.7	249.7	14.6%
System Support	57.3	61.5	66.8	95.1	122.5	12.2%
Communication	21.0	24.5	28.2	38.6	47.9	11.8%
Graphics	1.2	2.5	4.9	9.5	13.7	32.8%
Other	18.4	21.8	25.6	43.5	65.6	20.1%
GaAs	1.9	3.2	5.3	14.0	22.0	37.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 5

Estimated North American Military/Aerospace Memory Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Total Memory	$311.4	$333.6	$366.5	$493.6	$591.8	10.0%
Bipolar Memory	$ 95.4	$ 89.3	$ 87.0	$ 80.9	$ 73.8	(3.1%)
RAM	26.8	24.3	22.6	19.7	17.3	(5.5%)
TTL	22.2	19.6	17.8	14.1	11.1	(9.0%)
ECL	4.6	4.7	4.8	5.6	6.2	4.6%
PROM/ROM	56.6	53.0	52.6	50.8	46.7	(2.1%)
Other	12.0	12.0	11.8	10.4	9.7	(3.4%)
MOS Memory	$216.0	$244.2	$279.5	$412.7	$518.0	13.4%
DRAM	24.5	27.1	31.1	47.5	62.2	14.8%
SRAM	74.1	83.7	95.5	142.7	172.3	12.8%
EPROM	58.0	62.8	68.2	87.6	102.9	8.6%
ROM/PROM	16.5	18.5	20.6	27.5	33.2	10.2%
EE/Nonvolatile	18.5	22.0	26.7	44.7	60.6	18.4%
FIFO	14.0	15.8	18.2	24.5	29.6	11.0%
GaAs	2.9	5.0	8.4	23.1	37.1	39.5%
Other	7.5	9.3	10.8	15.2	20.1	13.7%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 6

Estimated North American Military/Aerospace Analog/Discretes/Optoelectronics Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Analog	$375.6	$403.5	$433.0	$557.9	$665.3	8.7%
Amplifier	81.7	82.5	83.3	94.1	102.0	3.6%
Comparator	28.2	28.5	28.8	32.8	35.2	3.6%
Voltage Reg./Ref.	25.4	25.7	26.3	29.7	32.8	4.1%
Interface	66.4	68.8	71.1	83.4	94.3	5.4%
Data Conversion	78.2	83.3	89.1	114.1	132.7	8.1%
Intelligent Power	19.5	25.8	32.8	59.4	87.2	22.5%
GaAs	31.9	43.4	55.2	95.5	129.7	20.0%
Other	44.3	45.6	46.4	48.9	51.5	2.0%
Discrete	$245.9	$258.5	$275.8	$323.1	$368.4	6.1%
Sm.-Sig. Diode	34.7	35.4	36.3	40.0	42.5	3.1%
Sm.-Sig. Transistor	61.2	61.8	63.3	67.5	70.2	2.2%
Rectifier	39.8	42.3	44.2	51.1	58.4	5.5%
Power MOSFET	24.7	31.5	40.4	63.1	86.3	18.3%
Power Bipolar Trans.	39.9	37.0	36.5	32.4	30.8	(3.0%)
GaAs	34.4	39.4	43.8	56.6	67.3	9.4%
Other	11.2	11.2	11.3	12.2	12.9	2.4%
Optoelectronic	$ 69.5	$ 73.0	$ 76.5	$ 91.0	$103.0	5.9%
LED Lamp/Display	18.0	18.5	19.0	20.7	22.1	3.0%
Coupler/Isolator/ Interruptor	16.0	16.7	17.4	19.5	21.8	4.5%
Emitter/Detector/Other	35.5	37.8	40.1	50.8	59.1	7.7%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 7

Estimated North American Military/AerospaceConsumption
GaAs Recap
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
GaAs	$138.5	$168.0	$202.2	$312.5	$413.7	16.2%
Standard Logic	2.6	3.6	5.1	10.8	16.4	28.7%
ASIC	5.2	9.7	16.2	28.5	46.2	29.7%
Microdevice	1.9	3.2	5.3	14.0	22.0	37.9%
Memory	2.9	5.0	8.4	23.1	37.1	39.5%
Linear	31.9	43.4	55.2	95.5	129.7	20.0%
Discrete	34.4	39.4	43.8	56.6	67.3	9.4%
Optoelectronic	59.5	63.7	68.2	84.0	95.0	6.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

Table 8

Estimated North American Military/Aerospace Semiconductor Consumption
Digital Signal Processing (DSP) Recap
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
DSP	$100.6	$124.0	$149.4	$252.9	$359.8	19.4%
DSP MPUs	22.4	29.9	38.5	84.3	139.6	29.3%
Microprogrammable	41.0	45.9	51.0	66.7	76.4	8.9%
ASICs	26.8	35.2	43.4	76.5	114.0	21.7%
Special-Function	10.5	13.1	16.5	25.5	29.8	14.7%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 9

Estimated Western European Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Total Semiconductor	$579.9	$664.7	$724.8	$930.6	$1,112.9	9.0%
IC	$447.8	$518.5	$572.7	$759.6	$ 926.0	10.1%
Bipolar Digital	135.3	144.8	146.0	160.6	172.2	2.9%
Memory	19.5	19.8	18.8	18.1	16.9	(2.6%)
Microcomponent	16.5	18.8	19.9	25.0	29.7	7.9%
Logic	99.3	106.1	107.3	117.4	125.6	2.9%
Standard (S/MSI)	71.3	73.1	71.3	70.6	69.4	(0.9%)
ASIC	28.1	33.0	36.0	46.8	56.3	9.3%
MOS Digital	208.5	256.5	298.4	437.8	560.6	13.9%
Memory	216.0	244.2	279.5	412.7	518.0	13.4%
Microcomponent	52.1	65.1	78.8	121.3	160.4	16.2%
Logic	89.9	113.1	129.9	181.2	226.5	12.3%
Standard (S/MSI)	16.4	18.5	18.1	24.0	30.7	8.8%
ASIC	73.5	94.6	111.8	157.2	195.8	12.9%
Analog	103.9	117.3	128.3	161.2	193.2	8.7%
Discrete	$113.4	$125.3	$129.9	$145.0	$ 157.0	3.8%
Optoelectronic	$ 18.8	$ 20.9	$ 22.2	$ 26.0	$ 30.0	6.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 10

Estimated Western European Military/Aerospace Logic Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Total Logic	$189.2	$219.3	$237.2	$298.7	$352.2	8.2%
Bipolar Logic	$ 99.3	$106.1	$107.3	$117.4	$125.6	2.9%
Standard (S/MSI)	71.3	73.1	71.3	70.6	69.4	(0.9%)
TTL	65.2	66.5	64.4	63.1	61.1	(1.4%)
LS	32.2	31.2	28.7	22.8	18.4	(8.5%)
FAST	15.6	17.3	18.1	22.9	25.4	6.7%
AS	2.3	2.4	2.3	2.0	1.9	(3.6%)
ALS	5.0	5.6	6.0	7.7	8.7	7.5%
S	3.9	3.8	3.5	2.6	2.3	(8.3%)
Standard	4.3	4.3	3.9	3.2	2.7	(7.2%)
Other	1.9	1.9	1.9	1.8	1.7	(2.2%)
ECL	4.4	4.8	5.2	6.2	7.2	7.1%
Other	1.7	1.8	1.7	1.3	1.1	(8.2%)
ASIC	28.1	33.0	36.0	46.8	56.3	9.3%
Gate Array	18.2	20.6	21.8	27.5	32.8	8.0%
ECL	12.4	14.5	16.0	22.3	27.9	11.5%
Other	5.9	6.1	5.8	5.2	4.9	(3.6%)
Cell-Based IC	1.0	2.1	3.2	6.2	8.6	26.0%
Programmable Logic	6.8	8.2	9.0	11.4	13.5	8.7%
Full-Custom	2.0	2.0	1.9	1.7	1.4	(5.6%)
MOS Logic	$ 89.9	$113.2	$130.0	$181.3	$226.6	12.3%
Standard (S/MSI)	16.4	18.5	18.1	24.0	30.7	8.8%
HC/HCT	7.0	7.5	8.0	8.7	9.1	3.2%
AC/ACT/FCT	0.9	1.5	2.1	5.1	9.4	35.2%
4000/54C	4.2	4.5	3.5	3.3	3.2	(5.3%)
BICMOS	0	0	0.1	0.2	0.4	63.2%
GaAs	0.9	1.3	1.5	3.1	4.7	23.4%
Other	3.4	3.7	2.9	3.5	3.9	1.3%

Note: Columns may not add to totals shown because of rounding.

(Continued)

 © 1988 Dataquest Incorporated August

Table 10 (Continued)

Estimated Western European Military/Aerospace Logic Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
ASIC	73.5	94.6	111.9	157.2	195.9	12.9%
Gate Array	53.6	67.1	77.6	105.7	126.9	11.2%
CMOS	53.4	66.5	75.0	100.6	119.5	10.3%
BICMOS	0.1	0.6	2.6	5.1	7.4	52.1%
Cell-Based	9.0	12.5	15.5	23.9	31.4	16.7%
Programmable Logic	3.0	5.2	7.4	11.1	14.5	18.6%
Full-Custom	6.1	6.6	6.6	7.1	7.4	1.8%
GaAs	1.8	3.2	4.8	9.4	15.6	30.1%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 11

Estimated Western European Military/Aerospace Microcomponent Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Total Microcomponent	$68.7	$84.0	$98.7	$146.4	$190.1	14.6%
Bipolar Microcomponent	$16.5	$18.8	$19.9	$ 25.0	$ 29.7	7.9%
MPU/Bit-Slice	12.5	14.2	15.0	18.7	22.1	7.6%
Peripheral	4.1	4.6	4.9	6.3	7.6	8.6%
MOS Microcomponent	$52.1	$65.1	$78.8	$121.3	$160.4	16.2%
MPU	6.9	8.7	11.9	18.5	24.7	18.9%
8-Bit	1.9	1.8	1.8	1.7	1.5	(3.0%)
16-Bit	4.6	5.6	6.5	10.1	13.4	15.6%
32-Bit	0.4	1.3	3.6	6.7	9.8	40.0%
MCU	6.4	7.7	8.9	12.2	15.3	12.1%
4-Bit	0.6	0.6	0.6	0.5	0.5	(3.4%)
8-Bit	5.5	6.5	7.1	9.0	10.5	8.3%
16-Bit	0.3	0.6	1.2	2.7	4.3	38.8%
DSP MPU	5.5	8.0	10.1	16.3	22.5	18.8%
MPR	32.9	39.8	46.5	70.8	92.7	15.1%
System Support	17.9	20.3	23.0	34.1	44.3	13.9%
Communication	8.0	9.5	10.7	14.7	18.7	11.9%
Graphics	0.4	0.9	1.5	4.3	5.8	36.0%
Other	6.5	9.1	11.2	17.7	23.8	17.5%
GaAs	0.5	0.8	1.4	3.5	5.2	35.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 12

Estimated Western European Military/Aerospace Memory Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Total Memory	$86.0	$98.0	$108.5	$153.4	$190.5	11.7%
Bipolar Memory	$19.5	$19.8	$ 18.8	$ 18.1	$ 16.9	(2.6%)
RAM	8.0	8.1	7.7	7.6	7.4	(1.5%)
TTL	7.0	7.0	6.6	6.3	5.9	(2.9%)
ECL	1.0	1.1	1.1	1.3	1.5	5.7%
PROM/ROM	8.4	8.6	8.1	7.8	6.9	(3.4%)
Other	3.0	3.1	3.0	2.8	2.6	(3.2%)
MOS Memory	$66.5	$78.2	$ 89.8	$135.3	$173.6	14.2%
DRAM	8.4	9.7	11.3	16.9	22.2	14.8%
SRAM	22.7	26.7	30.6	47.5	62.2	15.1%
EPROM	17.3	19.4	21.4	28.3	33.3	9.4%
ROM/PROM	4.7	5.2	5.7	7.8	9.1	9.8%
EE/Nonvolatile	6.1	7.9	9.6	15.6	20.6	17.4%
FIFO	4.4	5.2	5.8	8.6	10.8	12.8%
GaAs	0.8	1.4	2.4	6.6	10.6	39.5%
Other	2.2	2.6	2.9	4.0	4.8	10.5%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 13

Estimated Western European Military/Aerospace Analog/Discretes/Optoelectronics Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Analog	$103.9	$117.3	$128.3	$161.2	$193.2	8.7%
Amplifier	25.3	26.3	27.5	29.6	31.5	3.0%
Comparator	9.4	9.9	10.3	10.8	11.5	2.6%
Voltage Reg./Ref.	6.6	7.0	7.3	7.7	8.1	2.5%
Interface	18.9	21.2	22.9	28.0	32.8	7.6%
Data Conversion	21.7	24.9	27.3	33.4	39.8	8.1%
Intelligent Power	4.8	7.0	9.0	17.8	26.1	24.5%
GaAs	7.3	10.2	12.9	22.6	31.3	20.6%
Other	10.0	10.9	11.1	11.3	12.1	1.8%
Discrete	$113.4	$125.3	$129.9	$145.0	$157.0	3.8%
Sm.-Sig. Diode	17.7	19.3	19.9	22.0	23.7	3.5%
Sm.-Sig. Transistor	31.6	34.4	35.3	37.4	38.9	2.0%
Rectifier	18.7	20.7	21.4	24.1	26.3	4.0%
Power MOSFET	5.2	6.3	7.2	10.6	13.7	13.8%
Power Bipolar Trans.	24.1	25.6	25.6	25.5	25.1	(0.3%)
GaAs	11.2	13.5	15.0	19.4	23.1	9.3%
Other	5.0	5.4	5.5	5.9	6.2	2.3%
Optoelectronic	$ 18.8	$ 20.9	$ 22.2	$ 26.0	$ 30.0	6.2%
LED Lamp/Display	4.9	5.3	5.4	5.9	6.3	3.0%
Coupler/Isolator/ Interruptor	4.3	4.8	5.0	5.6	6.2	4.5%
Emitter/Detector/Other	9.6	10.8	11.8	14.5	17.4	8.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 14

Estimated Western European Military/Aerospace Semiconductor Consumption
GaAs Recap
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
GaAs	$38.6	$48.7	$57.3	$87.6	$116.5	15.7%
Standard Logic	0.9	1.3	1.5	3.1	4.7	23.4%
ASIC	1.8	3.2	4.8	9.4	15.6	30.1%
Microdevice	0.5	0.8	1.4	3.5	5.2	35.3%
Memory	0.8	1.4	2.4	6.6	10.6	39.5%
Linear	7.3	10.2	12.9	22.6	31.3	20.6%
Discrete	11.2	13.5	15.0	19.4	23.1	9.3%
Optoelectronic	16.1	18.2	19.3	22.9	26.1	6.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

Table 15

Estimated Western European Military/Aerospace Semiconductor Consumption
Digital Signal Processing (DSP) Recap
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
DSP	$25.7	$33.2	$39.7	$61.3	$81.1	16.1%
DSP MPUs	5.5	8.0	10.1	16.8	23.8	20.0%
Microprogrammable	10.1	11.5	12.5	15.3	16.4	6.1%
ASICs	7.2	10.1	12.5	22.5	31.9	21.1%
Special-Function	2.8	3.6	4.7	6.8	9.2	16.6%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 16

Estimated Rest of World Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Total Semiconductor	$137.6	$156.1	$177.4	$246.4	$308.8	12.0%
IC	$113.7	$129.9	$148.8	$210.5	$267.1	12.8%
Bipolar Digital	35.8	38.8	41.8	51.4	60.1	7.6%
Memory	6.9	6.7	6.6	6.2	5.9	(2.2%)
Microcomponent	3.7	4.1	4.5	6.0	7.4	10.3%
Logic	25.2	27.9	30.7	39.2	46.8	9.0%
Standard (S/MSI)	22.1	24.1	26.2	32.1	37.5	7.7%
ASIC	3.2	3.8	4.5	7.1	9.3	15.9%
MOS Digital	46.7	56.1	68.0	107.4	145.0	17.2%
Memory	20.4	24.2	29.9	45.1	59.0	16.0%
Microcomponent	7.8	9.7	11.8	18.9	26.0	17.8%
Logic	18.4	22.1	26.3	43.4	60.0	18.1%
Standard (S/MSI)	12.5	14.1	16.0	23.0	28.6	12.5%
ASIC	6.0	8.0	10.3	20.4	31.4	25.6%
Analog	31.2	35.1	39.0	51.8	61.9	9.9%
Discrete	$ 20.7	$ 22.5	$ 24.4	$ 30.5	$ 35.5	7.9%
Optoelectronic	$ 3.3	$ 3.7	$ 4.2	$ 5.3	$ 6.3	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Standard Logic

OVERVIEW

Dataquest defines standard logic as a semiconductor logic device that is of typically less than 500 gates and is available in industry-standard functions. Standard logic devices typically are grouped into families of like electrical characteristics following the 54XXX catalog definitions.

The use of standard logic in military systems is very broad, as it is found in almost every type of equipment. Older system architectures use 50 to 60 percent of their standard logic for control and glue logic and the remainder for bus interface. Newer system designs are using application-specific integrated circuits (ASICs) for control and glue logic functions, with 70 percent or more of the standard logic being used for local and backplane bus applications.

In general, the most significant trend is a decline in use of bipolar transistor-transistor logic (TTL) logic as it is displaced by ASICs and advanced CMOS logic. The desire to reduce board space, power consumption, and, most recently, obsolescence problems has become paramount in avionic and electronic warfare systems. New and upgraded systems are using ASIC solutions and advanced standard logic families.

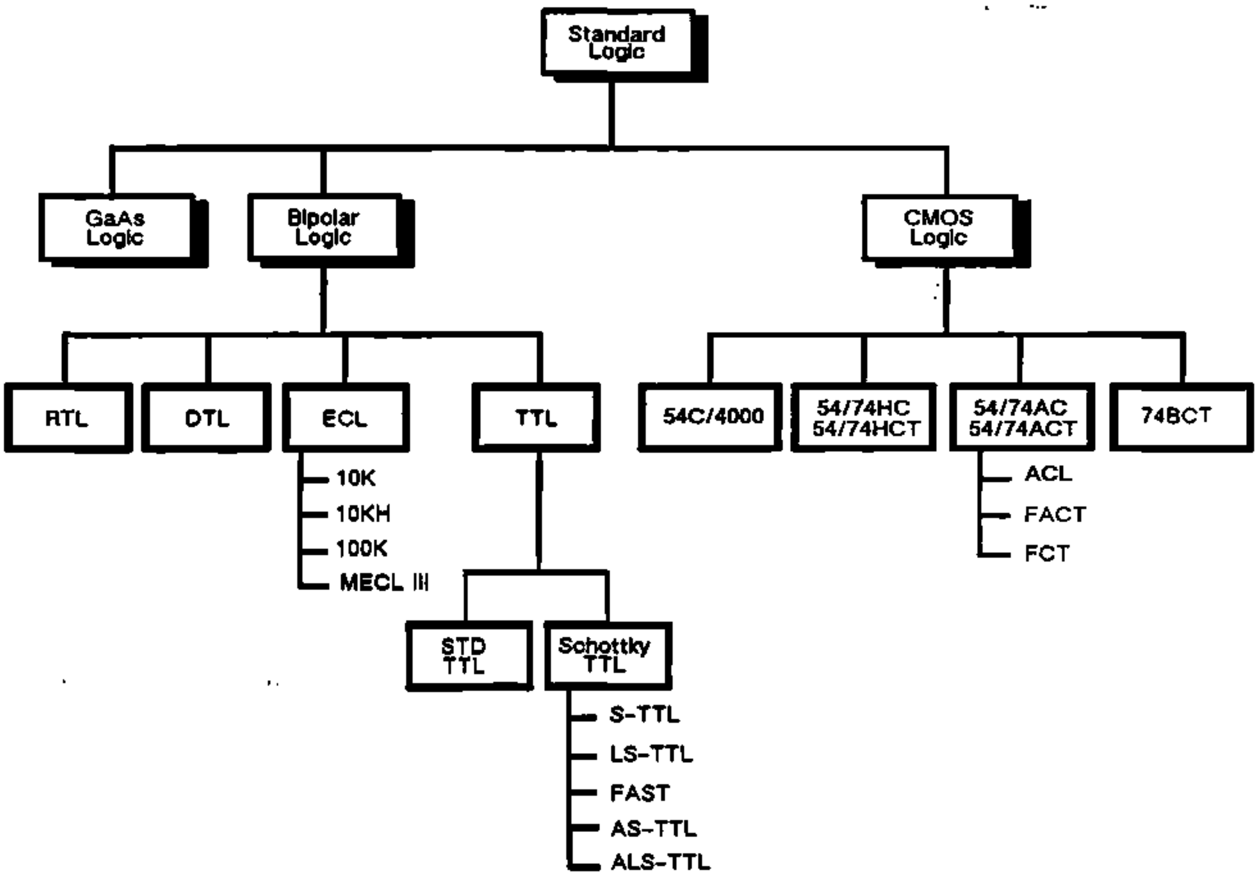
PRODUCT AND TECHNOLOGY TRENDS

Figure 1 illustrates the standard logic family tree. Figure 2 presents a comparison of selected standard logic technologies and the application performance ranges they most commonly serve.

©1990 Dataquest Incorporated February

Figure 1

Standard Logic Family Tree

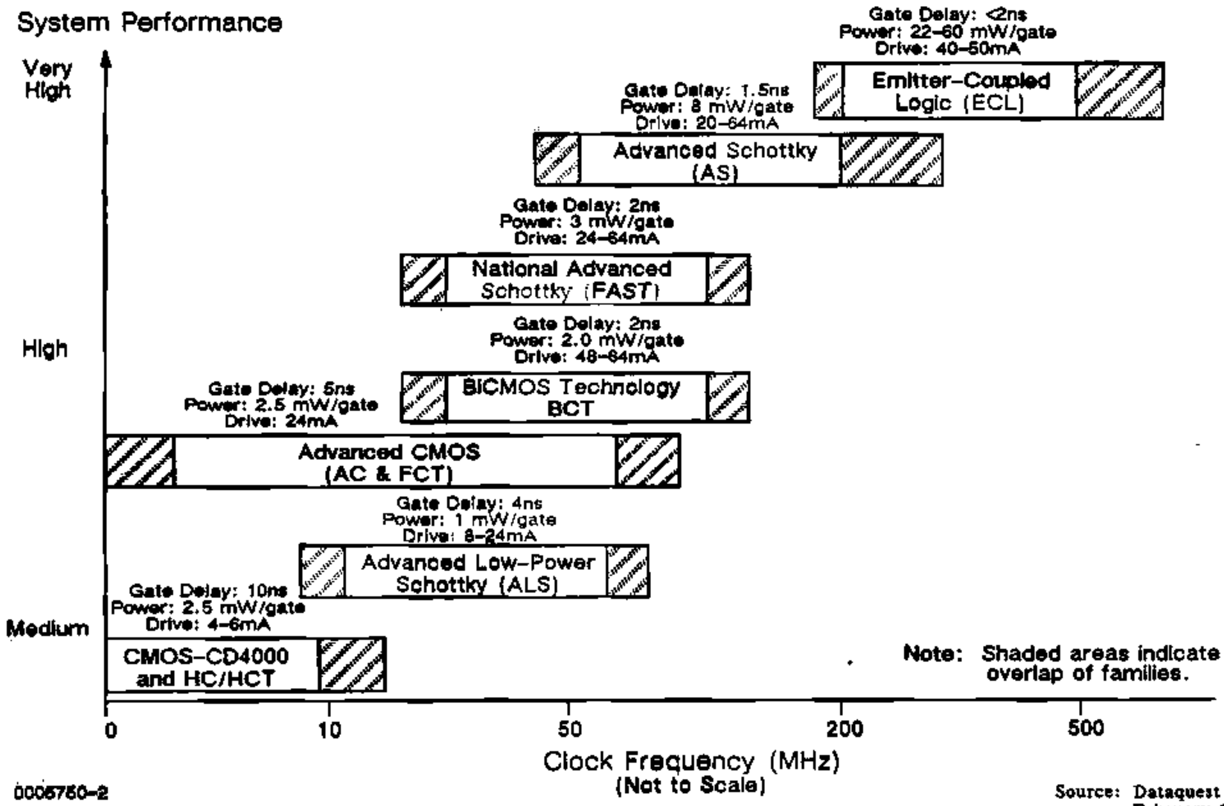


0005750-1

Source: Dataquest
February 1990

Figure 2

Standard Logic Components
Spectrum of Use Based on System Performance and Frequency



0005750-2

Source: Dataquest
February 1990

BIPOLAR TTL

For the last 10 years, low-power Schottky (LS) has been the dominant TTL logic family for military and commercial applications. Now, however, it is being displaced rapidly by ASICs and newer logic families that have most of LS's benefits along with faster switching times. In higher-performance systems, the Fairchild Advanced Schottky TTL (FAST) family has found wide design-in acceptance and has become the second most commonly used family for military applications. Advanced low-power Schottky (ALS) has found good acceptance in medium-performance applications where power is a more critical factor. Schottky and the 54XX standard families continue to be designed out slowly.

In response to the requirements of MIL-M-38510 for electrostatic discharge (ESD) marking, some manufacturers are modifying their product lines to withstand at least 4,000 volts. Much of the investment regarding ESD redesign appears to be going toward the FAST family.

©1990 Dataquest Incorporated February

CMOS TTL

Introduced commercially in 1985 and 1986, the new advanced CMOS products are beginning to be qualified to 883, SMD, and JAN specifications. These products provide the speed of the midrange bipolar offerings but at a fraction of the gate power.

The advanced CMOS (AC/ACT) product lines offer 24mA output drive current, and the FCT line offers 48mA. The ACL family from Texas Instruments and Philips-Signetics offers an alternate to the traditional JEDEC end-pin pin-out scheme as a solution to switching noise found with high-performance logic. National Semiconductor recently announced a redesigned version of the FACT family called QS, or Quiet Series, as a solution to the noise problem.

The HC/HCT family, like LS, is being replaced by ASICs and advanced CMOS families in many new system designs. The 54C/4000 metal-gate logic, although mostly yielding to silicon-gate alternatives, has found continued use because of its rad-hard properties.

BiCMOS

Commercially introduced by Texas Instruments and Toshiba in 1987, this technology offers advanced bipolar propagation delays and 64mA output drive capability at an estimated 60 percent power savings. BiCMOS has been primarily targeted at backplane bus applications. Texas Instruments has also introduced a version of BiCMOS octal that incorporates the Joint Test Action Group (JTAG) standard scan test capability. These JTAG (aka IEEE 1149.1) octals are designed to be incorporated into JTAG board designs along with ASICs.

Advanced ECL

A sub-500ps bipolar logic is emerging from several companies. In general, these bipolar logic families represent a new generation of ECL standard logic that will displace the older families with substantial reductions in power consumption and increased switching speeds. The Motorola ECLinPS line is an example of one of the new families available in MIL-STD-883 versions. The principal uses of ECL standard logic are as complements to ASIC implementations and as building blocks in DSP or bit-slice applications.

Gallium Arsenide (GaAs)

Used initially in high-performance computing, GaAs standard logic is finding its way into military and aerospace applications. GaAs is well suited for applications requiring sub-200ps switching. It is principally available as a catalog replacement for ECL 100K I/O logic and as multiplexers, counters, and dividers for applications with high data rates. Selected mil-spec versions are available.

OBSOLESCENCE OR DIMINISHING MANUFACTURING SOURCES (DMS)

Perhaps the major issue facing military consumers of standard logic is the continued deterioration of availability of the older bipolar families such as DTL, HTTL, LTTL, standard gold-doped TTL, and Schottky TTL, as well as early CMOS families such as 4000 and 54C. The situation has been worsened by eroding profitability of the these product families as the commercial and military markets turn to ASICs and newer logic families. In particular, the JAN market for these components has been unprofitable, as pricing has remained low relative to costs.

The problem is further compounded as military equipment (e.g., F-14 fighters) life cycles remain long—typically 15 years or more—while commercial equipment (e.g., workstations) life cycles get shorter—less than five years. Because military/aerospace semiconductor end use represents only 10 percent of the U.S. merchant market, events in the commercial market typically drive product support decisions. This fact is part of an overall problem in the U.S. Department of Defense known as Diminishing Manufacturing Sources (DMS).

For a thorough discussion of logic obsolescence, turn to the "Semiconductor Procurement" section of this binder. In many situations, last-time buys have been announced and many of the families have only a partial catalog available. The emergence of various aftermarket suppliers that buy equipment and masks from the initial manufacturers has helped alleviate the problem.

SUPPLIERS

The principal suppliers of standard logic for the military temperature range or to military specifications are listed in Table 1. Harris Semiconductor, National Semiconductor, Motorola, Philips-Signetics, and Texas Instruments are the dominant suppliers of family standard logic to this market. IDT, with its FCT family, has become a leading supplier of advanced CMOS logic. Many suppliers offer a limited product line (most often bus interface octals) to round out their product lines. Suppliers such as Lansdale and Teledyne MIL are part of a growing list of aftermarket suppliers that address the DMS problem. Distributors such as Rochester Electronics inventory discontinued products (finished wafers and die) from companies such as National and Texas Instruments.

©1990 Dataquest Incorporated February

Table 1

Principal Military Specification Standard Logic Suppliers

	Bipolar	CMOS	GaAs	BiCMOS
AMD	I/F, S, LS	AC/ACT, I/F		
Analog Devices	I/F			
Circuit Technology		HC/HCT		
Gigabit			X	
Harris	I/F	HC/HCT, AC/ACT, 4000		
Hughes	I/F			
IDT		FCT		
Lansdale	STD, H, DTL			
Logic Devices		I/F		
Matra-Harris		HC/HCT		
Marconi		HC/HCT, I/F		
Micrel		4000		
Motorola	LS, ALS, F, 10K 10KH, MECL III ECLinPS	HC/HCT, FACT 14XXX		
National	STD, L, S, LS, ALS, AS, F, 100K, DTL	54C, FACT, HC/HCT FCT		
Performance		PCT		
Philips-Signetics	STD, S, LS, F	AC/ACT		
Plessey	I/F	I/F, dividers		
Raytheon	I/F			
SGS-Thomson	LS	4000, HC/HCT		
Sprague		4000		
Supertex		HC/HCT		
Teledyne	10K	AC/ACT		
Texas Instruments	STD, S, LS, ALS, AS, F	HC/HCT, AC/ACT		BCT
TriQuint			I/F	
Universal		HC/HCT		
VTC		AC/ACT, FCT		

AC/ACT = Advanced CMOS
ALS = Advanced Low-Power Schottky
AS = Advanced Schottky
F = FAST
LS = Low-Power Schottky
S = Schottky
STD = 54XX
I/F = Bus Interface

Source: Dataquest
February 1990

©1990 Dataquest Incorporated February

ASICs

OVERVIEW

Application-specific integrated circuits (ASICs) are defined as including user-customizable gate and analog arrays, programmable logic devices (PLDs), and cell-based ICs (CBICs); fully hand-crafted designs; and mixtures of these elements.

Although ASICs initially were slow to catch on, designers of military and aerospace systems now are finding great benefit using ASICs. The custom nature of ASICs is very similar to the custom nature of most military and aerospace programs. User advantages of ASICs include the following:

- System size reduction
- System performance improvement
- System reliability improvement
- System-sensitive technology protection
- System development time reduction
- System cost reduction
- Design documentation

Both strategic and tactical systems are enjoying the benefits of ASICs. Tactical systems such as missile guidance and avionics absolutely require the ASIC benefits of high integration and power reduction. Strategic computer and communication systems are utilizing ASICs for reasons not very different from their cousin commercial systems.

The major obstacle to using ASICs so far has been a procurement system that is oriented toward cost-justified, multisourced, standard semiconductor products. However, as concepts such as the Qualified Manufacturer List (QML), which addresses built-in instead of tested-in quality and reliability, become reality, a major barrier to using ASICs will be lowered.

ENABLING TECHNOLOGY

The trend toward higher-complexity, higher-performance, and mixed-signal ASICs has caused suppliers to focus on the fields of computer-aided design, testing, and packaging.

Computer-Aided Design (CAD)

Background

ASIC CAD can be broken into two major categories: electronic computer-aided engineering (ECAE) and IC layout. ECAE addresses the following front-end functions of creating an ASIC:

- Logic/circuit design automation
- Design entry
- Simulation

©1990 Dataquest Incorporated February

- Electrical rule checking
- Test

The principal output of the ECAE phase of design is a logical or functional netlist and frequently also test patterns, bonding diagrams, and design documentation.

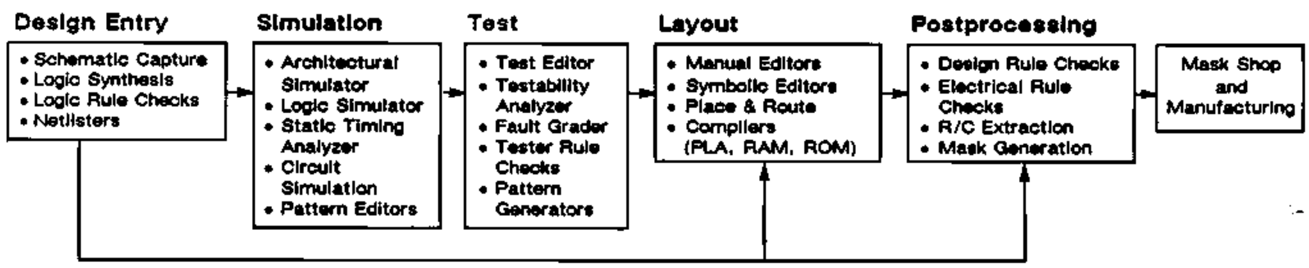
The IC layout takes the overall logical or physical design information and creates the database for physically manufacturing the IC. IC layout includes the following functions:

- Place and route
- Layout verification
- Manual polygon creation and editing

Figures 1 and 2 depict the design-to-manufacturing flow outlining the typical categories of tools and software files, respectively.

Figure 1

Design Environments—Tools

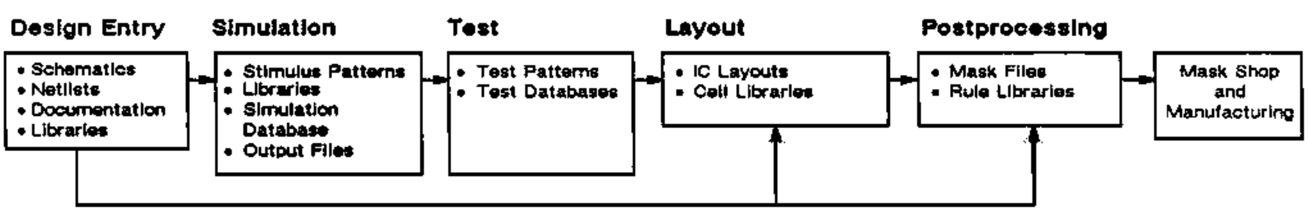


0006204-1

Source: Dataquest
February 1990

Figure 2

Design Environments—Software Files



0006204-2

Source: Dataquest
February 1990

©1990 Dataquest Incorporated February

CAD Technology Trends

The largest companies in overall electronic design automation are Mentor Graphics and Cadence, followed by Daisy/Cadnetix and Valid Logic Systems. The most notable trend for these companies is embodied in the success Cadence has had marketing its Framework product. Portable to industry standard workstations, the Framework product provides value with a common, integrated user interface and database shared by many application tools. The Framework definition has a chance to become an industry software interface standard.

Perhaps the major stumbling block to date for ECAE is analog and mixed-mode simulation and layout. Table 1 lists representative analog mixed-signal design tool vendors. Analog simulation generally is done with a variety of the SPICE simulation language. Once a few hundred transistors are exceeded in the design, however, the SPICE simulation becomes very compute intensive; then accelerators and even high-speed computers are needed.

The problem with mixed-mode simulation has been that the analog and digital portions are typically done separately and then "glued" together. The Analogy Saber product and the SCS Lsim product are examples of simulators that handle feedback between the digital and analog portions of a design. Because layout and routing of analog and mixed-signal ASICs remains a semiautomated process, most ASIC vendors in this area provide this service. Standard automation of the physical design still appears to be a few years off.

Another new area of CAD tools is represented by those that fall under the heading of logic design automation. These products are employed before schematic capture and address specification and architectural analysis, technology selection and instantiation, and logic optimization and minimization. Altera, Data I/O, Futurenet, SCS, Silc, Synopsis, Trimeter, and Xilinx are some of the companies offering this type of product.

Table 1

Analog Mixed-Signal Design Tools by Vendor

Company	Design Entry	Simulation	Layout	Verification
Analogy		X		
Cadence	X	X	X	X
Daisy/Cadnetix	X	X	X	
EEsof	X	X	X	
EES		X		
Intergraph	X	X	X	X
Intusoft	X	X		
Mentor	X	X	X	X
Meta-Software		X		
MicroSim		X		
SCS	X	X	X	X
Valid Logic	X	X	X	X
Viewlogic	X	X	X	X

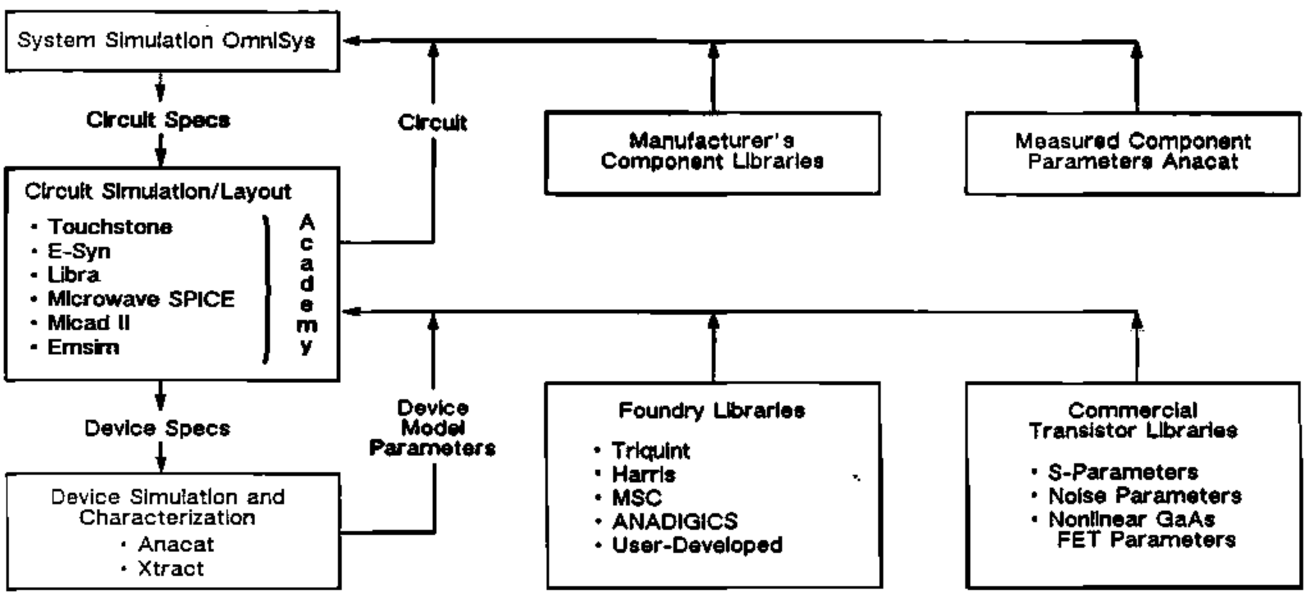
Source: *ASIC Technology and News*

MMIC-based CAD tools are receiving a boost from the MIMIC program as the various contractor teams develop design libraries on the brassboard demonstration project. The principal problem to date has been achieving acceptable first-pass designs. Figure 3 shows a microwave design system from one CAD vendor, EEsof. Because of idiosyncrasies of high-frequency board partitioning and layout, microwave IC CAD must include system-level simulation. Table 2 shows an example microwave cell library from Pacific Monolithics, one of the few but growing number of merchant libraries.

Seattle Silicon has announced a line of GaAs ASIC design and simulation tools as part of its relationship with Gigabit Logic.

Figure 3

EEsof's Hierarchical Microwave Design System



0006204-3

Source: Microwave Journal

Table 2

Pacific Monolithic's Cell Library

Existing Function	Frequency (GHz)	In Development Function	Frequency (GHz)
Amplifier Gain Blocks:		Amplifiers:	
10dB	2 to 6	SS amp, 10 dB	6 to 18
15dB	0.1 to 2	SS amp, 10 dB	6 to 12
15dB	1 to 3	LNA, 12dB	11 to 14
AGC amp, 10dB	2 to 6	Power amp, 10dB	6 to 18
		Power amp, 10dB	6 to 12
Oscillators (VCOs, DROs):		AGC amp, 10dB	6 to 18
Neg. resistance	1 to 3		
Neg. resistance	3 to 6	Mixers:	
		Balanced-Diode	6 to 10
Double-Balanced Mixers:		Balanced-Diode	10 to 18
Diode Mixer	1 to 3	Dual-Gate	2 to 6
Diode Mixer	3 to 6	High-Dynamic Range	6 to 10
Diode Mixer	6 to 8		
		Oscillators:	
Attenuator	DC-12	Neg. resistance	6 to 12
		Neg. resistance	12 to 18
FET SPDT switch	DC-12		
		Subsystems:	
Low-Noise Amplifiers		Freq. Downconv.	10 to 14
FET LNA, 16dB	3.7 to 4.2	Freq. Downconv.	6 to 17
FET LNA, 13dB	4.4 to 5.0	Freq. Synthesizers	DC-5
FET LNA, 16dB	1.2 to 1.6		
		Digital ICs:	
Power Amplifier, 12dB	3 to 7	Dividers	6
		Flip-Flops/Latches	1.5
Biphase Modulator	5 to 10		
		Other Building Blocks:	
QPSK Modulator	5 to 10	Balun	6 to 12
		Balun	6 to 18
Power Splitter/Combiner	5 to 10	Attenuator	6 to 18
90° Hybrid	3.5 to 4.5	Limiting Amplifiers	2 to 6
Active Isolator	0.1 to 10	Vector Modulator	5 to 10

(Continued)

©1990 Dataquest Incorporated February

Table 2 (Continued)

Pacific Monolithic's Cell Library

Existing		In Development	
Function	Frequency (GHz)	Function	Frequency (GHz)
Balun	1 to 3	Subsystems:	
		Freq. Downconv.	1 to 3
Balun	2 to 6	Freq. Downconv.	3 to 6
		Freq. Downconv.	5 to 8
Balun	5 to 8	Image-Rej. Downconv.	3.7 to 4.2

Source: Pacific Monolithics

VHSIC Hardware Description Language (VHDL)

VHDL is an emerging ECAE tool standard being promoted by the U.S. Department of Defense (DOD) for use in designing embedded computing systems. It is known also as IEEE 1076. VHDL principally addresses the problem of device model/simulation standardization, whereas the EDIF standard addresses data communication between various CAD tools.

VHDL was developed as an outgrowth of the VHSIC program; it helped to formally describe a hardware design in a multilevel, standardized manner all the way to the gate level. Because it is a mandatory feature on all new DOD designs, as prescribed by MIL-STD-454, it will have a specific impact on how ASICs are designed and which software tools will be employed.

The advantages of using VHDL include standardized design documentation, ease of reengineering, and the capability to evaluate different system-level design alternatives more easily. The areas of ASIC design affected by the standard include digital logic design automation, design capture, behavioral simulators, and cell/macro library models. ASIC companies supporting VHDL include Harris, National Semiconductor, and VLSI Technology. There are many third-party tool companies, among them Cadence, CLSI, Gateway, GenRad, Intermetrics, Mentor, Quadtree, SCS, Synopsis, Valid, Vantage, Viewlogic, Vista Technologies, and VLSI Technology. Zycad has announced that its acceleration products also support VHDL. The third-party vendors provide design capture, simulation, device model building, and VHDL synthesis software as well as translation software of existing models.

Rigorous implementation of VHDL by IC and CAD tool vendors could eventually alleviate many of the problems with discontinued parts because IC design data and models could be reimplemented later in different technology. However, rigorous implementation has remained somewhat elusive to date because of major problems with looseness of the specification and the expense of creating device models. To address the specification problem, an EIA VHDL Model Standards Subcommittee has issued more specific design guidelines to allow different vendors' models of the same part to generate the same results. The other problem has been lack of incentive or funding to develop industry-standard device models (e.g., TTL Logic) or company proprietary models. This issue has yet to be resolved.

An EIA subcommittee will be meeting over the next two years to develop a VHDL extension to analog designs as well. The 1076 standard can be revised in 1992 if necessary.

Libraries

As new systems require more high-performance, embedded-control, and digital signal processing features, we expect MPU/MCU core-anchored libraries to find increasing popularity. The ability to customize and to reduce space and pin count will be highly desirable in military and aerospace designs, and core-based designs are well suited to that purpose. Analog cells are finding their way onto more designs in such forms as data conversion and filters. SCS's GENESIL compiler design system is very popular in the military ASIC community in part because of its participation in the VHSIC program.

Dataquest expects continued new library development for radiation-hardened (rad-hard) features and JTAG/1149.1. Because of special design, special layout, and even different process considerations, rad-hard libraries often are built separately. SCS's GDT system has been used to develop rad-hard designs. Because of the scan registers and control circuitry, frequently JTAG/1149.1 libraries are developed separately.

The following are examples of existing and emerging military/aerospace (mil/aero) design library elements:

- Core architectures including 8051, 68000, 8086, 80286, 2900, and 1750A
- Microperipherals
  - Floating-point units
  - 1553B data bus
  - Bus controllers (e.g., Multibus II, PI bus)
  - Test-management ICs (e.g., VHSIC TM, VHDL controller)
- Memory
  - SRAM, FIFO
  - ROM, EPROM, EEPROM
- DSP
  - ALUs
  - Multipliers/multiplier-accumulators
  - Filters, fast Fourier transformers
- 54/74XX logic catalog functions
- Secure communication functions
- Analog functions
  - Analog switches
  - Operational amplifiers
  - UARTS
  - A/D, D/A
  - Comparators

©1990 Dataquest Incorporated February

Testability

Overview

For mil/aero systems, testability is very crucial. Mil/aero ASIC use is characterized by custom, small production run designs that often go into life-critical equipment used in harsh environments. Therefore, testability of each part becomes an economic and technical issue because of these constraints.

When designing high-complexity ASICs, the designer must give consideration to testability. With densities exceeding 100K gates, speeds passing 300ps, pin counts exceeding 300, and mixed-signal technology emerging rapidly, testability and fault coverage are major issues. Testability can be designed in by the following procedures:

- Physical or logical partitioning (the technique of breaking the design into smaller blocks that can be tested more efficiently)
- The use of synchronous (clock oriented) design practices
- Built-in self-test (BIST), which is a chip- or system-level algorithm that is initiated at power up or in a test mode
- Scan path (e.g., TM or JTAG/1149.1) circuitry on-chip allowing card edge functional tests

Fault Coverage

Automatic test pattern generation out of simulators, synthesizers, and compilers is helping the productivity issues with fault coverage. This process is being aided by more powerful and less expensive workstations that can manage these compute-intensive operations.

JTAG/1149.1

During 1989, much interest was generated by the proposed IEEE 1149.1 (IC-level boundary scan) and IEEE 1149.X (backplane) testability standards. The 1149.1 (JTAG) standard is based principally on elements of both the European-developed Joint Test Action Group (JTAG) and the VHSIC ETM standards. The principal motivation for 1149.1 was to develop a way to do detailed board-level testing without using board-of-nails testing, a process that is very complex and difficult to accomplish with new high-density, surface-mount packaging.

Implementing 1149.1 involves placing on each IC, on a given board, boundary scan circuitry and adding four control pins. Board testing will be governed by a separate controller IC. Implementing 1149.1 adds additional die area and pin count to each IC, depending on the circuit size and design partitioning. The user advantage of 1149.1 is the overall cost saving resulting from thorough board testing and early detection of defective components and manufacturing errors.

Texas Instruments has introduced its SCOPE design library, which incorporates 1149.1 features. LSI Logic and VLSI Technology have also announced support for 1149.1 in their libraries.

©1990 Dataquest Incorporated February

Testers

ASIC device testers can cost from $500,000 to $2 million. State-of-the-art test rates are as high as 200 MHz (Tektronix), but the average is about 80 MHz. Test accuracy can reach 250ps; however, average accuracy is approximately 800ps. These figures leave many of the BiCMOS, ECL, and GaAs ASICs untestable. Many testers can handle up to 512 pins if other features are traded off. LTX, Eagle, Schlumberger, STS, and Teradyne have mixed-signal testers for addressing that technology.

Packaging

The principal developments in ASIC packaging center on surface mounting and increases in density, reliability, speeds, and power-handling capabilities.

Due in part to the reliability thermal mismatch problem between LCCC and the printed circuit board, ceramic quad flatpacks are emerging as the ASIC package of choice along with PGAs for pin counts greater than 68. TAB bonding technology for improved bond reliability also is winning favor in the mil/aero marketplace.

Process Technology

The key trends in ASIC process technology continue to be the diminishing feature sizes; the evolving triple and quadruple metal layering; the emergence of BiCMOS, high-density ECL, and GaAs; and for military applications, the refinement of specialized high-temperature and rad-hard processes. Channelless approaches dominate high-density gate array development. Embedded technology, which mixes cell and array technology, is emerging also. The employment of direct-write e-beam technology for quick-turn prototype and small production runs is proving to an acceptable alternative for the mil/aero market.

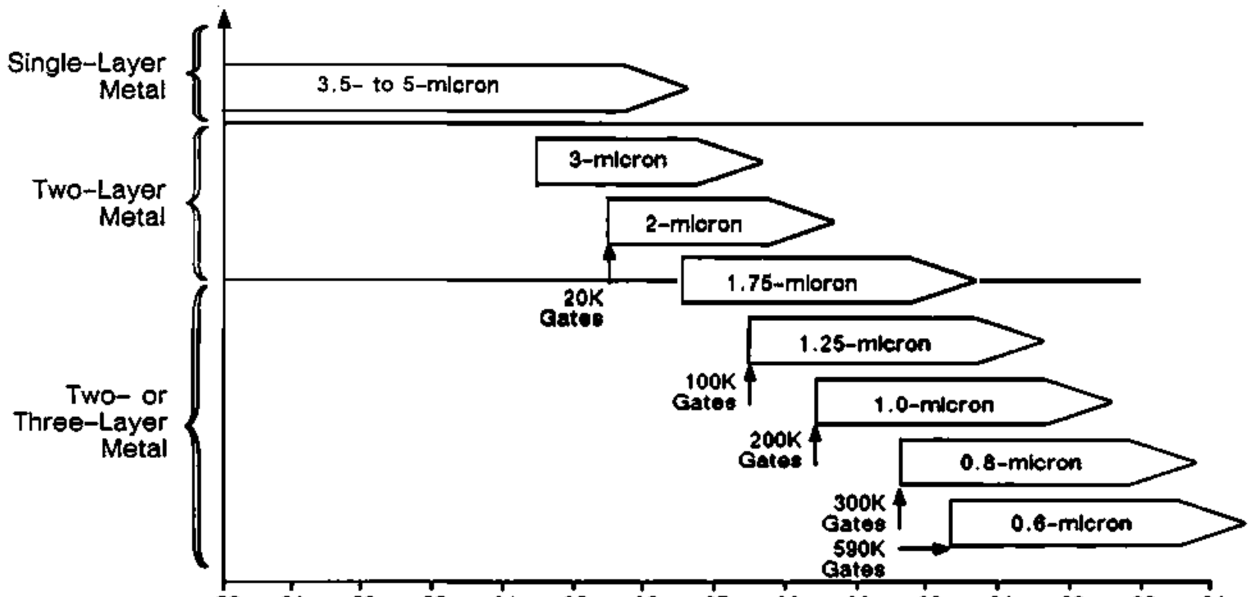
New process technologies for 1989 and 1990 have feature sizes of 0.8 micron with total densities exceeding 200K gates. Figure 4 presents digital CMOS ASIC process trends. Figure 5 shows how technology required to make ASICs efficiently will continue diverging from the traditional DRAM-driven process technology.

New BiCMOS processes are capable of exceeding 100K gates with 400ps gate delays and have the flexibility of ECL or TTL I/O levels. ECL processes have announced capabilities of 100K gates and 50ps gate delays but are currently produced with 30K-gate and 150ps capabilities. GaAs densities are exceeding 15K and 70ps delays utilizing 1.0-micron E/D MESFET technology. The capability exists to scale GaAs processes down to 0.25 micron, achieving 50K-gate densities.

A state-of-the-art analog or mixed-signal process is characterized by additional features such as, but not limited to, the f_t of the transistors, bandwidth of the op amps, resolution of the data converters, and power-handling capabilities. The transistor f_t ranges from greater than 100 GHz for experimental GaAs to 6.5 GHz for bipolar. Op amp bandwidths up to several hundred MHz are possible, as are 12-bit data converters. Several 40-volt capabilities are possible for power-handling functions.

Figure 4

CMOS ASIC Process Trends



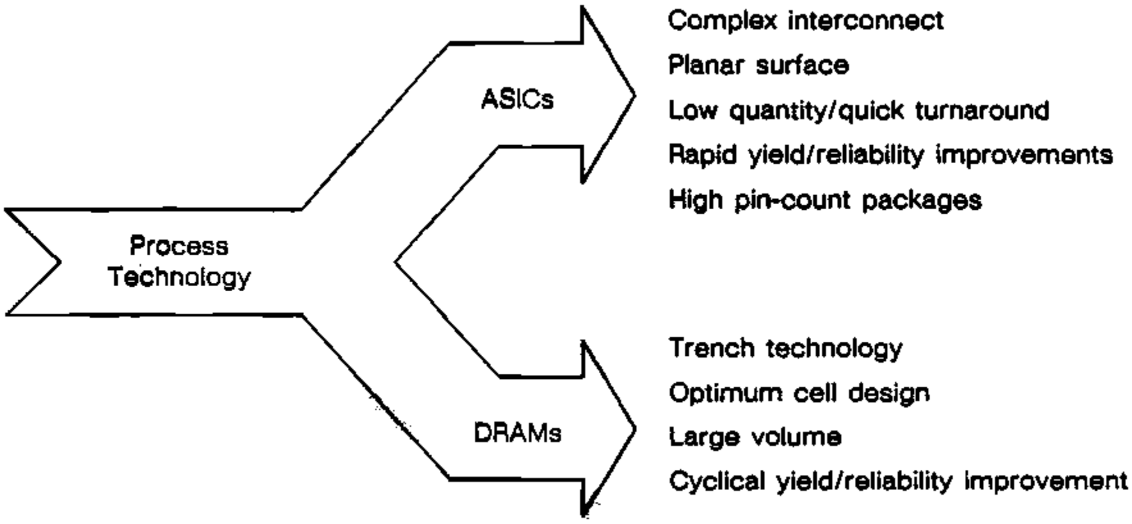
0006204-4

Source: Dataquest
February 1990

©1990 Dataquest Incorporated February

Figure 5

ASICs and DRAMs: A Parting of the Ways



0006204-5

Source: Dataquest
February 1990

Programmable Logic Device (PLD) Technology

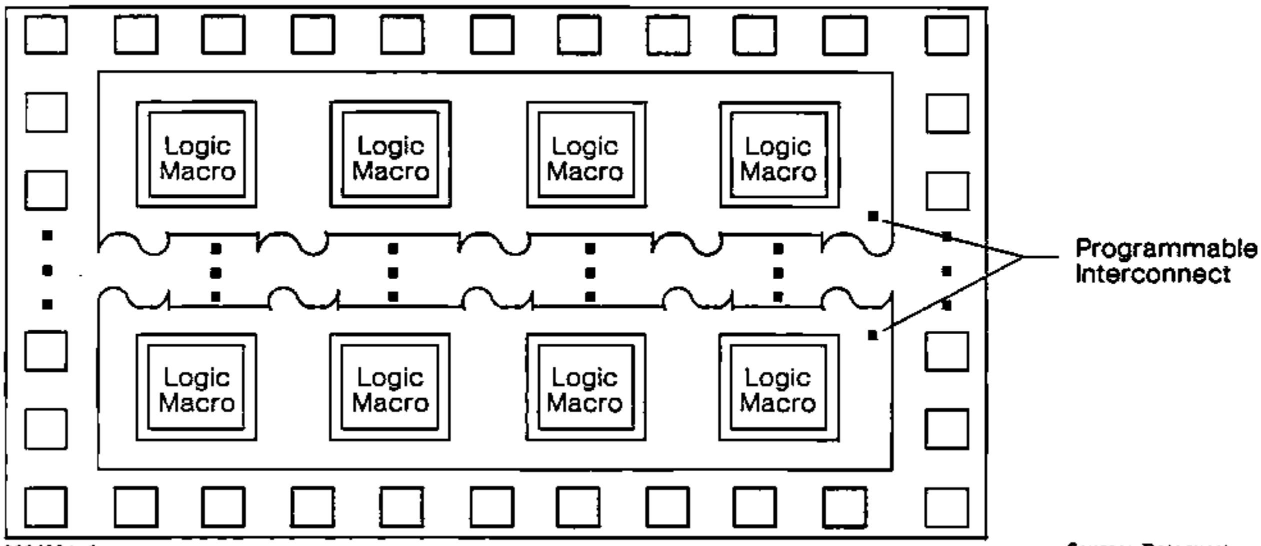
Trends in PLDs include the emergence of high-speed ECL and GaAs versions capable of 3ns propagation delays and the introduction of high-density 5K-to-9K CMOS field-programmable gate arrays (FPGAs). Leading-edge TTL technology is at 5ns delays (7.5ns for 22V10 versions).

FPGAs incorporate an array of programmable logic elements that are not architecturally preconnected as are other PLDs (see Figure 6). Another important trend with PLDs is an expanding array of PC-based logic design tools from companies such as Actel, Altera, Cypress, Data I/O, International CMOS Technology, Texas Instruments, and Xilinx.

©1990 Dataquest Incorporated February

Figure 6

Typical FPGA Block Diagram



Source: Dataquest
February 1990

NONRECURRING ENGINEERING (NRE) CHARGES

Service and NRE charges for the military and aerospace market are very similar to those for the other markets. The traditional service charges include CAD hardware and tools, computer time, custom macro or cell development, engineering design and consulting, IC CAD functions (layout and routing), mask sets, and testing. Converting netlists generated from PLD/FPGA prototype designs is becoming more popular. Unique requirements for military and aerospace markets include the following:

- Secure design, communication, and storage facilities
- Source-control drawing (SCD) handling
- Rad-tolerant/hard processing, including testing for specific parameters such as total dose and special layout considerations

THE MIL/AERO ASIC MARKET

General Market Trends

The following are some important ASIC technology and market-acceptance trends to note for the military and aerospace market:

- The importance of ASICs is underscored as they have become the largest mil/aero IC market category ($460 million worldwide in 1988) after standard analog. ASICs are also projected to be the fastest-growing general semiconductor technology for mil/aero applications through the mid-1990s.

 ©1990 Dataquest Incorporated February

- The mil/aero ASIC market is maturing in phases.
  - The first and ongoing market phase is that of technology upgrading to improve system reliability and maintainability and for avoiding the obsolescence of older standard logic families. This phase is characterized by the use of bipolar PLDs and lower-density (less than 10K) gate arrays.
  - The next market phase, now being entered, is addressing new system designs where complexities are jumping beyond 40K gates and analog designs are migrating onto the ASIC. This phase will be served to an increasing degree by cell technology and compiled, mixed-signal technology.
- Analog and mixed-signal ASICs are beginning to gain acceptance with the availability of improved and user-friendly design/simulation software and testing capability. Bandwidths, converter resolution, and offsets are refining enough to displace traditional standard analog designs.
- Mainstream CMOS technology is clearly centered on the 1.0- to 1.2-micron range, with gate densities climbing over 100K gates. Leading-edge ECL technology is at 1.0 micron with gate densities of 60K being introduced. BiCMOS technology is just beginning to emerge as a desirable midpoint between ECL speeds and drive, and CMOS density. BiCMOS is perceived as desirable for analog and mixed-signal implementations.
- A DARPA insertion program is helping to develop the future supply and use of digital GaAs.
- New designs will be utilizing MPU cores such as MIL-STD-1750A, 68000, and 80C51, as well as peripherals such as MIL-STD-1553B.
- Mil/aero system designers are enjoying using DSP ASIC building-block libraries of such items as multipliers and MACs to implement signal processing solutions.
- Maturing PC-based CAD tools are helping rapidly develop the FPGA market. Quick turnaround, small volumes, and intermediate densities (5K to 10K) are attracting many gate array and PLD designs to FPGA.
- The JTAG (IEEE 1149.1) scan test and VHDL design/model standards now are supported by several IC companies and independent tool firms. The issue of customer "real estate" costs probably will hinder rapid acceptance of JTAG until users comprehend long-term test/manufacturing savings. VHDL acceptance is being slowed while funding of standard and proprietary device models is being debated.
- Both the very rad hard (≥10(7) total dose, ≥10(-10) SEU) market for space and strategic applications and the tactical-level (10(3)-10(4)) markets for ASICs will expand faster than the overall market for ASICs.
- CQFP is emerging as a preferred packaging technique for uses greater than 68 pins.
- The implementation of the QML per MIL-I-38535, now in beta site development, should help lower barriers for introducing new ASIC technology. It should help standardize communication between vendors, users, and government supervisors regarding new technology and ongoing quality and reliability issues associated with semicustom designs.

©1990 Dataquest Incorporated February

Market Drivers

ASIC use in mil/aero systems is accelerating for several reasons, including the following:

- IC replacement for reliability and maintainability (R&M) including reducing total board lead count, power consumption reduction, implementation with surface-mount components, and improved testability
- Replacement to avoid obsolescence of standard logic or linear devices
- Improved functionality or the addition of extra capabilities such as programmability and higher frequencies
- Relatively easy prototype development with PLD/FPGAs
- Design documentation with ASICs aligning with new mandatory documentation standards such as VHDL and the Computer Aided Logistics Program (CALS)
- Use in the wide range of new-start, recompeted, or major redesign programs
- The general match between a highly customized need (each program having distinct requirements) and a customized but economic technology solution

As gate densities approach subsystem levels and core functions and linear elements become available, ASICs are being used increasingly in signal processing, functional applications such as communication ICs and embedded control applications.

Figure 7 details the distribution of mil/aero ASIC design starts by equipment type. The semiconductor-intensive radar/sonar area presents the largest opportunity, especially for R&M improvements, whereas missiles/weapons and space equipment represent areas where ASICs are just beginning to penetrate substantially. In general, the avionics area—which overlays radar, comm/nav, electronic warfare, and aircraft systems—presents a fertile ground for increased ASIC use.

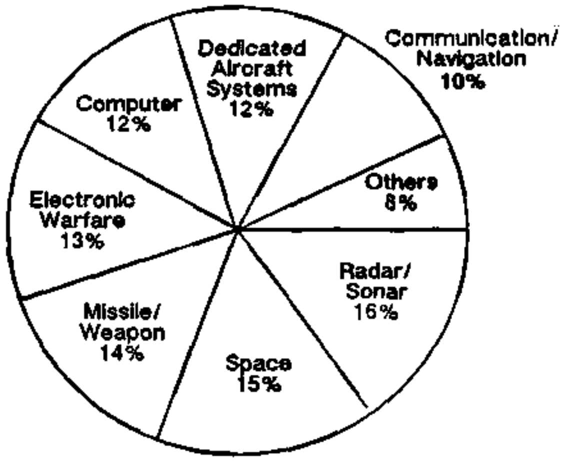
The following are examples of ASIC use in military/aerospace applications along with example programs:

- Embedded computers—AN/UYK computers
- Communication transceivers—SINCGARS, MSE
- Warning receivers—ALQ, AAR series
- Electronic countermeasures—ALQ, decoys
- Aircraft computers (air data, mission)—Common modules
- Weapon guidance and control—AAWS, smart munitions
- Radar/sonar data processing—EFA radar, sonobouys
- Simulator data processing—ATF, EFA aircraft training
- Specific test equipment—All new aircraft
- Navigation processing—GPS receivers, ICNIA
- Space computers—Common modules, SDI elements

©1990 Dataquest Incorporated February

Figure 7

Military/Aerospace ASIC Design Start Profile
by Equipment Type



0006204-7

Source: Dataquest February 1990

Mil/Aero ASIC Consumption Profile

Overview

Figure 8 profiles worldwide mil/aero ASIC consumption by category. Although consumption is currently dominated by CMOS gate arrays, Dataquest believes that CMOS CBICs and CMOS PLDs will grow to complement gate arrays by the early 1990s. For high-performance applications in computing and bit manipulation, GaAs and ECL technology should have substantial design preference. We expect BiCMOS to address the situations where density, power, and performance are simultaneously critical.

Figure 9 illustrates that the bulk of the ASIC consumption remains in North America, with Japan/Rest of World growing rapidly to serve a growing aerospace business.

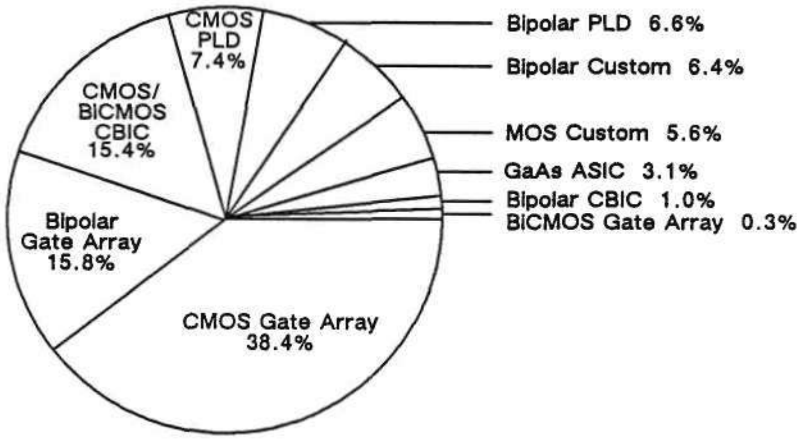
Design-Start Analysis

Figures 10 through 14 profile the design-start demand for array, cell-based (including custom) products. Dataquest estimates that the NRE associated with the 2,465 design starts in 1989 made up 35 percent of the array/cell market. We expect the number of design starts to grow at a slower rate than in the past, in the 3 to 5 percent range, as the average new design start becomes increasingly more complex.

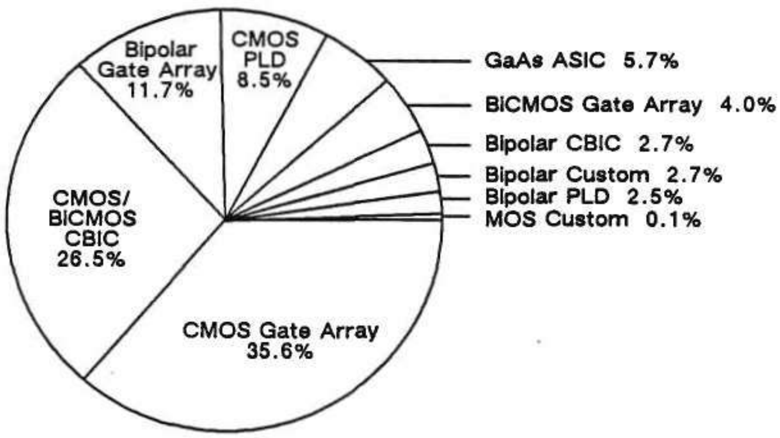
©1990 Dataquest Incorporated February

Figure 8

Estimated Mil/Aero ASIC Consumption by Category (Worldwide)



1989



1994

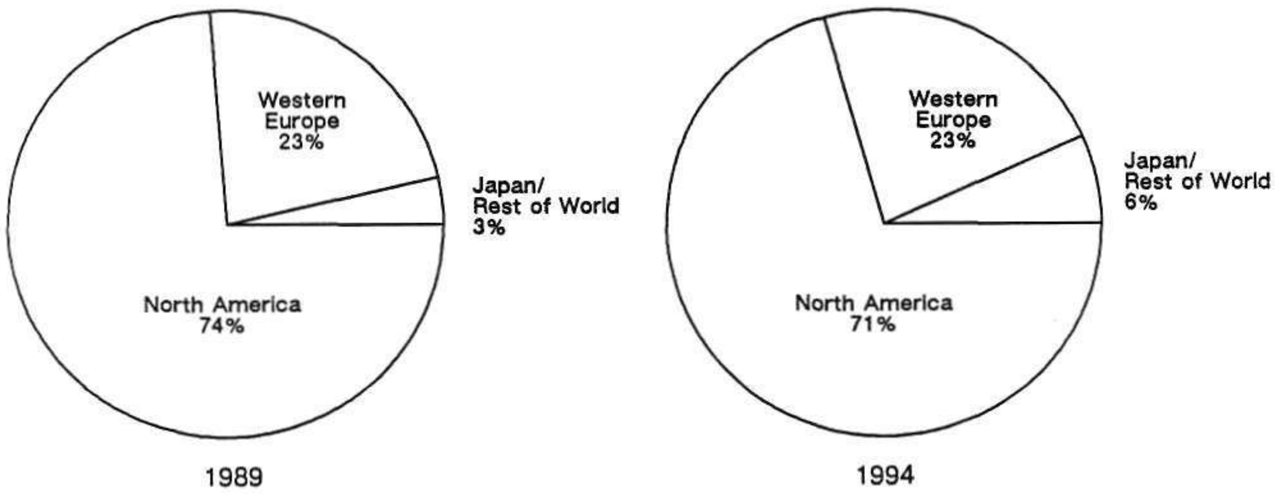
0006204-8

Source: Dataquest
February 1990

©1990 Dataquest Incorporated February

Figure 9

Estimated Mil/Aero ASIC Consumption by Geographic Region

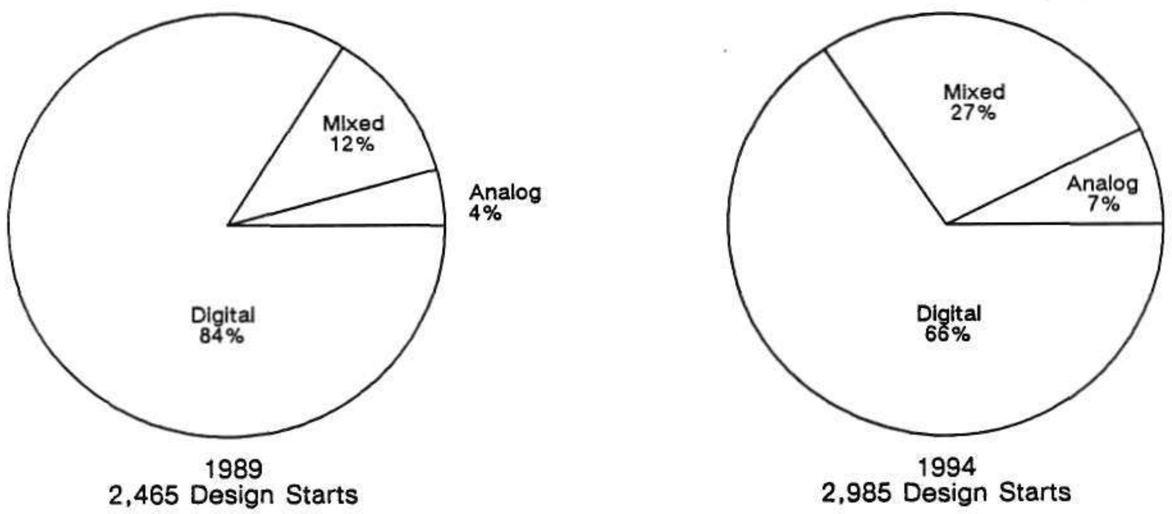


0006204-9

Source: Dataquest
February 1990

Figure 10

Estimated Mil/Aero Array/Cell Design Starts by Signal Type (Worldwide)



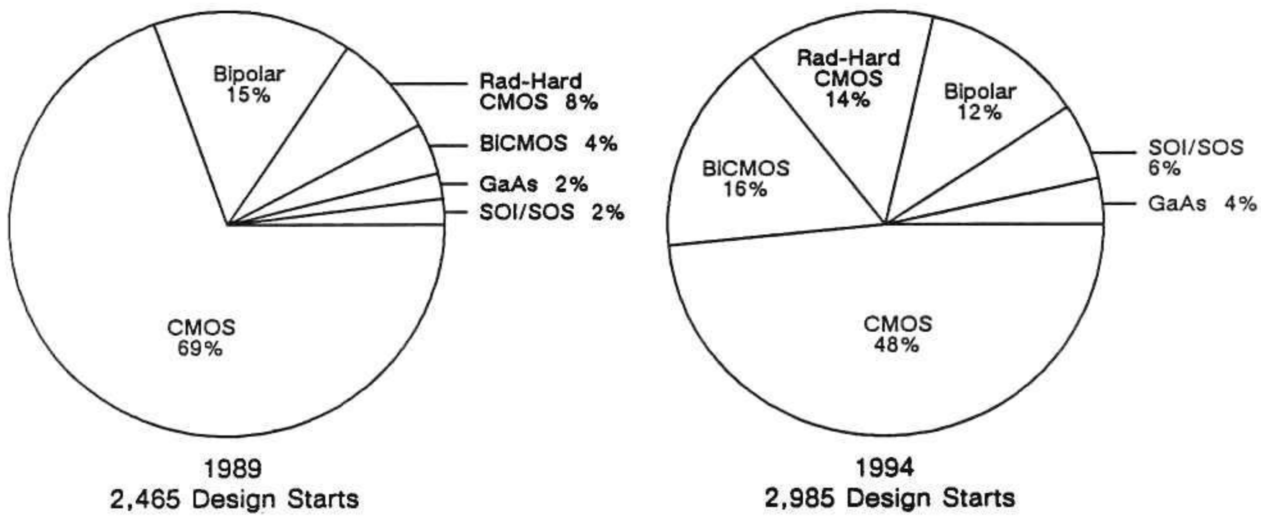
0006204-10

Source: Dataquest
February 1990

©1990 Dataquest Incorporated February

Figure 11

Estimated Mil/Aero Array/Cell Design Starts by Process Technology (Worldwide)

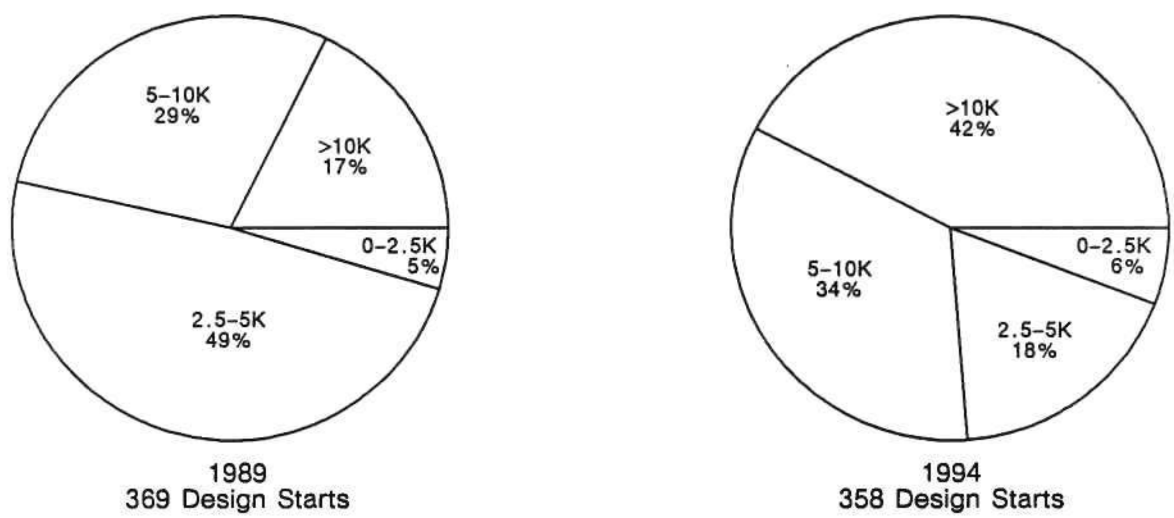


0006204-11

Source: Dataquest
February 1990

Figure 12

Estimated Mil/Aero Array/Cell Bipolar Design Starts by Density (Worldwide)



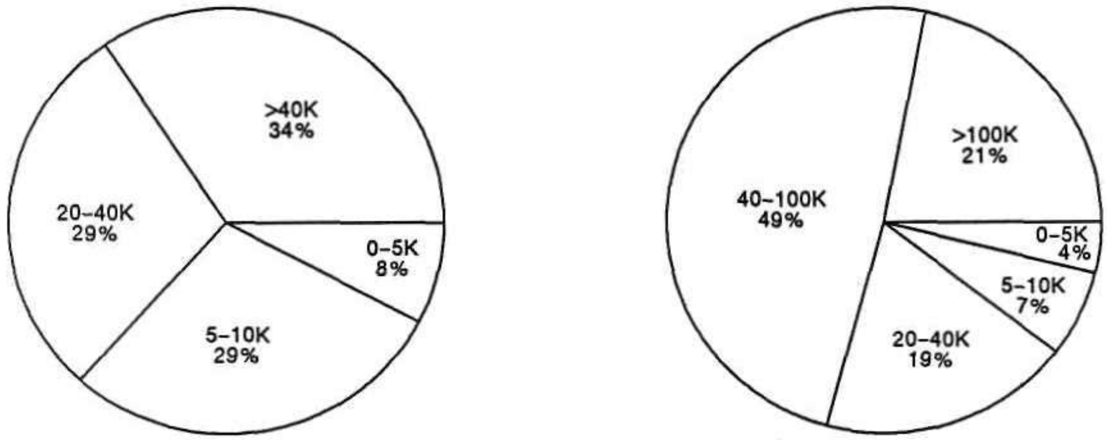
0006204-12

Source: Dataquest
February 1990

©1990 Dataquest Incorporated February

Figure 13

Estimated Mil/Aero Array/Cell CMOS/BiCMOS Design Starts by Density (Worldwide)



1989
1,997 Design Starts

1994
2,328 Design Starts

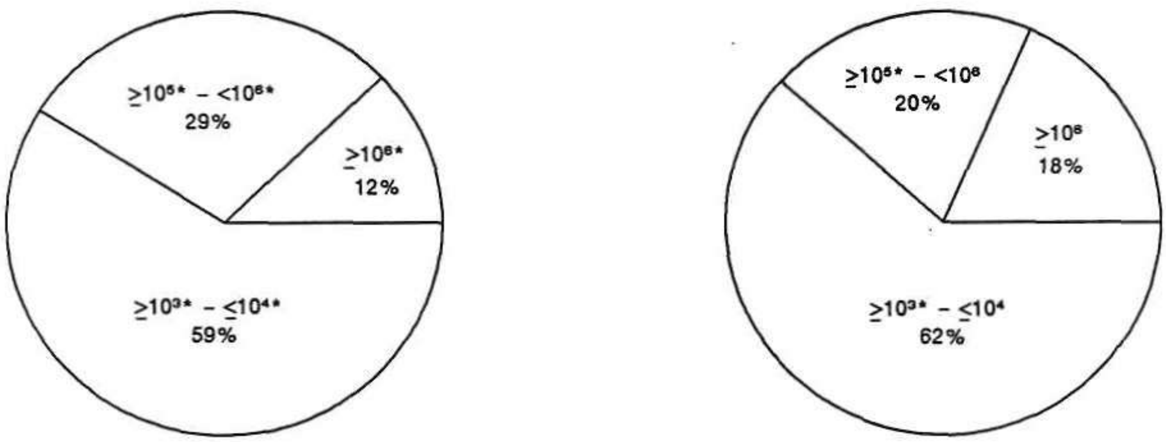
*Including radiation-hardened processes

0006204-13

Source: Dataquest February 1990

Figure 14

Estimated Mil/Aero Array/Cell Radiation-Hardened Design Starts (Worldwide)



1989
986 Design Starts

1994
1,415 Design Starts

*Total dose rads (Si)

0006204-14

Source: Dataquest February 1990

©1990 Dataquest Incorporated February

With increasing availability and maturity of customer-owned analog and mixed-signal CAD tools, we expect demand for those versions to become increasingly heavy for the real-time analog, embedded, mil/aero applications. We also expect CMOS to remain the dominant technology but to lose share to BiCMOS and radiation-hardened CMOS. Bipolar will lose overall share, but ECL, analog, and obsolete logic family emulation processes will maintain moderate growth.

The bulk of bipolar design business remains in the 2.5K to 5.0K total gate range, with leading-edge 15K to 30K gate designs just beginning to be captured. The high-density bipolar products are used along critical data paths in signal processing and sensor systems. Small gate count designs will find use as logic family replacement parts. Clearly the bulk of CMOS/BiCMOS designs are moving up to and surpassing 40K gates as system/subsystem implementations become more commonplace.

An estimated 40 percent of 1989 total mil/aero array/cell design starts had some sort of radiation-tolerance specification (either explicit or implicit) associated with it in 1989. Of that amount, 59 percent was at the tactical radiation levels and the balance was at 10^5 rads or greater (strategic) levels. We estimate that demand for both the 1-Meg rad and higher class will grow substantially as well as the tactical levels. The higher-tolerance class will be fed by a surge in space-based systems, partly propelled by SDI elements. The surge at the tactical level represents the large markets for avionics and tactical missiles/weapons that are formalizing their need for tolerant products. For memory macros and cells, the requirement for single-event upset (SEU) tolerance will most likely increase as the systems become more memory intense. We expect 10^{-10} upsets/bit-day to become a requirement for memory arrays on many programs. Increasingly, dose rate will become a more visible specification by which this technology will be judged.

Array and Cell-Based IC Suppliers

Tables 3 through 6 list the principal suppliers of military gate arrays, digital cell-based ICs, analog arrays, and analog/digital cell-based ICs, respectively. A list of GaAs foundry companies can be found in the GaAs section.

 ©1990 Dataquest Incorporated February

Table 3

Military Gate Array Suppliers

	Product Name	Process (Drawn)	Total Gate Count	Usable Gate Count	I/Os	Gate Delay (ns) FO = 2	Toggle Freq. (MHz)	Macro Library Size
CMOS								
Fujitsu	AU2/AS	0.8	160K	100K	332	0.55	75	250
Gould AMI	GB	2.0	10K	9K	192	0.90	50	300
	GC	1.2	100K	54K	324	0.50	100	300
Harris	AGC40K	1.2	N/A	10K	N/A	0.65	N/A	N/A
	AGC50K	1.0	N/A	70K	N/A	0.45	N/A	N/A
	AUA	1.2 SOS	N/A	14K	N/A	1.00	N/A	N/A
	TAGC50K	1.2 rad hard	N/A	35K	N/A	0.95	N/A	N/A
	TSGC60K	1.0 SOI	N/A	150K	N/A	0.45	N/A	N/A
Honeywell	HCT	1.2	15K	N/A	144	0.60	170	N/A
	HCS	1.2 rad hard	15K	N/A	144	0.90	150	40
	HC	1.2	40K	N/A	184	0.60	170	N/A
Hughes	HU	2.0	41K	N/A	248	1.20	150	N/A
IMI	IMI	1.5	8K	N/A	178	1.50	100	N/A
LSI Logic	LCA 100K	1.0	235K	100K	418	0.45	>250	>500
	LCA10000	1.5	129K	50K	348	0.54	>220	>500
	LMA9000	1.5	35K	15K	174	0.54	>220	>500
	LRH9000	1.5 rad hard	10K	N/A	232	1.10	N/A	>500
	LRH10000	1.0 rad hard	129K	N/A	368	0.57	N/A	>500
Matra-Harris	MB	2.0	7.5K	N/A	168	1.50	45	N/A
Marconi	MA4000	2.0	10K	N/A	160	0.90	100	N/A
	MA9000	3.0 SOS	4K	N/A	98	1.70	50	N/A
	SOS DLM	1.5	20K	N/A	N/A	N/A	140	N/A
Motorola	HDC	1.0	105K	75K	512	0.25	N/A	N/A
	HCA	2.0	9K	N/A	168	2.80	N/A	N/A

(Continued)

©1990 Dataquest Incorporated February

Table 3 (Continued)

Military Gate Array Suppliers

	Product Name	Process (Drawn)	Total Gate Count	Usable Gate Count	I/Os	Gate Delay (ns) FO = 2	Toggle Freq. (MHz)	Macro Library Size
CMOS (Continued)								
National	CS-200	2.0	6K	90%	N/A	N/A	N/A	N/A
	CS-150	1.5	15K	90%	N/A	N/A	N/A	N/A
	N/A	0.8	250K	N/A	N/A	N/A	N/A	N/A
NCR	VGX1500	1.5	56K	25K	240	1.40	122	174
Plessey	CLA5000	2.0	10K	90%	160	1.20	40	N/A
	CLA60000	1.5	110K	N/A	256	0.65	70	N/A
Raytheon	RV/RL	2.0/1.25	20K	N/A	160	0.40	250	N/A
SGS-Thomson—Thomson TMS	TSGB	2.0	10K	N/A	192	1.00	N/A	N/A
	TSGC	1.2	10K	N/A	192	1.50	N/A	N/A
	ISB	1.2	128K	50K	256	0.30	N/A	N/A
Siemens	SCxC1	1.5	129K	50K	256	2.00	150	581
	SCxD4	1.0	172K	68K	256	1.40	200	581
Texas Instruments	TPC10	1.2	2K	90%	94	3.00	70	209
	TGC100	1.2	26K	90%	256	0.50 (FO = 3)	208	234
UTMC	UTD-(R)	1.5 rad hard	11K	N/A	188	1.00	N/A	N/A
	UTE-R	1.2 rad hard	50K	N/A	208	0.60	N/A	N/A
VLSI Technology	VGT-10	2.0	11K	N/A	106	2.50	N/A	225
	VGT-100	1.5	67K	N/A	N/A	2.33	180	225
BiCMOS								
AMCC	Q14000	1.5	14K	N/A	226	1.00	240	75
LSI Logic	LDD10000	0.9	117K	N/A	342	1.10	250	>400
Motorola	BCA	2.0	7.5K	N/A	228	1.70	135	N/A
Texas Instruments	N/A	0.8	100K	90%	N/A	0.40	N/A	N/A

(Continued)

©1990 Dataquest Incorporated February

Table 3 (Continued)

Military Gate Array Suppliers

	Product Name	Process (Drawn)	Total Gate Count	Usable Gate Count	I/Os	Gate Delay (ns) FO = 2	Toggle Freq. (MHz)	Macro Library Size
Bipolar								
AMCC	Q20000	1.0	23K	N/A	252	0.10	1,500	75
	Q5000	2.0	5K	N/A	160	0.45	800	300
AT&T	SFOXIL	N/A	6K	N/A	120	0.40	600	350
	BEST	N/A	15K	N/A	200	0.15	3,000	150
Fujitsu	ET Std.	1.0	6K	N/A	136	0.33	800	180
	H Series	0.5	10K	N/A	200	0.15	1,000	85
	VH Series	0.4	30K	N/A	300	0.11	1,100	100
Motorola	MCA-2	2.0	3K	N/A	120	0.35	770	105
	MCA-3	1.5	12K	N/A	256	0.15	1,500	280
	MCA-3 ETL	1.5	6K	N/A	168	0.15	2,400	280
	MCA-4	1.0	60K	N/A	400	0.12	3,000	250
National	FGA	ASPECT II	30K	N/A	256	0.22	1,200	150
	N/A	ASPECT III	60K	N/A	N/A	N/A	N/A	N/A
NEC	ECL-3B	1.4	5K	N/A	172	0.61	300	115
	ECL-4A	0.7	35K	N/A	236	0.29	1,700	245
Plessey	ELA	N/A	3K	N/A	96	0.20	2,000	N/A
Raytheon	Low Pwr. ECL	N/A	13K	N/A	176	0.46	1,200	165
Siemens	SH 100E	1.5	16K	N/A	256	0.19	1,700	250
GaAs								
TriQuint	TQ 3000	1.0	4K	N/A	84	0.31	6,000	36
Vitesse	Fury	0.8	17K	N/A	196	0.07	1,200	136

N/A = Not Available

Source: *ASIC Technology & News*
Dataquest
February 1990

Table 4

Military Digital Cell-Based IC Suppliers

	Product Name	Process (Drawn)	Total Gate Count	Gate Delay (ns) FO = 2	Toggle Freq. (MHz)	Library Size
CMOS						
AT&T	Cell Based	1.25, 0.9	75K	1.30	650	106
ES2/US2	Solo 1400	1.2/2.0	60K	1.80-2.50	80-120	350
	Cadence/Edge	1.2/2.0	60K	1.80-2.50	80-120	350
	SCS/Genesic	1.2/2.0	60K	1.80-2.50	80-120	350
Fujitsu	AU	1.2	60K	1.00	75	200
Gould AMI	2 Micron	2.0	16K	0.60	50	600
	1.25 Micron	1.2	35K	0.45	100	350
Harris	HSC1000	1.5	25K	0.80	N/A	N/A
	ASC50K	1.0	80K	0.45	N/A	N/A
	TASC50K	1.2 rad hard	80K	0.90	N/A	N/A
	TSSC50K	1.0 SOI	80K	0.75	N/A	N/A
LSI Logic	LEA100K	1.0	150K	0.45	250	500
	LCB007	1.0	200K	0.45	250	500
	LCB15	1.5	100K	0.54	250	500
Marconi	CELLSOS	3.0	6K	N/A	40	N/A
	MACROSOS	2.5 SOS	6K	1.20	90	N/A
	MACROSOSII	1.5 SOS	N/A	N/A	140	N/A
	CELLMOS	3.0	N/A	N/A	N/A	N/A
National	N/A	2.0	6K	N/A	N/A	N/A
	N/A	0.8	250K	N/A	N/A	N/A
NCR	VS1500	1.5	50K	1.46	151	181
Plessey	Megacell	2.0	Varies	1.70	N/A	N/A
Seattle Silicon	Chip Crafter	0.8-2.0	50K	0.80	500	>500

(Continued)

©1990 Dataquest Incorporated February

Table 4 (Continued)

Military Digital Cell-Based IC Suppliers

	Product Name	Process (Drawn)	Total Gate Count	Gate Delay (ns) FO = 2	Toggle Freq. (MHz)	Library Size
CMOS (Continued)						
SGS-Thomson— Thomson TMS	TSGSB	2.0	Varies	1.00	N/A	N/A
	TSGSD	1.2	100K	N/A	N/A	N/A
STC	N/A	1.25	Varies	N/A	N/A	N/A
Texas Instruments	TSC500	1.2	45K	0.50	208	450
VLSI Technology	VSC320/M	1.0	Varies	3.10	250	299
	VSC300/M	1.0	Varies	1.90	250	299
	VSC120	1.5	Varies	2.33	180	225
	VSC10	2.0	Varies	3.48	130	83
VTC	VL5000	1.0	50K	0.58	N/A	100
Bipolar						
AT&T	SFOXIL	N/A	6K	0.40	600	350
	BEST	N/A	20K	0.15	3,000	150
Motorola	CDA	1.0	90K	0.12	3,000	250
GaAs						
Gigabit	SC 5000	0.8	5K	0.05	2,700	55
	SC 10000	0.8	15K	0.05	1,700	95
TriQuint	QLSI	1.0	10K	0.12	3,500	90
Vitesse	VCB 50K	N/A	25K	0.07	1,300	128

N/A = Not Available

Source: *ASIC Technology & News*
Dataquest
February 1990

Table 5

Military Analog Array Suppliers

	Product Name	Process (Drawn)	741 Op Amp Potential	Digtal Gate Count	I/Os	Toggle Freq. (MHz)	Power Supply (V)
Analog Array							
Cherry	Genesis	Bipolar	9	256	40	400	1-20
Custom Arrays	MM, MV	Bipolar	28	100	48	500	1-30
EXAR	Various	Bipolar, JFET	25	250	48	450	20-75
Gennum	LA200/50	Bipolar	12	N/A	40	350	20
Holt	HI-3500	CMOS 4u	9	208	64	N/A	-0.3, ±15
Honeywell	BDA	Bipolar	26 trans.	0	16	N/A	5
	HPBDA	Bipolar	208 trans.	0	26-51	Varies	40
	TGA	Bipolar	18 trans.	0	24	N/A	5
LSI Logic	LAD310	BiCMOS 0.9u	200	45K	64	6,500	5, 10
MCE	UNIRAY	Bipolar	4	50	40	500	20, 40, 80
Plessey	MM/MO	Bipolar	9	0	46	400	1-20
	MV	Bipolar	6	0	36	350	1-40
	MF	Bipolar	15	120	52	3,000	1-20
	MA/MH	CMOS 4u	15	1600	84	40	3-15
	P/G	Bipolar	22	1.1K	420	3,000	0-12
	DF/DS	Bipolar	49	10K	138	3,000	0-5
Raytheon	RLA	Bipolar	15	N/A	44	800	0-32
SGS-Thomson—Thomson TMS	K, J	Bipolar	24	486	40	3,000	0-15
Silicon Systems	MSA	Bipolar, CMOS	24, 40	96, 1.6K	52, 44	12, 2,000	4-15
Sipex	SP1100	Bipolar	24	N/A	24, 40	1,200 NPN	20, 50
Tektronix	Quickchip	Bipolar	48	300	70	6,500	32
VTC	VJ900	Bipolar 2u	612 trans.	N/A	68	6,000	±5, 12

N/A = Not Available

Source: *ASIC Technology & News*
Dataquest
February 1990

©1990 Dataquest Incorporated February

Table 6

Military Analog/Digital Cell-Based IC Suppliers

	Product Name	Process (Drawn)	Analog Cells	Digital Cells	Op Amp Bandwidth (MHz)	Toggle Freq. (MHz)	Converter Bits	Power Supply (V)
Advanced Linear	Functional	CMOS	14	38	2.1	2.5	N/A	±12, ±15, ±2
Custom Arrays	N/A	Bipolar	100	0	250	1,000	6	1-50
ES2/US2	Solo 1200	CMOS 1.5, 2u	58	200	14	N/A	8	5
Gould AMI	Analog/Mix	CMOS 2, 3u	Several	170	5.0 3u	Variable	8	±5, 12, 40
Harris	Bipolar Analog	Bipolar/DI	N/A	N/A	N/A	1,000	N/A	20, 40
	CMOS Analog	CMOS	32	25	4.6	N/A	N/A	10
Holt	Cell Based	CMOS 3, 4u	35	50	N/A	N/A	12, 8	1.5-15
Marconi	ANAMOS	CMOS 3, 1.5u	30	BITMOS	N/A	45	12	5, 10
	ANASOS	SOS 3, 1.5u	30	BITSOS	N/A	N/A	12	5, 10
MCE	N/A	Bipolar	20	N/A	1.0	500	12	20, 40, 80
National	CLASIC	CMOS, bipolar	N/A	N/A	N/A	N/A	N/A	N/A
NCR	VS 2000	CMOS 2.0u	20	250	2.4	80	12	5
	VS 1500	CMOS 1.5u	10	250	2.9	120	N/A	5
Plessey	MVA5000	CMOS 2.0u	15	100	2.0	N/A	8	3-5.5
	MVA6000	CMOS 1.4u	15	250	2.0	N/A	8	3-5.5
	ZNC	Bipolar	50	100	100	3,000	10	0-5
SGS-Thomson—Thomson TMS	TSGM	CMOS	66	94	3.0	10.0	12	3-12
Standard Micro.	Customation	CMOS 2.0u	N/A	N/A	N/A	N/A	N/A	4-6
Sipex	N/A	Bipolar, DI	30	10	100	1,200	N/A	20-35
TLSI	N/A	CMOS 5, 3, 2u	200	500	N/A	40	12	3-16
	N/A	Bipolar	300	200	N/A	N/A	N/A	3-40
VTC	VL1000/2/3	Bipolar 2u	73	106	500	6,000	Avail.	±5

N/A = Not Available

Source: *ASIC Technology & News*
Dataquest
February 1990

©1990 Dataquest Incorporated February

Programmable Logic Devices (PLDs)

The advantages of rapid prototype turnaround and generally low NRE investment and risk (in case a program is not funded), have made PLDs a favorite choice of mil/aero system designers. A significant percentage of PLD use in mil/aero is for commercial temperature range, brass board use during the development phase of programs. Principal applications include logic consolidation, decoders, memory controllers, and state machine implementations. Netlists from many of these designs are converted into other ASICs for volume orders when production contracts are awarded.

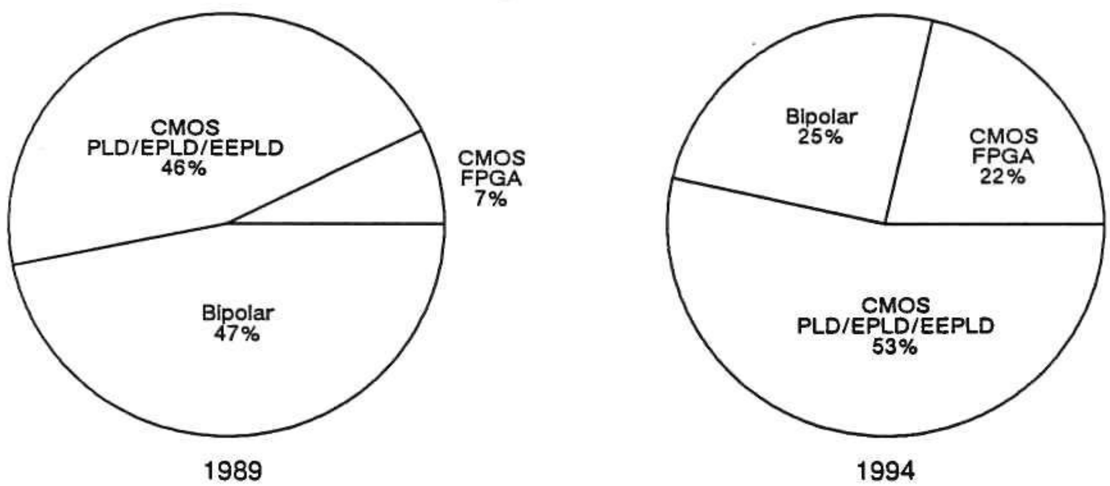
The most popular bipolar PLD architectures are 16XX, 22V10, and 20XX. These versions are also popular for CMOS technology but complemented by the EPXX, EPMXX, GAL, and PEEL higher-density (greater than 750-gate) versions. The ACT and XC types of field-programmable logic are the predominant architectures for that technology. The bipolar TTL PLD market has experienced severe price erosion in the last two years, allowing the CMOS market to catch up in size (see Figure 15).

Although higher-speed, higher-density bipolar TTL versions (such as 22V10) remain popular, the mil/aero market appears to be rapidly embracing the high-density, erasable CMOS versions. Figures 16 and 17 illustrate the demand for speed for bipolar and CMOS, respectively. We expect the windowed EPLD versions to remain the most popular of the erasables for most of the early 1990s until EE and FPGA become dominant.

The FPGA and the architecture-less, high-density (up to 9,000 gates) versions—as offered by leaders Xilinx and Actel—are proving to be very popular with designers. The availability of user-friendly PC-based design tools has helped accelerate to user acceptance. As with some other PLD offerings, the option of converting a netlist into a gate array design later has proven to be attractive once prototyping is complete. We expect FPGAs to dominate new designs in the 3K to 10K gate ranges.

Figure 15

Estimated Mil/Aero PLD Dollar Consumption



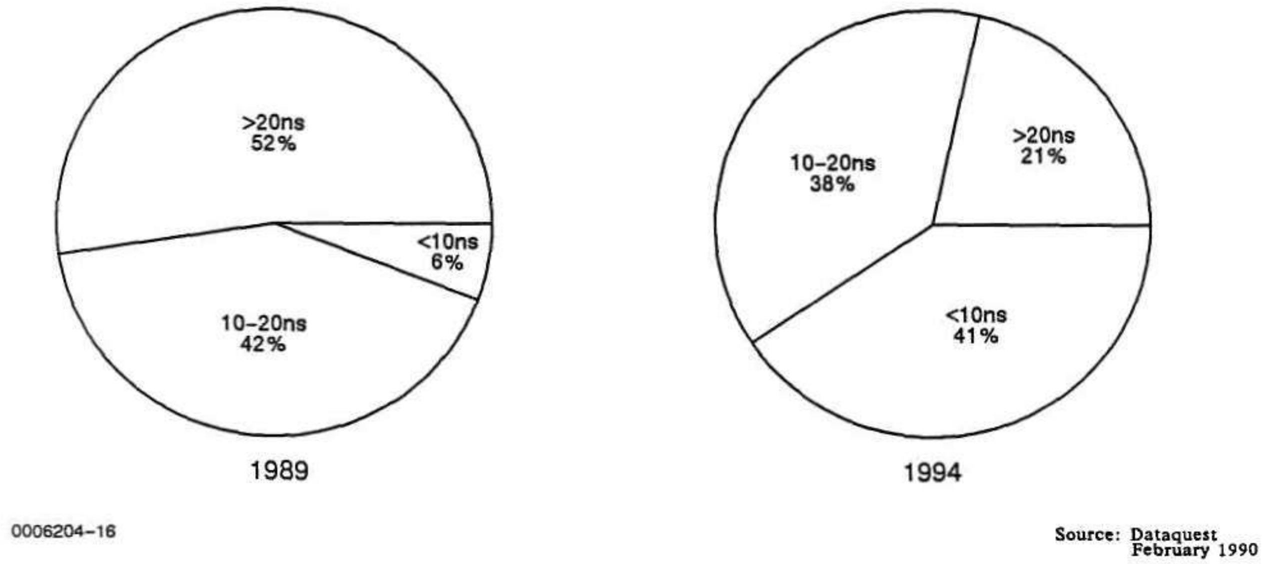
0006204-15

Source: Dataquest
February 1990

©1990 Dataquest Incorporated February

Figure 16

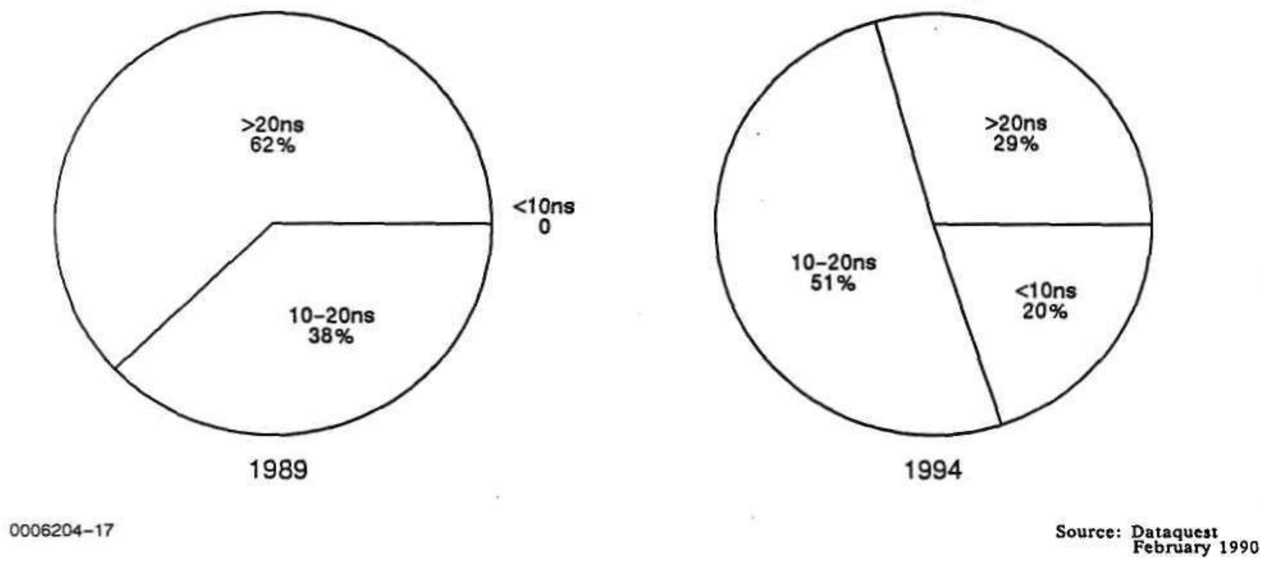
Estimated Mil/Aero Bipolar PLD Consumption by Speed



Source: Dataquest
February 1990

Figure 17

Estimated Mil/Aero CMOS PLD Consumption by Speed



Source: Dataquest
February 1990

Table 7 presents the array of PLD offerings by company.

Table 7

Worldwide PLD Suppliers by Technology

Company	Architecture PLA	Architecture FPGA	Bipolar TTL Fuse	Bipolar TTL Mask	Bipolar ECL Fuse	Bipolar ECL Mask	CMOS Fuse	CMOS Mask	CMOS EPROM	CMOS EEPROM	CMOS RAM	GaAs Fuse	BiCMOS Mask
Actel Corporation		X					X						
Advanced Micro Devices	X	X	X	X	X			X		X	X		
Altera Corporation	X								X				
Aspen Semiconductor	X												X[2]
Atmel Corporation	X								X	X			
Cypress Semiconductor	X								X				
Exel Microelectronics Inc.	X									X			
Fujitsu	X								X				
Gazelle Microcircuits	X											X[3]	
Gould Semiconductor	X									X			
Harris Semiconductor	X						X						
Hyundai Semiconductor	X									X			
Intel Corporation	X								X				
International CMOS Technology	X									X			
Lattice Semiconductor	X									X			
National Semiconductor	X		X		X					X[1]			
Philips/Signetics	X		X		X				X				
Plessey Semiconductor		X									X		
Ricoh/Panatech Semiconductor	X								X				
Samsung	X								X				
SEEQ Technology	X									X			
SGS-Thomson	X									X[1]			
Texas Instruments	X	X	X		X		X		X				
Toshiba	X								X				
WaferScale Integration	X								X				
Xilinx		X			X						X		
	23	5	4	1	5	0	3	1	11	10	3	1	1

[1] National and SGS-Thomson have acquired the rights to make EEPLDs from Lattice Semiconductor.
[2] Aspen plans to ship a 22V10 in 1990.
[3] Gazelle is a GaAs PLD supplier.

Source: Dataquest
February 1990

©1990 Dataquest Incorporated February

Captive Capabilities

As the VHSIC program phases out, we note that the OEMs are increasingly backing out of maintaining large capital investments in fab facilities and are concentrating on maintaining design capabilities. Because of the huge expense of maintaining partially filled fabs, companies such as Honeywell, Hughes, and TRW have chosen either to reduce or to sell off their fab technology investments in such mainstream ASIC technologies as digital CMOS. This may also be the case with MMIC or GaAs capabilities, as many analysts have observed too much capacity relative to demand.

The key factor forcing these OEMs to reduce their positions in ASIC technology comes from the economies of scale that can be achieved by the merchants as they serve broader markets and still keep their costs down. What many OEMs are concentrating on for the future is building better in-house ASIC design expertise and technology. In many cases, because many merchant vendors are missing mil/aero cells or macros in their design libraries, OEMs have taken it upon themselves to further design these products. Many OEMs are using skills in ASIC design technology to implement advanced price/performance solutions for new contracts and for reliability and maintainability improvements and sunset technology avoidance on existing programs.

U.S. Government Programs

The Qualified Manufacturer List (QML), Microelectronics Manufacturing Science and Technology (MMST), and Microelectronic Technology Support Program (MTSP) initiatives will impact the future of the military ASIC industry.

The QML is a procedure to qualify the various building blocks of designing and manufacturing a semiconductor device. Rather than emphasizing individual part testing to ensure quality, the QML would monitor the process through techniques such as statistical process control (SPC) and a technical review board (TRB). Once a manufacturing company is approved, it would be placed on the QML. This program is currently in beta site test.

The MMST program is a five-year program managed by the U.S. Air Force under contract to Texas Instruments (TI). TI's primary goal is to perfect an automated, multiprocess, quick-turn, low-volume ASIC technology tailored to military use.

The MTSP program will eventually have $650 million in funding to address the area of obsolescence and the use of ASIC technology to emulate primarily retiring standard logic and linear products. This program will be managed at the Sacramento Air Logistics Center in Sacramento, California, pooling funding across many U.S. Air Force avionic program offices to achieve economies of scale.

©1990 Dataquest Incorporated February

Microcomponents

OVERVIEW

Military and aerospace applications have emerged as very fertile ground for the standard digital logic LSI/VLSI devices known as microcomponents. OEM and government technologists have recognized the advantages of highly integrated standard solutions to address their needs for embedded control, data and bit manipulation, signal processing, man-machine interfacing, and communications. These integrated solutions offer the advantages of high performance, reduced board space and power consumption, standardization, and programmability. Likewise, depending on the level of customization required, they are coexisting with ASICs with standard cores in many applications.

Pressure to standardize hardware and software across US and NATO systems has brought additional importance to microcomponents. Standards such as MIL-STD-1750A, 1553B, and Ada are affecting nearly every new program and continue to be an important factor in upgrade programs as well. With the adoption of the standard military drawing program (SMD) and eventually a qualified manufacturer list (QML) system in the United States, the incorporation of state-of-the-art microcomponents into systems should be an easier process in the future.

APPLICATIONS

The military and aerospace applications for microcomponents continue to proliferate as these devices appear in almost every type of equipment. In either user-programmable or embedded-control situations, the ability of microcomponents to offer autonomous design solutions is extending the capabilities of many classes of equipment. In some cases, they are displacing SSI/MSI controls; in others, they provide an entirely new capability of programmable control. Aircraft avionics (e.g., controls, electronic warfare, radar) account for an estimated 44 percent of all microcomponent use. Specific equipment applications include the following:

- General-purpose data processing (e.g., IBM, Unisys, VME)
- Neural networks
- Airborne mission computers
- Airborne generic computing modules
- Flight data computers
- Fire control/targeting computers
- Navigation processing (e.g., GPS)
- Identification—Friend or Foe (IFF) processing
- Radar/sonar/FLIR signal processing
- Passive RF/IR signal processing
- Display terminals—Head-up displays
- Data storage
- Integrated systems (e.g., INEWS, ICNIA)

©1990 Dataquest Incorporated August

- Warning receivers
- Countermeasure systems
- Data/voice communication processing
- Satellite attitude/payload management
- Smart bombs/mines
- Missile/RPV/launch vehicle flight control

PRODUCT AND TECHNOLOGY OVERVIEW

General Technology Trends

Key technological trends for microcomponents include the continued introduction of higher-performance architectures, specialized architectures (e.g., graphics processors), design automation and simulation tools for use on design environment computers, high-level language compilers (e.g., Ada, LISP) and the employment of advances in process technology.

As submicron CMOS processes (e.g., VHSIC 2, 0.5 micron) become available, the densities of complex processors can easily reach 100,000 gates and on-chip clock rates can run at 100 MHz. Many of the industry-standard architectures either are being redone in CMOS or are being transferred to newer CMOS processes for performance improvements. The new generation of bipolar processes, which are capable of 20,000 gate/IC densities, will be used to create products for performance-sensitive applications.

BiCMOS is finding its way onto CMOS versions to help alleviate processing and I/O bottlenecks. Digital GaAs, which is capable of 15,000 gates per IC, is being used to implement many DSP functions, bit-slice processors, 32-bit microprocessors, and fiber-optic multiplexer control.

The packaging technology already developed for high pin-count gate arrays (surface-mount chip carriers and PGAs), will directly benefit microcomponents. Developments in radiation hardening such as improved substrate insulating techniques, harder bulk processes, and circuit design will further propagate microcomponent applications into severe environments.

Standards

Standards, or industry and government specifications, whether they are de facto or mandated, affect a large percentage of the market for microcomponents. Standards (Mil-Spec or otherwise) have a pronounced influence on instruction set architectures (ISAs), data communication, and software.

As electronic systems have proliferated on the various platforms (e.g., aircraft, ships, submarines, and tanks), problems with interoperability, maintenance, and obsolescence have become smothering. Therefore, standards such as ARINC and MIL-STD have emerged in an attempt to stabilize the problems noted above. The most important standards affecting microcomponents are those concerning structured design techniques (modularity), hardware transparency (form, fit, and function substitution), bus structures, data communication, and high-level language software (e.g., Ada).

©1990 Dataquest Incorporated August

STATUS AND TRENDS

The following paragraphs examine some of the more important market and technological topics concerning military/aerospace microcomponents.

Avionics

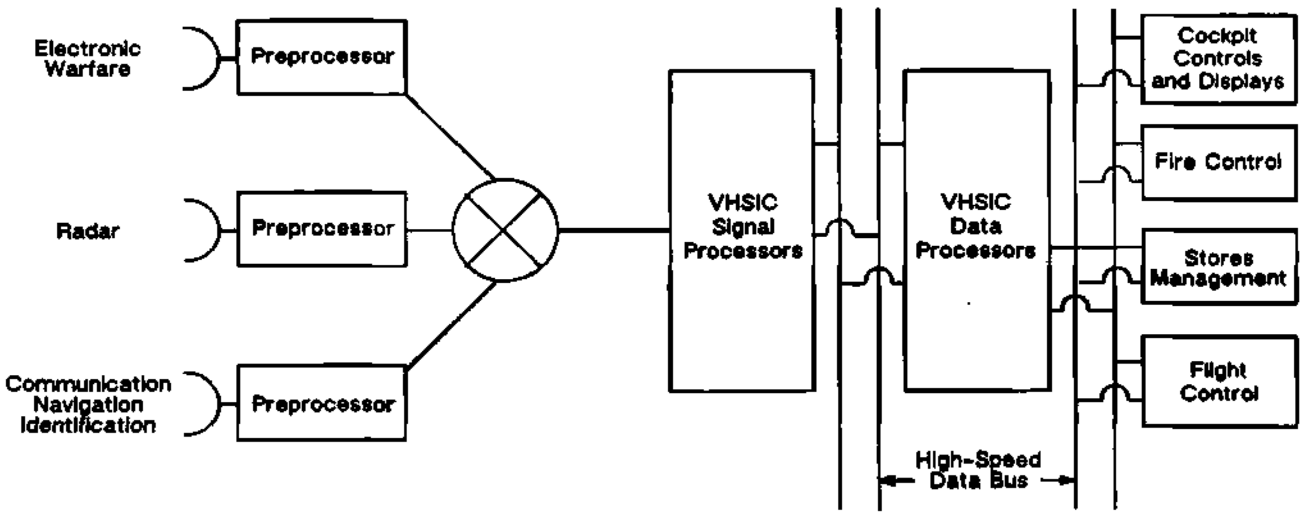
One important area of microcomponent development is driven by the military avionics industry. The twin events of aircraft upgrades (e.g., improved radar and navigation) and a new generation of digitally controlled aircraft entering production in 1990s (e.g., ATF, ATA, EFA) represent a tremendous force in shaping microcomponents. In the United States, the VHSIC program, the air force's Pave Pillar program, and the Joint Integrated Avionics Working Group (JIAWG) are key forces driving the specifications that affect microcomponents.

The JIAWG is responsible for coordinating common requirements with the armed services and with the avionics suppliers. At the heart of its work is a modular avionics architecture that can be configured to specific needs and allows upgradability to newer technologies. A block diagram of JIAWGs Advanced Avionics Architecture (A3) is shown in Figure 1. The current version of this architecture is known as Common Avionic Baseline III (CABIII).

Committees from the Avionics Systems Division of the Society of Automotive Engineers have been given the task of designing specific standards for a 32-bit ISA and a high data rate communication protocol and scheme including fiber-optic techniques.

Figure 1

Advanced Avionics Architecture



Source: US Department of Defense

©1990 Dataquest Incorporated August

Future output from these groups will have a significant impact on trends in the 32-bit microprocessor market (and associated peripheral ICs) and the data communications market. Currently, the Intel 80960 and the MIPS R3000 are the selected computing standards for JIAWG programs. The pressure is on to resolve these issues quickly in order to benefit the aircraft programs currently in development.

VHSIC Standards

Many standards that have emerged from the VHSIC program are impacting the VLSI microcomponent market. In particular, these include bus standards, the 16-bit ISA standard (MIL-STD-1750A), the VHDL hierarchical design language, and a cell library for standard building blocks (especially signal processing). Figure 2 describes generally how VHSIC ICs will be applied to avionics modules and systems.

The MIL-STD-1750A Standard

MIL-STD-1750A is the principal 16-bit computing standard that applies to chips, boards, and subsystems used in NATO electronics. It was pioneered by the US Air Force and has since found use in all the US services, many non-US NATO programs, and many of the European civilian space programs as well. The US Navy uses MIL-STD-1397 for its AN/UYK digital computers. Table 1 is a partial list of programs in which 1750A hardware is employed.

The specification for MIL-STD-1750A delineates the following:

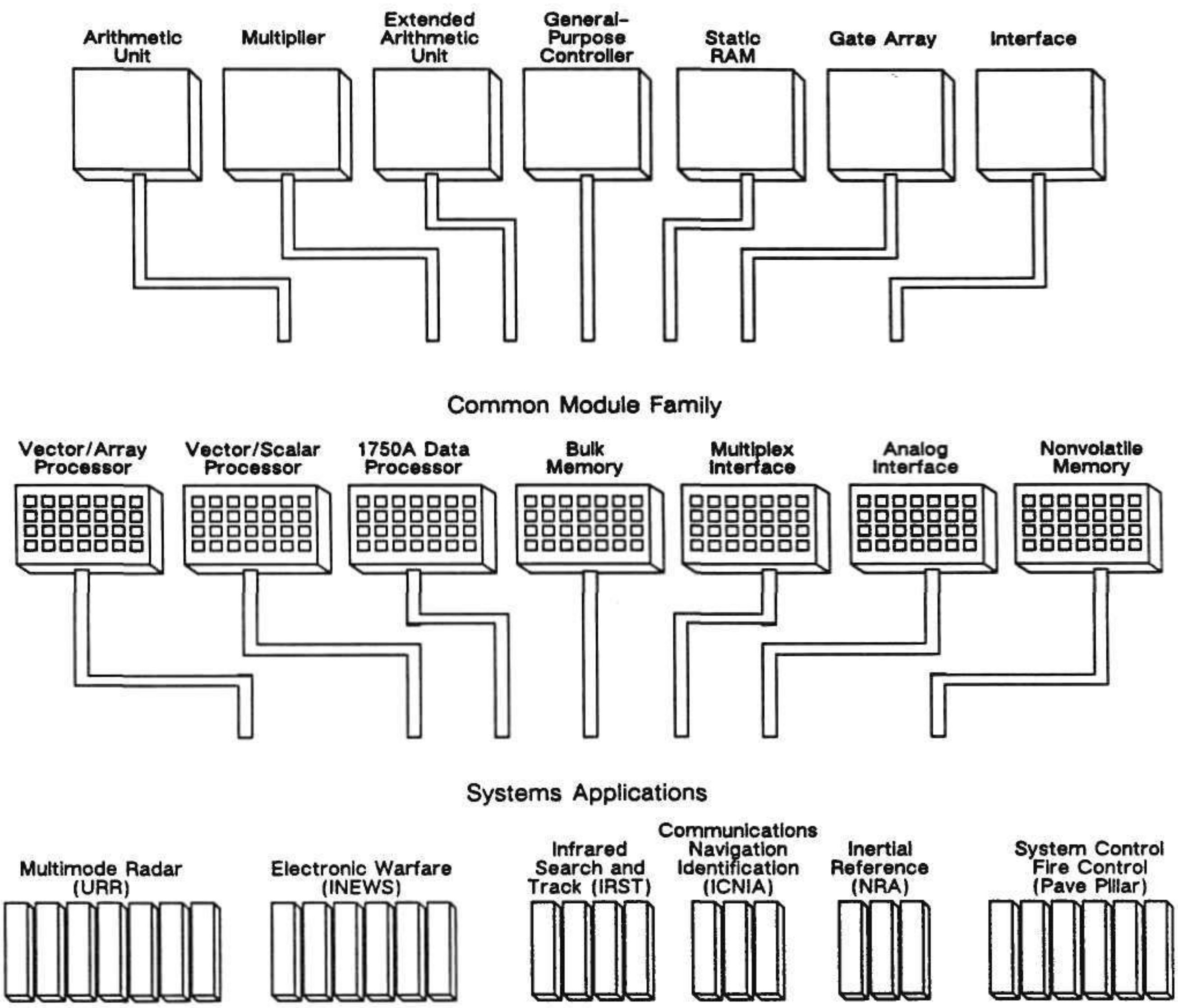
- Requirements for real-time operation
- Use of Ada, the US DOD standard high-level language
- A set of 288 instructions
- Acceptable word formats and types of data
- A uniform set of internal registers
- 16 interrupts and service details
- Multiprocessing requirements
- Graceful recovery from faults

The 1750A specification does not state processing speed, technology, number of chips, or power requirements. It leaves these aspects of implementation of a particular controller to the discretion of the contractor.

Trends in 1750A offerings include a movement toward faster speeds in the 3-mips range, the use of power-conserving CMOS process technology, the development of rad-hard bulk and SOS/SOI versions, and the use of versions that emulate the standard. Table 2 presents a listing of 1750A suppliers and the types of offerings. Many of the offerings are tested and validated by the Systems Engineering Facility (Seafac) at Wright-Patterson Air Force Base in Dayton, Ohio. A Seafac certification entails a series of benchmark software execution tests done over the military temperature range to determine a mips figure of merit. The two primary benchmark tests employed are the Digital Avionics Information System (DAIS) and the Szewerenko mix tests.

Figure 2

VHSIC Chip Set



Source: US Department of Defense

Table 1

MIL-STD-1750A Applications

System	Company
F-16 C/D Digital Flight Control Computer	Allied-Signal
F-16 MSIP	Delco, Teledyne
F-16 C/D Radar	Hughes, Westinghouse
F-16 Blanker Unit	SCI Systems
F-16 Stores Management System	General Dynamics
F-16 Head-Up Display for LANTIRN	Marconi
F-15 E AP-1R LRU	IBM
F-15 Radar	Hughes
ATA Mission computer	IBM
F-4 G Wild Weasel	Unisys
F-4 Navigation Weapon Delivery System	TBD
B-2 Modular computers	Unisys
LANTIRN Pod	Delco, Fairchild Weston
C-5B Radar	Delco
HH-60D	Delco
Pave Tack	Fairchild Weston
MATE	Fairchild Weston, Unisys
Pave Mint	Sanders
ALQ-189 F-111	Sanders
AN/AYK-18 F-111 Computer	Singer Kearfott
MILSTAR	Teledyne
B-1B Radar	Westinghouse
E-3 IRDC	Westinghouse
VHSIC Avionic Modular Processor (VAMP)	Westinghouse
MAST 1750: Space Applications	SCI Systems
Advanced Cruise Missile	General Dynamics
CAB-16 ATF, ATA, LHX	Unisys
AFWAL Module	Westinghouse, IBM, TRW
Electro-Optic Processor/Army Missile	Texas Instruments
M-1 Tank Upgrade	Texas Instruments
Small ICBM	TBD
Avionics Test Equipment	Allied-Signal
SCP-STAR	GE/RCA
European Space Agency (Ariane, Hermes)	Various

TBD = To Be Decided
Source: US Air Force, Dataquest (August 1990)

Table 2

MIL-STD-1750A Processors

Company	ID Number	Chip(s)	Board	Subsystem	Comments
Delco	Magic 5		x	x	7.5-10 mips
Elisra	SBC 1750/M			x	
National Semiconductor	59450/51/52	x	x		
IBM FSD	AP101/102		x	x	
LSI Logic	L64500/550	x			1.5 mips
McDonnell-Douglas	MDC281	x	x		3-chip hybrid
Mikros	MKS1750/SO	x	x	x	0.25 mips
Performance Semiconductor	PACE 1750A	x	x		1.3-5 mips
ROLM	7750		x	x	
Sanders	RTM-1750A			x	
Teledyne	TD1750		x	x	
TI	VHSIC	x	x		VHSIC, 3+ mips
Tracor			x		
TRW		x	x		VHSIC, 3+ mips
UTMC	1750AR	x	x		0.75 mips
Westinghouse	VP-2	x	x		VHSIC, 3+ mips
Marconi	MDC 17504	x			SOS
Control Data Corp.	444 CDU			x	
Fairchild Weston	1750A			x	
Harris	FLEX-MATE	x		x	
Honeywell	H1750A	x		x	
MATEX/TMI	1750			x	
GE/RCA	RCA RCPIIC	x	x	x	
Allied-Signal	BX1750A	x	x		1-chip, 50 MHz

Source: Dataquest (August 1990)

A proposed revision to MIL-STD-1750A, known as 1750B, would expand memory addressability (without MMU) to 8 million words, widen the memory word width to more than 16 bits, add more registers, and enhance the floating-point operations. This standard is also being set by the SAE Avionics Systems Division (AS-5).

The application of 1750A chip sets (most commonly a CPU and, for some applications, an MMU) should continue to expand into the mid-1990s. As new aircraft enter production at that time, however, the 32-bit alternatives should start eating into the market for certain applications. Dataquest estimates the dollar consumption of 1750A chip sets to be $26 million in 1989, including captive production (see Table 3). Driven by continued expansion of applications, it is projected to grow to $33 million by 1994. The CMOS 3-mips and greater versions will see the highest growth rate as second-generation implementations of 1750A enter the mainstream. Rad-hard versions also will enter the market for strategic applications.

©1990 Dataquest Incorporated August

Table 3

MIL-STD-1750A Chip Set Consumption

	1989	1994	CAGR 1989-1994
Dollars ($M)	$26	$33	5.0%
Units	28,500	50,100	11.9%
ASP	$912	$658	(6.3%)

Source: Dataquest (August 1990)

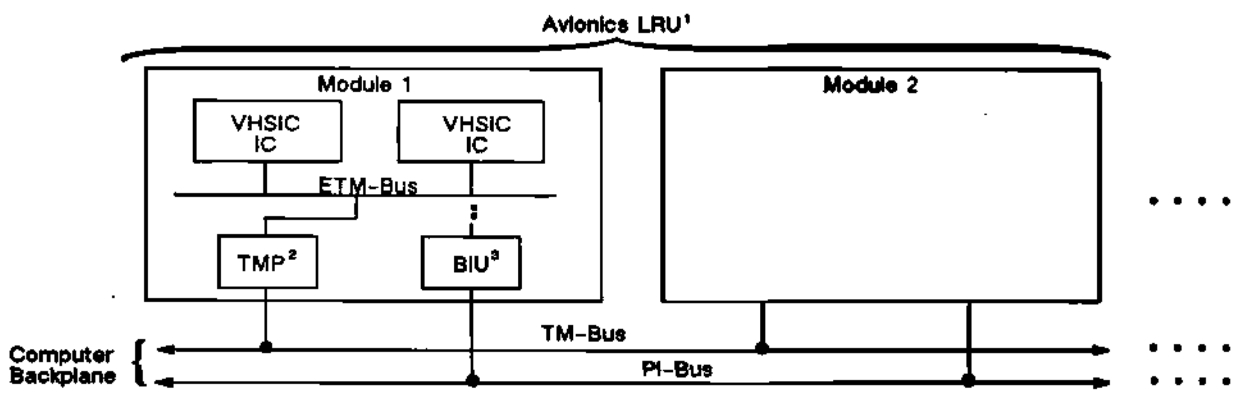
Bus Controller ICs

As part of the VHSIC Phase 2 program and its standard for interoperability, three bus standards were developed—one for data communication and control, called the parallel interface (PI) bus, and the other two for testing and maintenance, known as the test and maintenance (TM) bus and the element test and maintenance (ETM) bus. The ETM bus connects specific VHSIC ICs via a built-in-test (BIT) interface on the individual ICs. Only the PI bus and TM bus would need special control ICs. Figure 3 shows how these buses would operate.

Similar to TM is the JTAG or the IEEE 1149 test standard, which will also require control ICs. Market acceptance over the next few years will determine a winner between TM and JTAG.

Figure 3

VHSIC-Derived Bus Standards



[1] Line-Replaceable Unit
[2] Test and Maintenance Processor
[3] Bus Interface Unit

Source: GOMAC Paper, Honeywell, TRW, Navy Research Lab, Dataquest (August 1990)

The PI bus is a backplane bus standard for avionic data processing modules that allows the connection of up to 32 modules and can operate in the 12.5-MHz to 25-MHz range. The bus can operate with either 16- or 32-bit data paths, and its specifications are a modified version of the IEEE standard 896 Future Bus. Each connection to the bus will require at least one controller IC. Several programs have endorsed the use of the PI bus including JIAWG, the US Air Force Common Signal Processor (CSP), the Advanced Tactical Fighter (ATF), the Army Combat Vehicle Integration System (CVIS), the LHX, and the ATA aircraft.

The PI bus will compete with the VME and Multibus II standards to gain acceptance, and it is likely that some coexistence will occur. VME is currently the strongest bus standard with the most use. PI bus has been accepted as the ARINC bus standard of the future for the civil airliner industry. The following companies have been working on PI bus controllers:

- IBM
- Texas Instruments
- Honeywell
- Unisys (gate array foundered outside)
- Intel
- IBM

The TM bus is a backplane bus standard for test and maintenance signals. Operating at up to 6.25 MHz, it works in conjunction with the individual modules and their embedded ETM bus and data.

Microprocessors

Currently, the most popular bit-width microprocessor used for military and aerospace applications is 16 bits. By the mid-1990s, 16-bit MPU growth is expected to slow down as 32-bit components, designed into systems during the late 1980s, will displace many 16-bit applications. However, it will not be unusual to find 16- and 32-bit functions coexisting on many platforms in the 1990s.

Floating-point units (FPUs) are used in many compute-intensive applications. In some cases, this function either appears on-chip (e.g., 1750A) or is implemented with run-time software algorithms. For military/aerospace applications, we estimate that hardware FPUs are used in 70 percent of all applications.

Although there are many 16-bit microprocessor families for high-reliability use, the following are the most popular and are mentioned most often in our surveys:

- 68000
- 8086/80186/80286
- Z8000
- MIL-STD-1750A

The 32-bit market is still emerging, and key design wins for the 1990s are being fought for at present. Tables 4 and 5 list some of the 32-bit offerings on the market and some of their comparative features, respectively.

©1990 Dataquest Incorporated August

JIAWG has been tasked by the United States Congress to coordinate the development efforts of electronics systems for the ATF, ATA, and LHX programs. In that role, JIAWG has chosen twin standards, the Intel 80960 and the MIPS R3000. A final standard still may be designated when the ATF and LHX programs have chosen their production teams.

An important R&D project for microprocessors is the RH32 program sponsored by Rome Air Development Center (RADC). Its purpose is to develop a rad-hard 32-bit microprocessor. Honeywell and TRW are the contractors on the $8-million-each RH32 program. The purpose of Phase 2 of RH32, to be completed in November 1991, is to define architectures and design evaluation circuits that meet a 20-mips benchmark. The benchmark is based on the DARPA-developed MIPS computer system architecture. Two contractors are expected to continue with the Phase 2 silicon implementation contract. The significance of this program is the development of standards and technology for rad-hard environments such as space, strategic and tactical missiles, and avionics.

Table 4

32-Bit Microprocessor Characteristics

Manufacturer	Device	Transistor (K)	Die Size	Clock (MHz)	Process	Package	Pins
AMD	29000	206	418 x 418 mils	25	1.2u CMOS	PGA	169
Acorn	VL86C010	27	226 x 228 mils	12	2u CMOS	PLCC	84
Cypress	7C601	72	300 x 300 mils	33	0.8u CMOS	PGA	207
Fujitsu	S-25	51	400 x 400 mils	25	1.2u CMOS	PGA	179
Hitachi	HD32	300	NA	NA	1.3u CMOS	NA	NA
IDT	79R3000	100	400 x 400 mils	25	1.2u CMOS	CFP	172
Inmos	T800	208	434 x 346 mils	20	1.2u CMOS	PGA	84
	T414	143	344 x 379 mils	5	1.5u CMOS	PGA	84
Intel	80960KB	375	390 x 390 mils	25	1.5u CHMOS	PGA	132
	80386	275	380 x 380 mils	25	1.5u CHMOS	PGA	132
Intergraph APD	CLIPPER	132	NA	50	2u CMOS	LCC	132
Motorola	88100	165	440 x 440 mils	20	1.5u HCMOS	PGA	181
	68020	200	131.3	33	2.25u CMOS	PGA	114
	68030	300	378	25	1.2u HCMOS	PGA	128
National	32532	370	533 x 441 mils	25	1.25u CMOS	PGA	175
	32332	90	323 x 281 mils	15	2.1u NMOS	PGA	84
	32C032	NA	348 x 315 mils	10	2.4u CMOS	LCC/PLCC	68
	32032	70	302 x 270 mils	10	2.1u NMOS	LCC/PLCC	68
NEC	uPD70632 (V70)	385	14.35 x 14.24mm	20	1.5u CMOS	PGA	132
Zilog	Z80000*	93	385 x 390 mil	10	2u NMOS	LCC	68

NA = Not available
*Also known as Z320
Source: Dataquest (August 1990)

Table 5

Hardware-Related Features

Company	Product	Bus Type	MMU	Cache	Multiprocessor Support	Segmented Addressing	Paged Addressing	Pipeline (Queue)	Dynamic Bus-Sizing	I/O Addressing
AMD	29000	Nonmultiplexed	On-chip	Branch target	Yes	No	Yes	4-word instruction prefetch	No	Direct and memory mapped
Cypress	CY76C01	Nonmultiplexed	Off-chip	128 Kbyte	Yes	No	Yes	4 stage	NA	Memory mapped
Fujitsu	S-25	Nonmultiplexed	Off-chip	Off-chip	Yes	NA	NA	4 stage	NA	Memory mapped
IDT	79R3000	Nonmultiplexed	On-chip	Off-chip	Yes	NA	No	5 stage	NA	Memory mapped
Intergraph APD	CLIPPER	Multiplexed	2 chips (in module)	Data and instruction (part of MMU)	Yes	No	Yes	4-stage pipeline	No	Memory mapped
Inmos	T800	Multiplexed (memory bus)	NA	None	Yes	NA	NA	2-word instruction prefetch	No	Memory mapped
Intel	80386	Multiplexed	On-CPU	None	Yes	Yes	Yes	16-byte queue	Yes	Direct and memory mapped
	80960KB	Multiplexed	NA	512 bytes (instruction)	Yes	No	No	3-stage pipeline	Yes	Memory mapped
Motorola	68020	Nonmultiplexed	MC68851	Instruction (256 byte)	Yes	No	Yes	3-stage pipeline	Yes	Memory mapped
	68030	Nonmultiplexed	On-chip	Instruction Data (both 256 byte)	Yes	No	Yes		Yes	Memory mapped
	88100	Nonmultiplexed	Off-chip (88200)	(16K x 8 on each 88200)	Yes	No	Yes	3-stage instruction	NA	Memory mapped
National	32032	Multiplexed	32082	None	Yes	No	Yes	8-byte queue	No	Memory mapped
	32332	Multiplexed	32382	None	Yes	No	Yes	20-byte queue	Yes	Memory mapped
	32532	Nonmultiplexed	On-chip	Data and instruction	Yes	No	Yes	4-stage pipeline	Yes	Memory mapped
NEC	V70	Nonmultiplexed	On-chip	TLB*	Yes	No	Yes	6-stage pipeline	Yes	Direct and memory mapped
Zilog	Z80,000	Multiplexed	On-CPU	Data and instruction	Yes	Yes	Yes	6-stage pipeline	No	Direct and

*Translation lookaside buffer
NA = Not Available
Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Technology Trends

Some of the trends in advanced processors and peripherals include the following:

- RISC—This is the use of architectures with less than 100 instructions and simpler instructions. This technology is argued to be computationally faster in certain applications.
- Pipelining—This involves architectures that allow the concurrent fetching, decoding, and execution of instructions.
- Registers—To support high-level languages, arrays of multipurpose registers are available as well as are those for debugging, for tracing, and for configuration.
- Virtual memory—This is the adoption of the mainframe-style technique of expanding memory addressability.
- Memory management—The trend is toward either closely coupling the MMU or actually bringing its functions on-chip.
- Dynamic bus sizing—This allows the peripherals or memory to transmit varying widths of data on the bus.
- Caching—In general, the use of cache for performance enhancement is no longer an issue. However, issues still not commonly agreed upon are whether it should be on or off the CPU, its depth, and the use of separate instruction and data caches.
- Floating point—The trend is for users to utilize floating hardware. It is appearing in three forms: on the CPU chip, on a separate proprietary chip, or on a third-party chip (e.g., Weitek).
- Graphics—Graphics ICs are used in cockpit displays, special-purpose displays, image processing and display, simulators, and trainers. These ICs offload the main CPU and are dedicated to graphics processing; often programmable in high-level languages, they can act as a subsystem and can execute everything from the highest level graphics commands and data base manipulation through the actual CRT control itself.
- Other peripherals—Emerging are military applications of SCSI and other standard controllers for disk storage, data error detection and correction ICs (EDACs), and a host of DSP-oriented circuits. These devices include multiplier/accumulators, fast Fourier transform (FFT) ICs, and two-dimensional signal processors for image processing.
- Military features—Robust features such as fail-soft capabilities, extra buffering, parity bits on data paths, and extended temperature range operation are emerging more frequently, thanks to modern CAD capabilities.

Microcontrollers

Microcontrollers provide a highly integrated compute-and-control engine for real-time space-constrained applications. These applications fit many of the situations encountered in aircraft, missiles, and other platforms. The most predominant use of microcontrollers is in the 8-bit width but 16-bit-high performance offerings are appearing in greater frequency.

©1990 Dataquest Incorporated August

The Intel 8048 and 8051 families of 8-bit microcontrollers have come up in our surveys as the most popular with users. The National Semiconductor COP and Motorola 68XX are widely used also.

Technology Trends

Technological trends in microcontrollers include the following developments:

- Emergence of 16-bit offerings (e.g., Intel, National, Harris)
- Expansion of onboard ROM and RAM
- Incorporation of onboard EEPROM, A/D, UARTs
- Development of semicustom versions (e.g., variable memory, I/O configurations)
- Emergence of easier-to-use PC-based development systems

Standard Data Communication ICs

As microprocessors and controllers have expanded in usage, so have standard LSI/VLSI communication components that implement various standards. MIL-STD-1553B is perhaps the most well-known standard; however, its high-speed upgrade, with fiber-optics capability, is being formulated for use in the 1990s. The ARINC 429/629 data bus standard is an important application for commercial aviation. The following paragraphs present more detail on some of the more important trends in military/aerospace data communications.

MIL-STD-1553B

An important area in military data communication concerns the proliferation of the MIL-STD-1553B data bus standard. About 15 years old now, it is the primary data communication standard for avionic applications. Initially available in hybrid form, it is available now in an array of IC offerings.

The 1553B bus is a dual redundant bus, with shielded twisted-pair cable, capable of operating at 1 Mbps. Data are pulse code modulated using the Manchester technique and time division multiplexed. Data transmission is half-duplex and done asynchronously. The three types of interfaces to the bus are the bus controller (BC), the bus monitor (BM), and the remote terminal (RT). The controller initiates data transfers on the bus, the monitor extracts data as necessary, and the remote terminal responds to transmission commands from the controller. In a certain mode of operation, any terminal can be a controller and control can be passed from RT to RT. A controller can serve up to 31 remote terminals, in turn serving up to 30 subsystems.

Table 6 lists many of the avionics platforms currently employing the 1553B standard. In addition, the navy has adopted it for many of its shipboard networks and for the Trident missile program. The army has adopted it for some of its fire-control systems, and many of the C^3I programs use it as well.

©1990 Dataquest Incorporated August

Table 6

Avionics Platforms Utilizing the 1553B Data Bus

US Programs		European Programs
F-4	F-5	JAS-39
F-14	F-15	Toronado
F-16	F-18	
F-20	F-111	
C-5	C-17	
C-130	B-52	
B-1B	A-4	
EA-6B	CH-47	
UH-60	SH-60	
AH-64	V-22	
AV-8B	SR-71	
E-3	Space Shuttle	

Source: *Defense Electronics*

Semiconductor-derived implementations for 1553B can take many forms, and one or all of the various functions can be incorporated into monolithic or hybrid form. System designers have the choice of modular (e.g., separate transceivers, encoders, RTs) or highly integrated VLSI versions, which incorporate many features on the same IC or hybrid. Table 7 lists companies with 1553B product offerings.

Table 7

1553B Product Offerings

Company	Version
Aeroflex	Hybrid
Allied-Signal	Monolithic/Hybrid
Harris	Monolithic
ILC-DDC	Hybrid
Intel	Monolithic
Marconi/Circuit Technology	Monolithic/Hybrid
Micro-Rel	Monolithic/Hybrid
Plessey	Monolithic
Rockwell	Monolithic
Standard Microsystems	Monolithic
UTMC	Monolithic
VLSI Technology	Monolithic

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Table 8

MIL-STD-1553B IC and Hybrid Consumption

	1989	1994	CAGR 1989-1994
Revenue ($M)	$41M	$43M	1.0%
Units	53,500	23,500	6.6%
ASP	$766	$585	(5.3%)

Source: Dataquest (August 1990)

Table 8 presents the forecast for the MIL-STD-1553B shipments, including both hybrid and IC versions. Estimated at $41 million in 1989, this market is expected to reach $43 million by 1994. An estimated 53,500 connections were shipped in 1989; this is expected to increase to 73,500 by 1994. Drivers for growth will be avionic programs entering production and nonavionic uses for the army and navy. Currently, the ATF, ATA, and LHX programs are using 1553B devices in their designs. These new aircraft designs most likely will be using a high-speed bus standard also as a high-speed backbone to complement 1553B usage. The monolithic IC portion of this market is expected to continue emerging and displacing much of the current market for hybrid 1553B ICs.

High-Speed Ring Bus

Recognizing that the 1553B standard needed to be improved upon, the AS-2 committee of the SAE has established the high-speed ring bus (HSRB) as a standard. This standard, known as AS4074.2, is in competition with MIL-STD-1773 and the Token-Ring AS4074.1 standards. The HSRB features a 50-Mbps data rate for wire implementations and a 100-Mbps rate for fiber-optic versions. It also features a quick token passing protocol and very robust reconfiguration algorithm (see Figure 4). If any of the dual rings is damaged, the system can automatically reroute around the problem. The RIU (ring interface unit) and RIM (ring interface module—switch) in this example are the functional LSI/VLSI ICs required for implementation. Westinghouse and ILC Device Data Corporation have recently presented papers on the subject.

Other Data Communication Trends

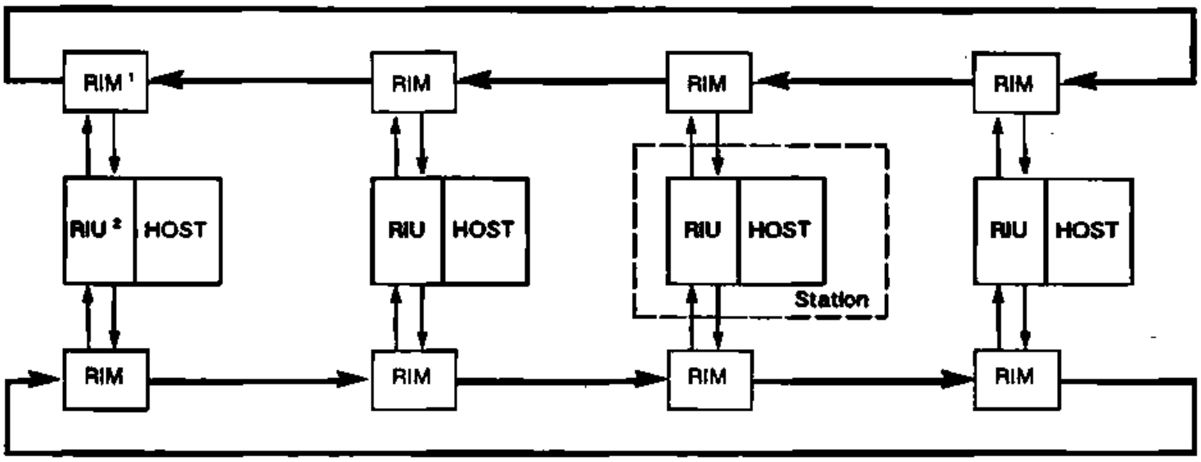
Several other military applications are emerging for communication ICs. Spilling over from the commercial world will be the popularity of LANs for many nonavionic applications. Currently, Ethernet has the largest installed base, but token ring is gaining in popularity. IC modems, including RF and fax versions, also are finding increased use as they displace entire boxes. In addition, the military is evaluating ISDN for upgrading its communication networks. The MIL-STD-1760 standard for stores interface also is an IC opportunity.

Many specialized data communication functions will most likely be implemented with ASICs (e.g., gate arrays moving to cell-based ICs). These include an entire class of functions such as data encryption and spread spectrum functions. This technology is strictly governed by the National Security Agency (NSA) in the United States.

©1990 Dataquest Incorporated August

Figure 4

HSRB Counter-Rotating Ring Topology



[1] Ring Interface Module
[2] Ring Interface Unit

Source: Westinghouse Electronic Systems Group

Digital Signal Processing (DSP)

Broadly, the digital signal processing (DSP) marketplace consists of a tremendous variety of different semiconductor product offerings targeted at a tremendous variety of end applications. The need for different DSP semiconductor products is driven by the performance requirements of DSP systems, where sample rates range from hundreds of hertz at the low-performance end to hundreds of megahertz at the high-performance end. Historically, this has allowed plenty of room for manufacturers to search for unique market niches in which to target their business.

Currently, the products serving the end DSP marketplace are undergoing some fundamental changes. It is important for semiconductor manufacturers to understand and react effectively to these changes, or risk disastrous business consequences. Highlights of these changes are presented in this section.

The semiconductor DSP marketplace is characterized by four different product categories, each addressing a different portion of the user market. Currently, each of these product categories is roughly the same size in revenue. However, the growth rates of these markets are not the same. Nearly 50 semiconductor companies are supplying products to different portions of this market. Very few of these companies have product offerings in all of the product categories; many offer products only in niches within one of the categories.

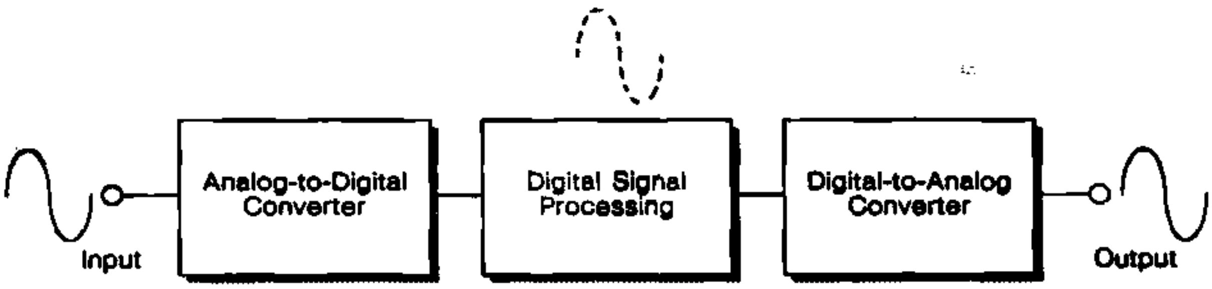
DSP Technical Introduction

Digital signal processing is a technique for manipulating (processing) signals digitally. A simple block diagram of a DSP system is shown in Figure 5. Because the world we live in is analog (i.e., continuous time, continuous sight, continuous smell), converters change the analog world into a digital representation upon which a DSP system can operate. Usually at least one (sometimes both) of these converters is present in a DSP system. Table 9 defines the basic classes of DSP ICs followed by Dataquest.

 ©1990 Dataquest Incorporated August

Figure 5

Block Diagram of a Generic DSP System



Source: Dataquest (August 1990)

Table 9

DSP Product Category Revenue Estimates
(Millions of Dollars)

DSP Microprocessors (DSMPU)
Microprogrammable DSP (MPDSP)
Special-Function DSP (SFDSP)
Application-Specific DSP (ASDSP)

Source: Dataquest (August 1990)

Factors Influencing DSP Revenue Growth

A number of factors are contributing to the continued growth of revenue for DSP products including the following:

- DSP design expertise continues to spread.
- Entirely new applications, which were not practical prior to maturing DSP techniques, have developed.
- Conversion of older analog products to newer, more reliable designs with more features using digital signal processing is taking place. An example is the migration from analog oscilloscopes to newer digital scopes.
- Availability of powerful hardware and software development tools has aided the system designer in incorporating digital signal processing into end products.

©1990 Dataquest Incorporated August

DSP Products

When discussing issues affecting each of the specific DSP product categories, it is important to consider category description, reasons for future revenue growth, major suppliers, trends, and competitive issues. Key issues, organized by category, include the following:

- DSP Microprocessors (DSMPUs)
  - DSMPU products are general-purpose, programmable digital signal processors. They are similar to microprocessor architectures containing hardware multipliers and other architectural optimizations that specifically address the needs of the DSP marketplace.
  - The DSMPU market can expect significant revenue growth through 1994 as design-ins enter production. New floating-point versions will drive growth.
  - The leading military DSMPU manufacturer is Texas Instruments.
  - Analog Devices, AT&T, and Motorola form the core group of "second-tier" DSMPU manufacturers.
  - Technical trends include 32-bit floating-point capability, 50 to 100ns instruction times, Harvard and/or RISC architectural features, and greater than 24-bit external address space.
  - For applications where DSMPUs are sufficiently fast, they will dominate over MPDSPs and ASDSPs on system cost alone.
  - Currently, 13 manufacturers (commercial and military) of different DSMPU architectures are available to designers of DSP systems.
  - Dataquest expects a shakeout in the number of suppliers to this market segment over the next three years, similar to the shakeout that occurred in the microprocessor market in the late 1970s and early 1980s. Ultimately, we expect no more than three major suppliers and two minor suppliers to the general-purpose DSMPU market.
- Microprogrammable DSP (MPDSP)
  - In the past, MPDSP components have been labeled by the industry as "bit-slice" processors. However, the term "bit slice" is somewhat archaic and does not adequately describe the newer 32- and 64-bit processors available today. The primary components which form this category are:
    - Microprogrammable Arithmetic Units (MAUs)
    - Multipliers and Multiplier-Accumulators (MACs)
  - The MPDSP category is heavily populated with IC manufacturers. Sixteen manufacturers supply products to this segment of the market. The leading suppliers are AMD, Analog Devices, IDT, Texas Instruments, TRW, and Weitek.
  - Although overall growth in this market is expected to be relatively flat, a subportion of this market, made up of floating-point multipliers and MAUs, should continue to experience growth.
  - Competitive pressures from products in both the DSMPU and SFDSP categories are the major contributors to the revenue slowdown in the MPDSP market.

©1990 Dataquest Incorporated August

- Special Functions DSP (SFDSP)
  - Products in this category have dedicated (usually not general-purpose) DSP features. They include modems, codecs, speech processors, digital television/circuits, filters, and FFT functions. Some of these functions have been traditionally implemented using analog techniques. This category includes only those devices which implement the functions using DSP architectures.
  - The bulk of the revenue in this category is for modems at present.

- Application-Specific DSP (ASPSP)
  - Products in this category generally are not standard products sold on the open market. Instead, they are usually custom architectures designed using standard cell or gate array techniques for a specific application and user.
  - More than 30 manufacturers are able to supply ASDSP solutions to their customers.
  - Many DSMPU manufacturers are in the process of migrating their early DSMPU architectures into standard cells.
  - Many of the applications now using MPDSP will shift to ASICs constructed from ALUs, MACs, and registers currently in cell libraries.

General DSP Issues

General issues and trends in DSP include the following:

- DSP devices are "design-win" products, much like microprocessors. Manufacturers must work with and support end users in order to secure design slots.
- As device architectures become more sophisticated, product support and application assistance become important issues to end users; in some cases, they become more important than the details of architectural differences between suppliers.
- Across all four DSP product categories, CMOS is the dominant process technology. Alternate technologies such as ECL or GaAs may achieve penetration in small performance niches, but none is expected to displace CMOS in the foreseeable future.

©1990 Dataquest Incorporated August

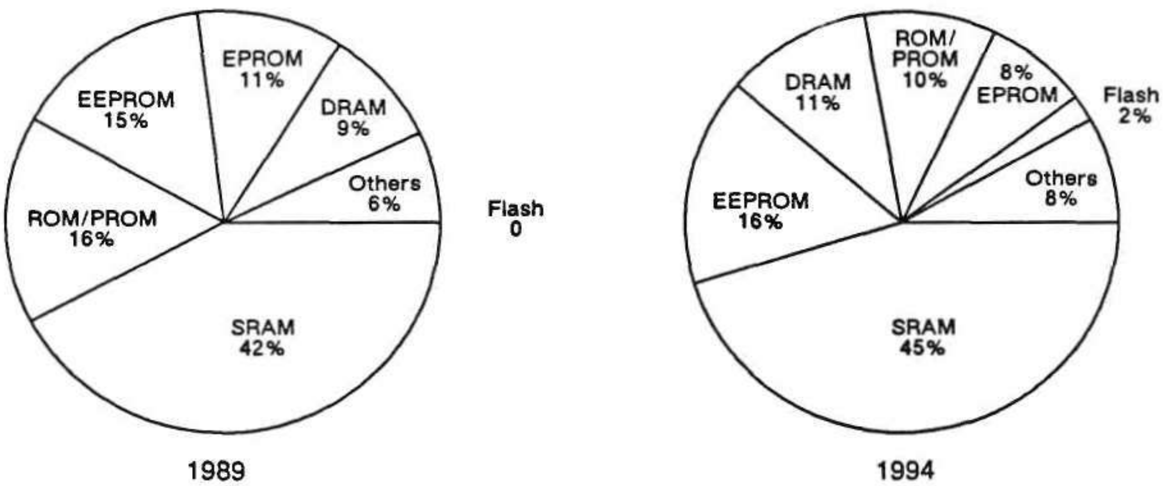
Memory

OVERVIEW

As aircraft, spacecraft, ground vehicles, communications, and weapons systems evolve and are upgraded, their appetite for digital VLSI control is exceeded only by their appetite for semiconductor memory. Used in conjunction with digital signal processing, digital computing, and control, memory's use is proliferating in military applications as it has done already in commercial applications. Volatile memory accounts for 51 percent and nonvolatile memory 49 percent of all semiconductor memory usage in military and aerospace systems. Volatility can be addressed also with the use of battery backup and circuit design schemes (e.g., the use of capacitors). Figure 1 presents a profile of memory usage by type. Dataquest expects static random access memories (SRAMs) to continue to be the largest category of memory used in military/aerospace applications throughout the early 1990s.

Figure 1

Military/Aerospace Memory Dollar Consumption (Bipolar and MOS)



Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

VOLATILE MEMORY

The three principal types of volatile memory technologies are as follows:

- Dynamic random access memories (DRAMs)
- Static random access memories (SRAMs)
- Specialty memories

Dynamic RAMs (DRAMs)

DRAMs traditionally have found limited use in military and aerospace systems, but this situation is changing as new applications have developed, utilizing the economy that they offer in both price and functional density. The traditional factors limiting the use of DRAMs versus SRAMs in mil-spec equipment include their perceived susceptibility to data loss during power glitches and losses, their relative lesser resistance to radiation effects, and their limited temperature range (110°C rather than 125°C).

In recent years, military and aerospace system designers have taken another look at uses for DRAMs and found many circumstances where they would be very appropriate. Suitable applications would be in situations where the environmental factors are relatively benign and where the system's operational life is short. Some of these applications include the following:

- Sonobouys
- Smart decoys/targets
- Selected missiles/torpedoes
- Unmanned aircraft payloads
- Submarine CPUs and signal processors
- Fixed, ground-based CPUs and signal processors
- Fixed, ground-based graphics terminals
- Simulators/trainers (commercial temperature)

Static RAMs (SRAMs)

SRAMs are the primary volatile random access memory used in military and aerospace systems, and they are used in almost all forms of tactical and strategic equipment. The most dominant uses for SRAMs in this market are as main memory, primary and secondary caches, writable control store, data buffers, and, in some cases, bit-mapped memory for graphics and imaging.

©1990 Dataquest Incorporated August

Demand for SRAMs will continue growing as military and aerospace systems continue shifting to digital technology, increasing the need for random access memory to handle real-time computing data storage. Important applications include the following:

- Standard CPUs (e.g., AN/UYK, VME bus)
- Common avionics module families (applied to INEWS, ICNIA)
- Air data/mission avionics computers
- Warning receivers/electronic countermeasure systems
- Fire-control computers (all platforms)
- Signal processing (radar, sonar, infrared, targeting, passive)
- Data communication (all platforms—switching, buffering)
- Missiles/RPV data memory

Specialty Memories

Other important volatile products include first-in first-outs (FIFOs), dual-port RAMs, and video RAMs. Digital signal processing architectures use FIFOs commonly available in 64, 512, 1K, 2K, 4K by 4, 5, and 9 configurations. Versions that allow serial/parallel conversions are being introduced.

Dual-port RAMs are used as common memory between two CPUs (e.g., microprocessors). Offered in x8 and x16 versions, densities up to 32K are available at 35 to 45ns speeds. Many control-system applications (e.g., flight management) find dual ports useful for access to common data and processing flags.

Video RAMs that can serialize data for output to a video screen are becoming popular in graphics applications also. The current mainstream product is 256K in density with a 1Mb version just being introduced.

Consumption Trends

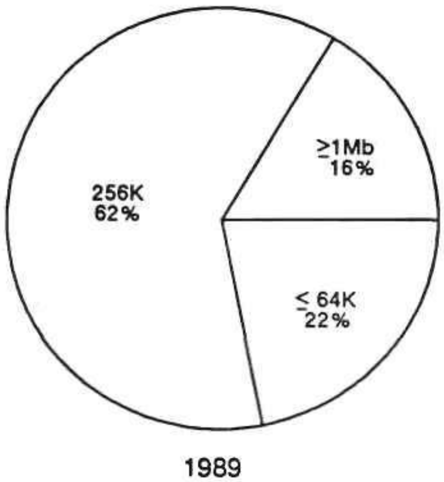
Figure 2 presents estimated DRAM military and aerospace usage by density. Because the bulk of DRAM usage is controlled by merchant suppliers who principally supply commercial uses, the density lifecycles of mil-grade DRAMs are driven mostly by commercial life cycles. The largest category of usage in 1989 was the 256K, with 62 percent of total dollars. By 1994 we expect a shift to the 1Mb level, which will account for 55 percent of all usage.

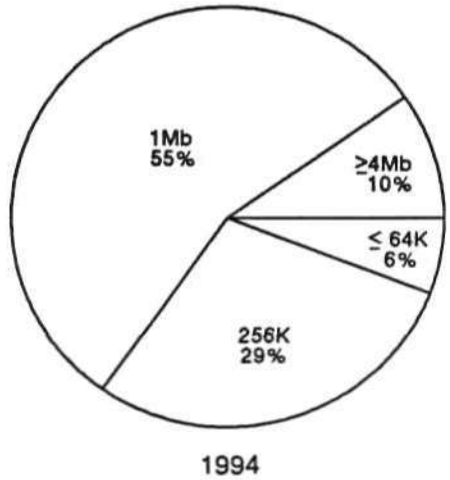
SRAM consumption by density is profiled in Figure 3. Dataquest estimates the largest category in 1989 to have been the 64K density level (64Kx1, 16Kx4, 8Kx8) with 46 percent of dollar consumption. The bulk of consumption is expected to shift to 256K (32Kx8, 64Kx4, 256Kx1) by 1994 as military system upgrades, in particular, acquire that density. Monolithic 1Mb versions in mil-temperature range will also be a factor in usage by 1992. Currently supplied mainly in module form, 1Mb versions and greater will be needed for main memory usage on avionics computers and on general-purpose CPUs in all platforms.

©1990 Dataquest Incorporated August

Figure 2

Military/Aerospace DRAM Dollar Consumption

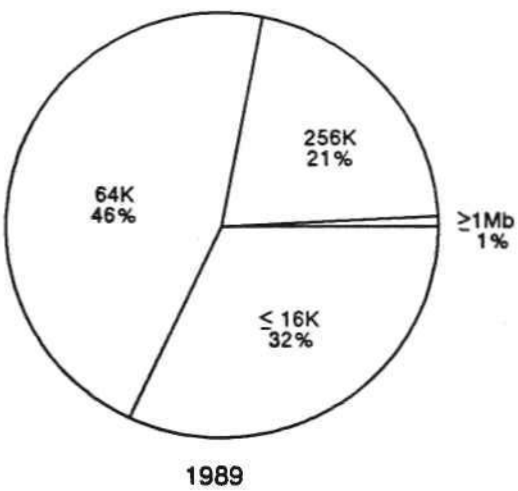


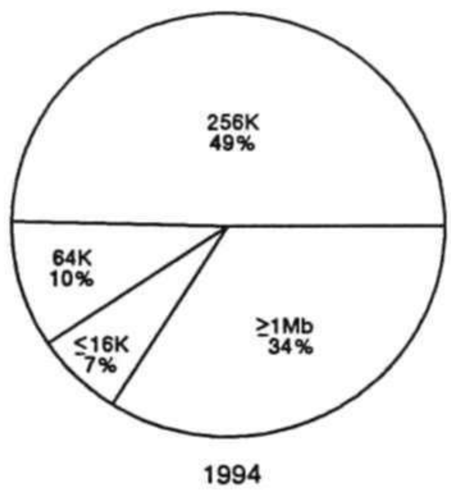


Source: Dataquest (August 1990)

Figure 3

Military/Aerospace SRAM Dollar Consumption





Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Demand for high-speed SRAMs in military and aerospace systems will continue to be strong. With processing speeds climbing into the hundreds of megahertz, higher access times will be required of main and cache memories. The resulting performance demands that we expect for various densities of SRAM are shown in Table 1. With the exception of the 1Mb densities, the majority of SRAM consumption by 1994 will be of technology capable of less than 45ns access

Table 1

Military/Aerospace SRAM Consumption (Percent of Total Dollars)

SRAM Type	1988	1992
16K		
<45ns	35%	76%
≥45ns	65%	24%
64K		
<45ns	33%	72%
≥45ns	67%	28%
256K		
<45ns	29%	60%
≥45ns	71%	40%
1Mb		
<45ns	0	38%
≥45ns	100%	62%

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Product and Technology Trends

DRAM

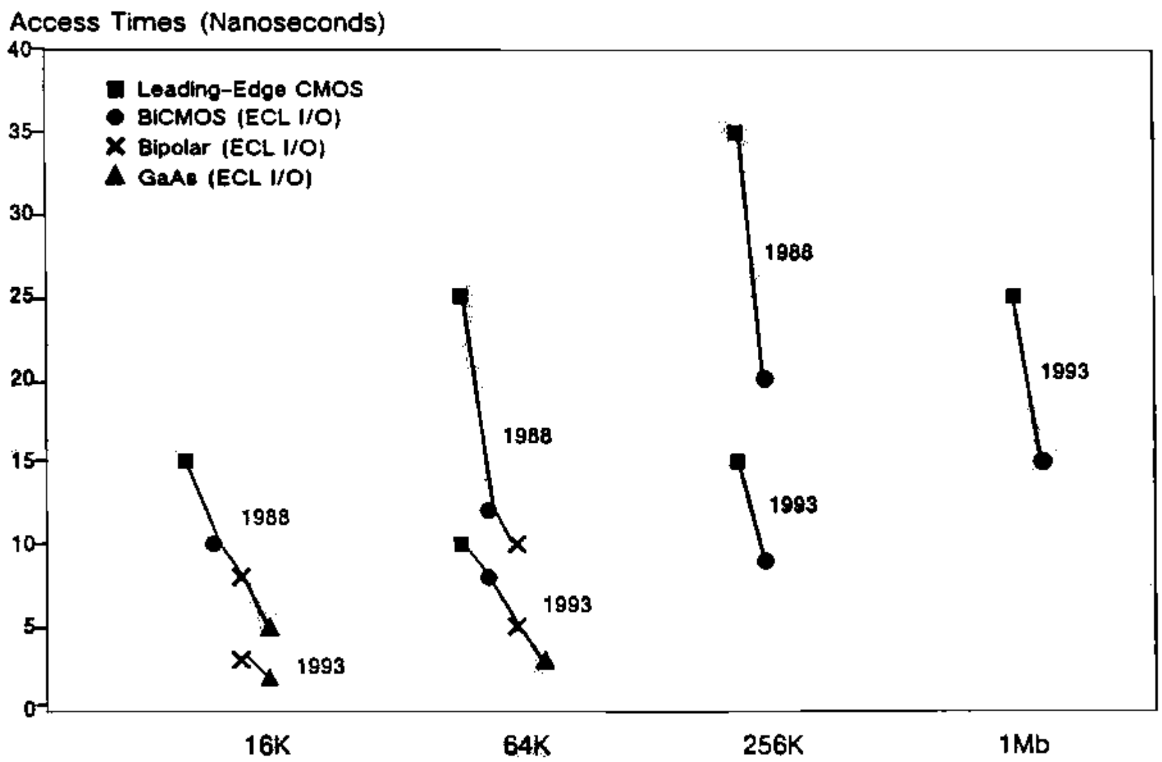
DRAM technology is currently battling on the 16Mb front as 4Mb versions enter the production stage. Issues such as the use of trench capacitor technology and the extension of optical stepper technology to the 0.5-micron range are being worked out. The development and mass production of 16 and 64Mb densities is believed by many experts to hinge on the further refinement of X-ray lithography. Alternate modes of operation including page, fast page, nibble, and static column are becoming more common in each new generation. Access times as fast as 70ns currently are available with 60ns projected for the 4Mb versions. Surface-mount packaging, such as SOJ, is emerging in importance for DRAM consumers.

SRAM

Figure 4 shows trends in performance at a given density for early production (not R&D) in various SRAM technologies. It should be noted that access times for military temperature range memories are typically 20 to 40 percent greater than the commercial range. Performance-optimized CMOS technologies with 1.2-micron features typically had 25ns access times for 64K densities in 1988. By 1993, the same density is expected to be able to achieve 10ns performance with 0.5-micron technology.

Figure 4

Fast SRAM Technology Outlook



Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

BiCMOS is expected to follow a moving window of one to two years in achieving better performance at a given density ahead of CMOS. For a similar 64K density and process feature size, BiCMOS achieved 12ns access times in 1988 and is expected to improve to 7 to 8ns by 1993. The cost of BiCMOS is raised by three to four extra mask layers, in contrast with CMOS, but then lowered by the better production distribution it achieves around faster speeds. The result is that BiCMOS is cost competitive with CMOS at fast speeds.

Bipolar (ECL) SRAMs fall into the performance niche between BiCMOS and GaAs, principally the 5 to 10ns performance area. Given constraints such as power dissipation per package, ECL technology is not expected to proceed beyond the 64K level in the near future, barring further process and packaging breakthroughs.

GaAs will continue its role as the speediest production technology. Currently, it is available in 16K densities with 5ns performance; by 1993, 64K versions are expected to perform at 3ns.

To address the need for higher density and wider (x16) RAM memory, module technology is being utilized a great deal in SRAMs. The new high-speed 32-bit microprocessors are demanding wider and deeper caches and main memory. Modules currently serve a major portion of the 1Mb density market and 2, 4, 8, and 16Mb versions are available. They are offered in monolithic (DIP) pin-outs and SIPs. LCCs are commonly used on SRAM modules with ceramic substrate matching techniques employed to avoid problems with thermal mismatching. A company called Inova Microelectronics has an interesting alternative to module technology that employs connected die (interdie metalization) on the same monolithic piece of silicon and placed in a large package.

Other features such as cache tags and parity (x9 versions) are becoming available. Low-power versions, which can operate on 2 to 3 volts rather than 5 volts, are important for data retention and for battery-operated or backed-up situations.

Radiation hardening is an important issue for SRAMs because of susceptibility to soft errors from single-event upsets (SEUs), which can flip bits caused by high-energy particles. Therefore, technology employing various hardening techniques such as insulating substrates (SOS or SIMOX) is very important for space applications, especially as feature sizes drop below 1 micron.

NONVOLATILE MEMORY

Nonvolatile semiconductor memories are storage devices that retain the state of the data after the power has been removed. Variations include different degrees of user programmability ranging from factory programmed (ROM), to user bench programmability (PROM, EPROM), to in-circuit programmability (EEPROM, FERRAM, and Bubble).

The non-in-circuit programmable varieties are principally used to hold microcode for processors and fixed processor program instructions for operating systems, utilities, and application code. They are often used to store programs utilized in conjunction with microprocessors and microcontrollers doing certain control tasks. So, in effect, wherever MPUs and MCUs go, so do these devices.

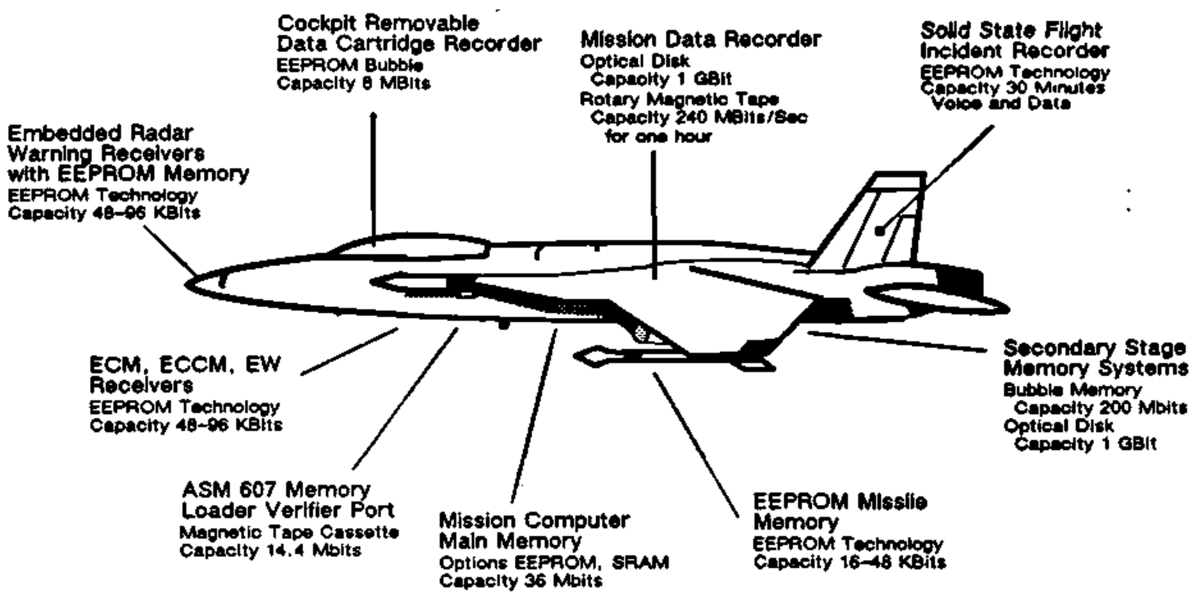
Applications for in-circuit programmable varieties can be the same as for non-in-circuit types, except that in-circuit varieties also can be used for real-time data capture and reprogrammable control functions. In effect, the in-circuit programmable versions compete with volatile RAM for dynamic store-and-retrieve applications.

©1990 Dataquest Incorporated August

Figure 5 shows typical applications of nonvolatile memory on an advanced aircraft. In military/aerospace applications, nonvolatile memory can be used for reprogramming mission parameters (e.g., type of threat, environmental conditions) in various types of equipment, including countermeasures, communication, and missile guidance and control. It can also be used in standard RAM applications as a backup memory to SRAMs or other registers.

Figure 5

Aircraft Applications of Nonvolatile Memory



Source: U.S. Department of Defense

Consumption Trends

EPROM

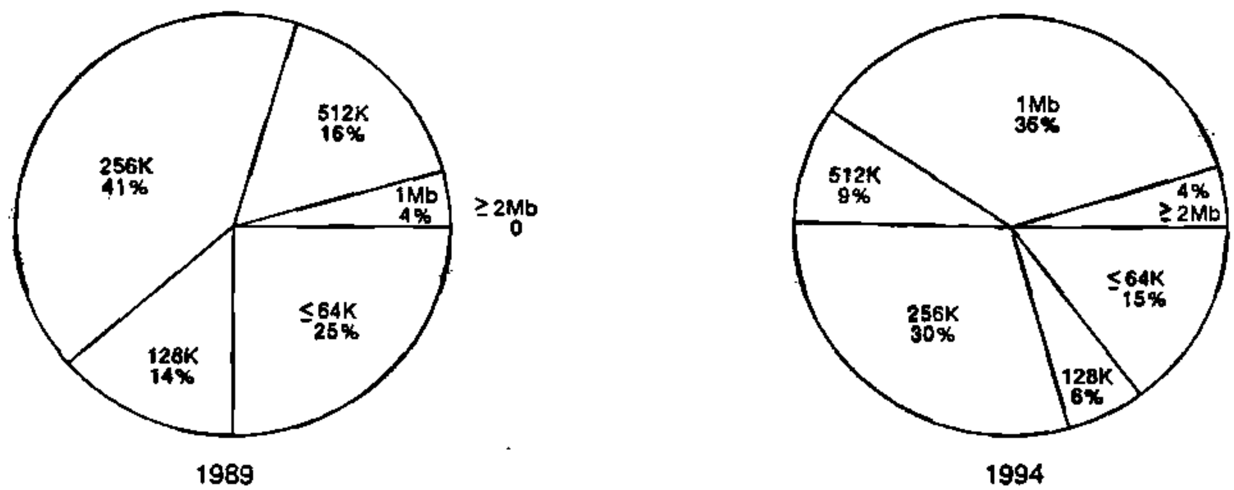
Figure 6 presents the consumption profile, by density, for electrically programmable read only memory (EPROM) devices. The largest single-density usage in 1989 was 256K (32Kx8), with an estimated 39 percent of EPROM consumption. However, with faster processors appearing, faster and x16 versions are needed. We forecast that by 1994, although 256K density will be important still, much of the usage will migrate to the 1Mb level, tracking EPROM technology rollover. As shown in Figure 7, the bulk of EPROM consumption in 1989 was for versions with access times slower than 150ns. With demands of processor speeds soaring past 15 and 20 MHz, however, sub-150ns EPROMs will become the dominant versions by 1994.

EEPROM

Figure 8 illustrates the consumption of electrically erasable programmable read only memory (EEPROM) devices by density. The dominant density for EEPROM usage in military/aerospace markets in 1989 was 256K. With continued demand for EEPROM main memory (and backup) for reprogrammable missile guidance, electronic warfare, and a myriad of adaptable control applications, 256K densities or greater will absorb the bulk of the growth through 1994. As in the EPROM case, the sub-150ns access time domain will absorb the bulk of growth in applications as well.

Figure 6

Military/Aerospace EPROM Consumption by Density

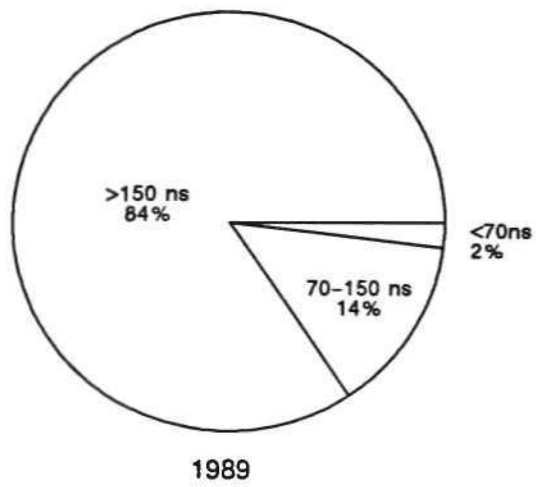


Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Figure 7

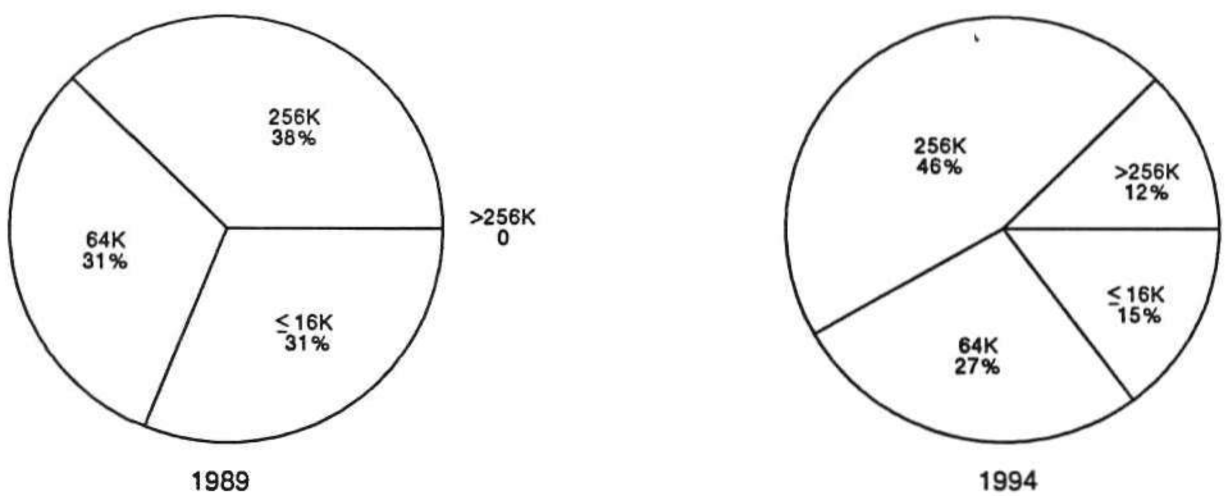
Military/Aerospace EPROM Consumption by Performance



Source: Dataquest (August 1990)

Figure 8

Military/Aerospace EEPROM Consumption by Density



Source: Dataquest (August 1990)

PROM

The other major nonvolatile memory categories used in military/aerospace applications are programmable read only memory (PROM) devices—both bipolar and the newer CMOS replacement versions. Applications requiring sub-70-second performance use PROMs. DSP, bit-slice architectures, and fast general-purpose processors (especially ones operating faster than 20 MHz) have continued needs for PROMs. We estimate that 16K is the most popular density, with 64K becoming equally so by the early 1990s. The sub-25ns market is currently dominated by bipolar (TTL and ECL I/O). In general, the CMOS versions (often EPROMs with a PROM pin-out) are replacing the bipolar versions in the 35ns and greater market.

Flash Technology

We expect the demand for Flash technology to emerge for applications not requiring frequent reprogramming (less than 10K write/erase cycles). This is the case for many threat-related changes in avionics, for example. Optimized to either EPROM or EEPROM versions, we accordingly count the Flash market in with those two categories. With its price per bit falling somewhere between EPROMs and EEPROMs, Flash technology provides an attractive alternative in an increasingly cost-conscious environment.

Product and Technology Trends

Table 2 presents a comparison of the various nonvolatile memory technologies available. Besides the programmability methods, the major technology parameters include density, performance, cost per bit, and write/erase cycles for in-circuit programmable versions.

©1990 Dataquest Incorporated August

Table 2

Nonvolatile Memory
Product Trade-Offs 1989

	Mask ROM	Bipolar PROM	Fast EPROM	QTP ROM	UV EPROM	Flash EPROM	Flash EEPROM	EEPROM	NVRAM	FERRAM
User Programmable	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reprogrammable	No	No	Yes/No	No	Yes	Yes	Yes	Yes	Yes	Yes
Programming Voltage	NM	21V	12V	12V	12V	12.5V	5-12.5V	5V	5V	5V
In-Circuit	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
Write/Erase Cycles	NM	NM	NM	NM	NM	100K-1K	1K-10K	10K-100K	10K-100K	1.00E+15
Performance	150ns	35ns	25ns	150ns	150ns	150ns	170ns	35-200ns	200ns	80ns
Highest Density	16Mb	128K	1Mb	1Mb	4Mb	1M	4M	1M	16K	4K
Millicents/Bit	0.4	NM	NM	1.3	1.7	NM	NM	43.2	NM	NM
Plastic Package	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Transistor	NM	NM	2-T	1-T	1-T	1-T	1-T	1&2-T	2&4-T	4 to 6-T

Source: Dataquest (August 1990)
NM = Not meaningful

©1990 Dataquest Incorporated August

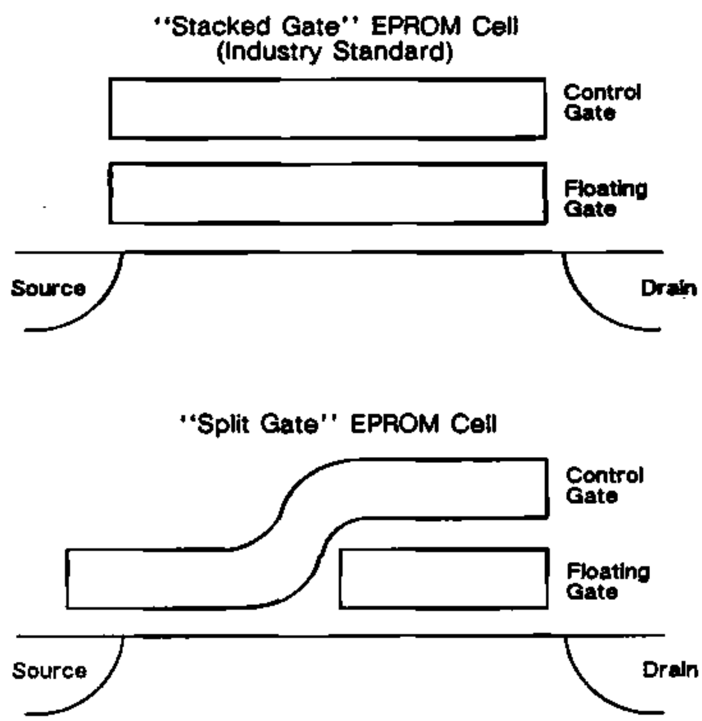
EPROM

The principal trends in EPROM technology, as in the other nonvolatile memories, is toward higher densities but, perhaps more importantly, also toward higher speeds. As processors move to higher frequencies, greater than 20 MHz, the corresponding EPROMs need to move below 70ns and even 50ns.

Figure 9 shows two typical EPROM technologies. The stacked-gate type is optimized toward higher densities, whereas the split-gate technology, as pioneered by Wafer Scale Integration, is optimized toward speed.

Figure 9

EPROM Technology



Source: WaferScale Integration

EEPROM

From 1973 through 1980, the first EEPROM devices pioneered by NCR and known as EAPROMs (electrically alterable programmable ROMs), were built exclusively around a P-channel MNOS (metal-nitride oxide silicon) process, which used trapped charges at the nitride interface for bit storage. The technology then passed through several other stages in the late 1970s, including N channel versions and a version known as silicon nitrox (SNOS), which could operate at +5 volts. In 1980, Intel introduced its floating-gate technology, known as FLOTOX, which was an extension of its EPROM technology. Xicor, founded in 1978, introduced the first nonvolatile shadow RAM (NOVRAM), followed closely by its 16K EEPROM. Xicor also introduced the first full-featured 16K EEPROM that had 5-volt programming as well as functions required for in-system programming. Other entrants at this time were AMD, Hughes, Motorola, National, SEEQ, and Siemens.

By the end of 1983, Xicor's X2816A emerged as a de facto standard in the EEPROM market; by the end of 1984, Exel, SEEQ, Tristar, and Xicor were all shipping functionally compatible 16K products. With further second sourcing, production volumes of 64K and 256K devices have validated the market viability of standard EEPROMs.

In general, the aspects that comprise a full-featured EEPROM are the following:

- Complete 5-volt operation, including the erase/write cycle
- On-board clocks
- Latched data and address

A recent trend is in Flash technology. This lower-cost version typically has fewer features and less write/erase cycle capability. Some versions are optimized to compete with EPROMs and some with EEPROMs for applications where the data is changed or updated infrequently. Dataquest believes that Flash technology will be suitable for the military/aerospace applications requiring infrequent data changes and/or for applications where higher densities (512K to 1Mb) are needed (e.g., control programs). Intel, National, SEEQ, and Toshiba currently offer Flash technology.

PROM

Traditionally offered in bipolar technology, CMOS versions have appeared on the market with comparable speed and density features. In addition, the CMOS versions (often EPROM derivatives) are UV erasable with packaged windows.

There are 128K bipolar versions entering the market with speeds as fast as 35ns. New introductions also are occurring for very high speed 10ns versions in the low-density ranges of 1K to 8K. In addition, 15ns 64K versions are available. New features include registered outputs.

Pursuing the demand from high-speed applications such as radar and image signal processing, we expect the speed-density envelope to continue pushing out. The 1 to 3ns advanced ECL and GaAs versions will most likely be available by 1992. CMOS technology will continue to be applied to all but the very fastest versions, for the advantage of power reduction.

Other Nonvolatile Technologies

Many other nonvolatile semiconductor memory technologies exist. However, two relatively well-known technologies—magnetic bubble and ferroelectric RAM (FERRAM)—are making a comeback with fresh research and applications.

FERRAM. FERRAM technology entails the application of ferroelectric material to the dielectric of a capacitor, in turn, using the capacitor in a memory cell. As the capacitor containing the dielectric is charged, the bipolar (+ on one end, - on the other) molecules in the ferroelectric material align themselves with the electric field. If the capacitor is discharged, these molecules stay aligned. If subsequent voltage is applied in the opposite direction to the first voltage, these molecules have to align themselves in the opposite direction and high current flows. If, on the other hand, the second voltage is applied in the same direction as the first voltage, only a small current flows because the bipolar molecules already are aligned in that direction. The capacitors can be applied to SRAMs or to DRAMs to make them nonvolatile when the power is turned off.

Recently, several key breakthroughs have brought FERRAMs under further scrutiny. One is the use of ferroelectric material in semiconductor technology rather than in coincident wire technology (for memories). Secondly, with proper processing, this ceramic-like material has been found to be robust and compatible with semiconductor processing. Finally, the deposition techniques have advanced to the point where it is possible to reliably deposit thin films of this material.

FERRAMs have several potential advantages. One is the much greater write/erase cycles permissible in comparison with today's electrically erasable technology, on the order of 10^{15} cycles. Radiation hardness is also an advantage, with initial test data indicating dose rate capability of 1 to 2 x 10^{11} rads/sec, total dose of 4 million to 5 million rads, and very little susceptibility to SEU. Another potential advantage is cost; with further development, FERRAMs could be on a par with EEPROMs by the early 1990s.

Today, small experimental parts with access times of 80ns exist, and projects to develop 256K densities are under way. Densities of 1Mb will be feasible in the early 1990s. Two start-up companies in the United States—Krysalis of Albuquerque, New Mexico, and Ramtron of Colorado Springs, Colorado—are the principal developers of the technology to date.

Magnetic Bubble. In bubble memory, data is stored in tiny magnetic domains in a garnet epitaxial thin film over a gallium-gadolinium-garnet (GGG) substrate. Structures of permalloy form input/output tracks and storage loops for the bubbles. There are circuits for writing, moving, and reading the 1 and 0 information as denoted by the presence of a magnetic bubble.

Although currently not price competitive at the IC level, bubble memory systems have other advantages for military data storage use. They are extremely resistant to radiation and have effectively infinite write/read cycle capability. Currently, production technology is at the 4Mb phase, with 16Mb in early introduction.

Hitachi, Fujitsu, Magnesys, and MemTek Technology (former Intel technology) are the principal suppliers of magnetic memory ICs. Magnesys has developed a series of cartridge-based storage units. A 720-Kbit IC version with an extended temperature range (-20° to +70°C) has an average access time of 30ns and a price of $800.

©1990 Dataquest Incorporated August

MEMORY SUPPLIERS

Table 3 lists the principal memory suppliers and their offerings. In addition, there are several suppliers of die and modules, particularly from Japanese foundries.

©1990 Dataquest Incorporated August

Table 3

MilAero Memory IC Suppliers

	DRAM	Fast SRAM	Slow SRAM	Bipolar SRAM	SRAM Modules	FIFO (MOS)	Other Volatile	EPROM	EEPROM	PROM (MOS)	PROM (Bipolar)	ROM Nonvolatile	Other
AMD		256K		1K		X		1M	256K		64K		
Atmel								512K	256K	64K			
Allied Signal		64K											
Gould-AMI												512K	
Cypress		256K				X	2-P	256K		64K			
Dense-Pac	1M, mods	256K	1M		4M	X	2-P mods	1M	8M mod				EE mods
EDI		256K	256K		4M								
Exel									64K				
Fujitsu		256K	256K								64K	256K	
Harris/GE		64K	64K		1M			4K					
Hughes									64K			64K	
Honeywell		64K	64K										
Inova		1M	1M										
IDT		256K	256K		4M	X	2-P, C-T						
Intel		64K	64K					1M	64K				Flash
Lansdale											16K		
Marconi		64K	64K			X							
Matra-Harris		64K	64K										
Microchip								512K	256K				
Micron	1M	256K	1M				VRAM						
MOSel		256K	256K										
Motorola				1K							16K		
National		256K BiC		2K				256K	64K		64K		
Performance		256K											
Philips-Signetics								512K			64K		
Plessey						X							

(Continued)

Table 3 (Continued)

MilAero Memory IC Suppliers

	DRAM	Fast SRAM	Slow SRAM	Bipolar SRAM	SRAM Modules	FIFO (MOS)	Other Volatile	EPROM	EEPROM	PROM (MOS)	PROM (Bipolar)	ROM Nonvolatile	Other
Ramtron													FERRAM
Raytheon									64K		32K		
SEEQ								256K	1M				Flash
SGS Thomson	256K	256K				X		256K			16K	256K	
Sprague												64K	
Texas Instruments	1M	256K	256K			X	VRAM	512K					
Thomson Mil. & Space		256K						256K					
TRW Space/Defense		64K											
UTMC		256K											
VLSI Technology		256K				X	2-P, C-T					1M	
WaferScale								256K		64K			
Xicor									256K, 1M mod				

Legend:
- BiC = BiCMOS
- 2-P = Dual Port
- Mod(s) = Module(s)
- C-T = Cache Tag
- VRAM = Video Ram

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

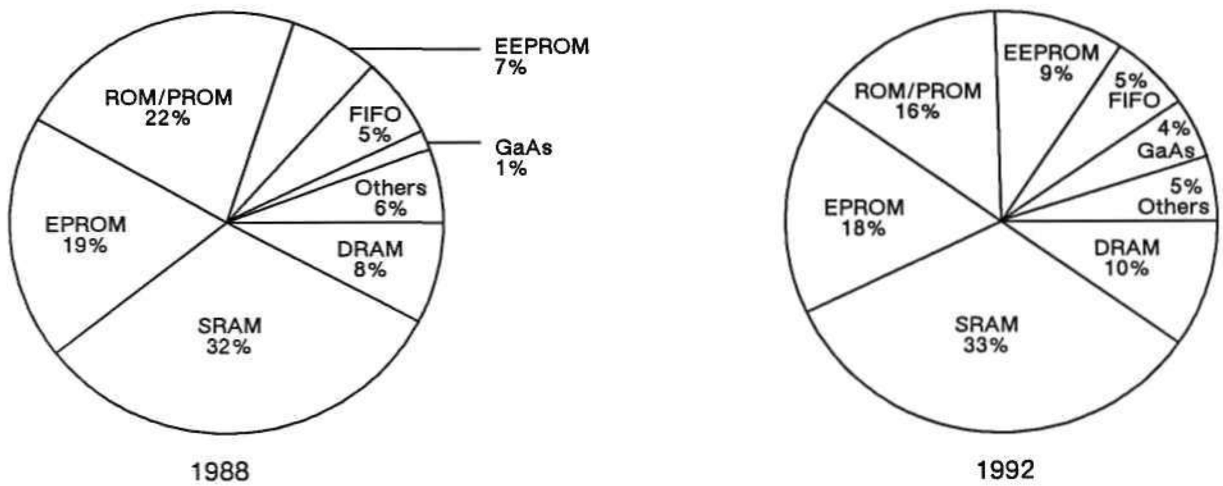
Memory

OVERVIEW

As aircraft, spacecraft, ground vehicles, communications, and weapons systems evolve and are upgraded, their appetite for digital VLSI control is exceeded only by their appetite for semiconductor memory. Used in conjunction with digital signal processing, digital computing, and control, memory's use is proliferating in military applications as it has done already in commercial applications. Volatile memory accounts for 48 percent and nonvolatile memory 52 percent of all semiconductor memory usage in military and aerospace systems. Volatility can be addressed also with the use of battery backup and circuit design schemes (e.g., the use of capacitors). Figure 1 presents a profile of memory usage by type. Dataquest expects static random access memories (SRAMs) to continue to be the largest category of memory used in military/aerospace applications throughout the early 1990s.

Figure 1

Military/Aerospace Memory Consumption



0003412-1

Source: Dataquest April 1989

© 1989 Dataquest Incorporated April

Memory

VOLATILE MEMORY

The three principal types of volatile memory technologies are as follows:

- Dynamic random access memories (DRAMs)
- Static random access memories (SRAMs)
- Specialty memories

Dynamic RAMs (DRAMs)

DRAMs traditionally have found limited use in military and aerospace systems, but this situation is changing as new applications have developed, utilizing the economy that they offer in both price and functional density. The traditional factors limiting the use of DRAMs versus SRAMs in mil-spec equipment include their perceived susceptibility to data loss during power glitches and losses, their relative lesser resistance to radiation effects, and their limited temperature range (110°C rather than 125°C).

In recent years, military and aerospace system designers have taken another look at uses for DRAMs and found many circumstances where they would be very appropriate. Suitable applications would be in situations where the environmental factors are relatively benign and where the system's operational life is short. Some of these applications include the following:

- Sonobouys
- Smart decoys/targets
- Selected missiles/torpedoes
- Unmanned aircraft payloads
- Submarine CPUs and signal processors
- Fixed, ground-based CPUs and signal processors
- Fixed, ground-based graphics terminals
- Simulators/trainers (commercial temperature)

Static RAMs (SRAMs)

SRAMs are the primary volatile random access memory used in military and aerospace systems, and they are used in almost all forms of tactical and strategic equipment. The most dominant uses for SRAMs in this market are as main memory, primary and secondary caches, writable control store, data buffers, and, in some cases, bit-mapped memory for graphics and imaging.

 © 1989 Dataquest Incorporated April

Demand for SRAMs will continue growing as military and aerospace systems continue shifting to digital technology, increasing the need for random access memory to handle real-time computing data storage. Important applications include the following:

- Standard CPUs (e.g., AN/UYK, VME bus)
- Common avionics module families (applied to INEWS, ICNIA)
- Air data/mission avionics computers
- Warning receivers/electronic countermeasure systems
- Fire-control computers (all platforms)
- Signal processing (radar, sonar, infrared, targeting, passive)
- Data communication (all platforms—switching, buffering)
- Missiles/RPV data memory

Specialty Memories

Other important volatile products include first-in first-outs (FIFOs), dual-port RAMs, and video RAMs. Digital signal processing architectures use FIFOs commonly available in 64, 512, 1K, 2K, 4K by 4, 5, and 9 configurations. Integrated Device Technology has introduced versions that allow serial/parallel conversions.

Dual-port rams are used as common memory between 2 CPUs (e.g., microprocessors). Offered in x8 and x16 versions, densities up to 32K are available at 35 to 45ns speeds. Many control-system applications (e.g., flight management) find dual ports useful for access to common data and processing flags.

Video RAMs that can serialize data for output to a video screen are becoming popular in graphics applications also.

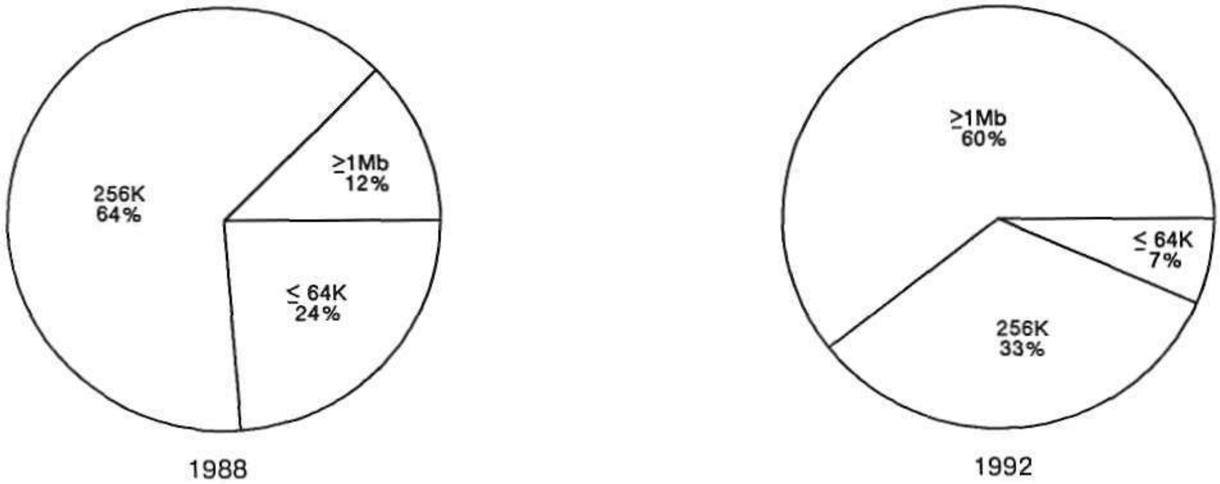
Consumption Trends

Figure 2 presents estimated DRAM military and aerospace usage by density. Because the bulk of DRAM usage is controlled by merchant suppliers who principally supply commercial uses, the density lifecycles of mil-grade DRAMs are driven mostly by commercial lifecycles. The largest category of usage in 1988 was the 256K, with 64 percent of total dollars. By 1992 we expect a shift to the 1Mb level, which will account for 60 percent of all usage.

© 1989 Dataquest Incorporated April

Figure 2

Military/Aerospace DRAM Consumption



0003412-2

Source: Dataquest
April 1989

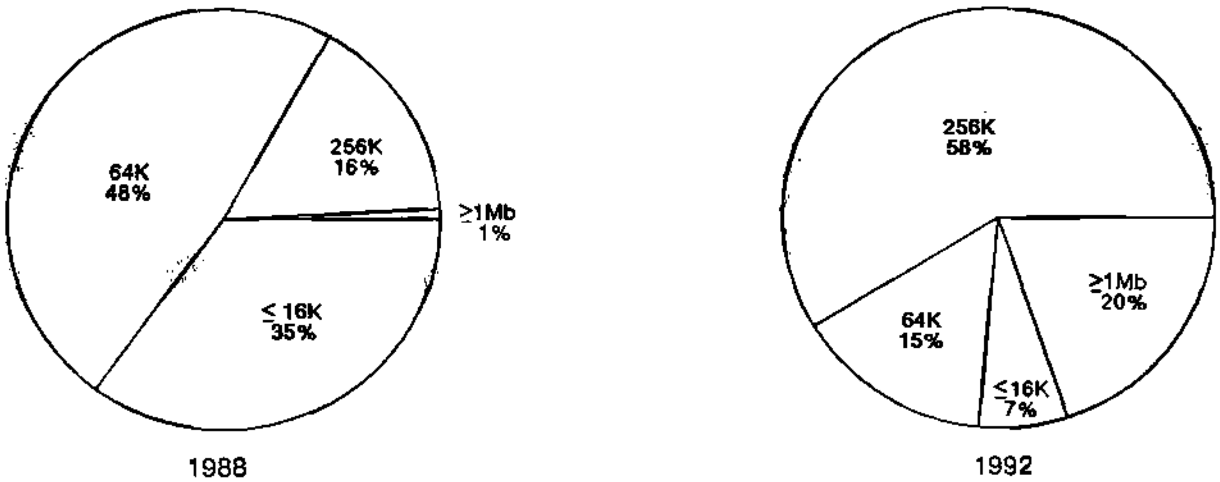
SRAM consumption by density is profiled in Figure 3. Dataquest estimates the largest category in 1988 to have been the 64K density level (64Kx1, 16Kx4, 8Kx8) with 48 percent of dollar consumption. The bulk of consumption is expected to shift to 256K (32Kx8, 64Kx4, 256Kx1) by 1992 as military system upgrades, in particular, acquire that density. Monolithic 1Mb versions in mil-temperature range will also be a factor in usage by 1992. Currently supplied mainly in module form, 1Mb versions and greater will be needed for main memory usage on avionics computers and on general-purpose CPUs in all platforms.

Demand for high-speed SRAMs in military and aerospace systems will continue to be strong. With processing speeds climbing into the hundreds of megahertz, higher access times will be required of main and cache memories. The resulting performance demands that we expect for various densities of SRAM are shown in Table 1. With the exception of the 1Mb densities, the majority of SRAM consumption by 1992 will be of technology capable of less than 45ns access time.

© 1989 Dataquest Incorporated April

Figure 3

Military/Aerospace SRAM Consumption



0003412-3

Source: Dataquest
April 1989

Table 1

Military/Aerospace SRAM Consumption
(Percent of Total Dollars)

SRAM Type	1988	1992
16K		
<45ns	27%	74%
≥45ns	73%	26%
64K		
<45ns	24%	56%
≥45ns	76%	44%
256K		
<45ns	21%	53%
≥45ns	79%	47%
1Mb		
<45ns	0	28%
≥45ns	100%	72%

Source: Dataquest
April 1989

© 1989 Dataquest Incorporated April

Memory

Product and Technology Trends

DRAM

DRAM technology is currently battling on the 16Mb front as 4Mb versions enter the sampling stage. Issues such as the use of trench capacitor technology and the extension of optical stepper technology to the 0.5-micron range are being worked out. The development and mass production of 16 and 64Mb densities is believed by many experts to hinge on the further refinement of X-ray lithography. Alternate modes of operation including page, fast page, nibble, and static column are becoming more common in each new generation. Access times as fast as 80ns currently are available with 60 to 70ns projected for the 4Mb versions. Surface-mount packaging, such as SOJ, is emerging in importance for DRAM consumers.

SRAM

Figure 4 shows trends in performance at a given density for early production (not R&D) in various SRAM technologies. It should be noted that access times for military temperature range memories are typically 20 to 40 percent greater than the commercial range. Performance-optimized CMOS technologies with 1.2-micron features typically had 25ns access times for 64K densities in 1988. By 1993, the same density is expected to be able to achieve 10ns performance with 0.5-micron technology.

BiCMOS is expected to follow a moving window of one to two years in achieving better performance at a given density ahead of CMOS. For a similar 64K density and process feature size, BiCMOS achieved 12ns access times in 1988 and is expected to improve to 7 to 8ns by 1993. The cost of BiCMOS is raised by three to four extra mask layers, in contrast with CMOS, but then lowered by the better production distribution it achieves around faster speeds. The result is that BiCMOS is cost competitive with CMOS at fast speeds.

Bipolar (ECL) SRAMs fall into the performance niche between BiCMOS and GaAs, principally the 5 to 10ns performance area. Given constraints such as power dissipation per package, ECL technology is not expected to proceed beyond the 64K level in the near future, barring further process and packaging breakthroughs.

GaAs will continue its role as the speediest production technology. Currently, it is available in 16K densities with 5ns performance; by 1993, 64K versions are expected to perform at 3ns.

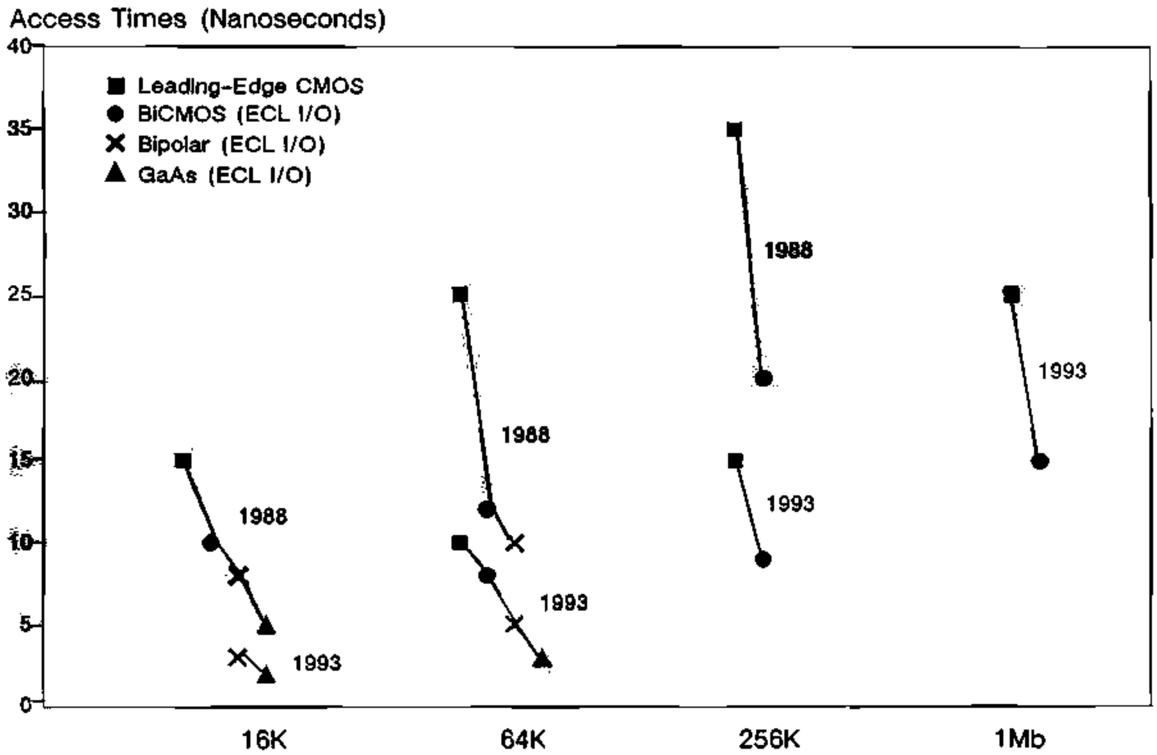
To address the need for higher density and wider (x16) RAM memory, module technology is being utilized a great deal in SRAMs. The new high-speed 32-bit microprocessors are demanding wider and deeper caches and main memory. Modules currently serve a major portion of the 1Mb density market and 2, 4, 8, and 16Mb versions are available. They are offered in monolithic (DIP) pin-outs and SIPs. LCCs are commonly used on SRAM modules with ceramic substrate matching techniques employed to avoid problems with thermal mismatching. A company called Inova Microelectronics has an interesting alternative to module technology that employs connected die (interdie metalization) on the same monolithic piece of silicon and placed in a large package.

Other features such as cache tags and parity (x9 versions) are becoming available. Low-power versions, which can operate on 2 to 3 volts rather than 5 volts, are important for data retention and for battery-operated or backed-up situations.

Radiation hardening is an important issue for SRAMs because of susceptibility to soft errors from single-event upsets (SEUs), which can flip bits caused by high-energy particles. Therefore, technology employing various hardening techniques such as insulating substrates (SOS or SIMOX) is very important for space applications, especially as feature sizes drop below 1 micron.

Figure 4

Fast SRAM Technology Outlook
Early Production



0003412-4

Source: Dataquest
April 1989

© 1989 Dataquest Incorporated April

NONVOLATILE MEMORY

Nonvolatile semiconductor memories are storage devices that retain the state of the data after the power has been removed. Variations include different degrees of user programmability ranging from factory programmed (ROM), to user bench programmability (PROM, EPROM), to in-circuit programmability (EEPROM, FERRAM, and Bubble).

The non-in-circuit programmable varieties are principally used to hold microcode for processors and fixed processor program instructions for operating systems, utilities, and application code. They are often used to store programs utilized in conjunction with microprocessors and microcontrollers doing certain control tasks. So, in effect, wherever MPUs and MCUs go, so do these devices.

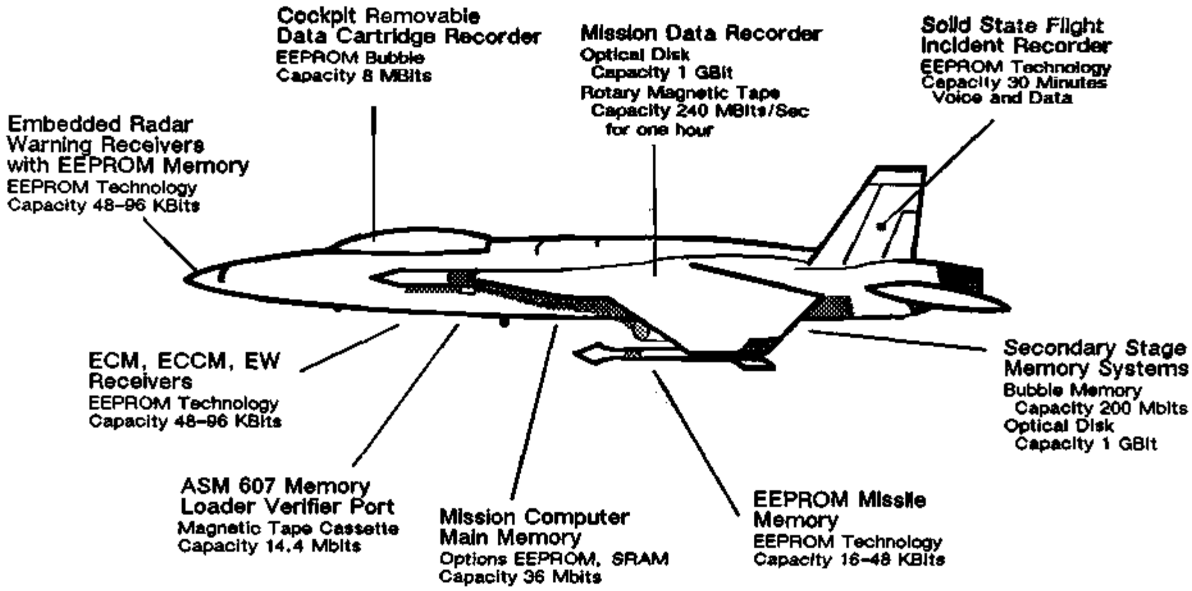
Applications for in-circuit programmable varieties can be the same as for non-in-circuit types, except that in-circuit varieties also can be used for real-time data capture and reprogrammable control functions. In effect, the in-circuit programmable versions compete with volatile RAM for dynamic store-and-retrieve applications.

Figure 5 shows typical applications of nonvolatile memory on an advanced aircraft. In military/aerospace applications, nonvolatile memory can be used for reprogramming mission parameters (e.g., type of threat, environmental conditions) in various types of equipment, including countermeasures, communication, and missile guidance and control. It can also be used in standard RAM applications as a backup memory to SRAMs or other registers.

© 1989 Dataquest Incorporated April

Figure 5

Aircraft Applications of Nonvolatile Memory



0003412-5

Source: U.S. Department of Defense

Consumption Trends

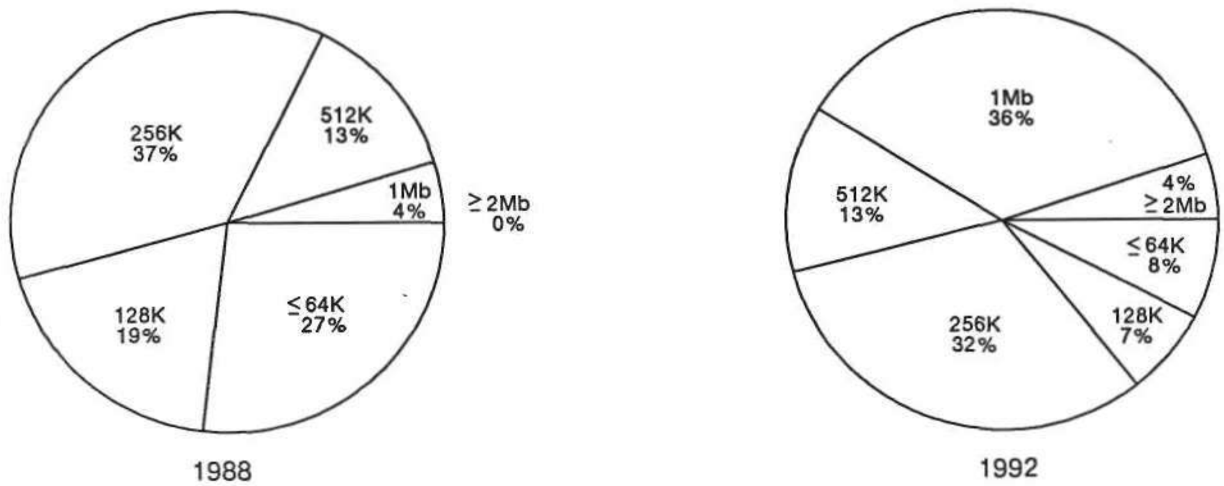
EPROM

Figure 6 presents the consumption profile, by density, for electrically programmable read only memory (EPROM) devices. The largest single density usage in 1988 was 256K (32Kx8), with an estimated 37 percent of EPROM consumption. However, with faster processors appearing, faster and x16 versions are needed. We forecast that by 1992, although 256K density will be important still, much of the usage will migrate to the 1Mb level, tracking EPROM technology rollover. As shown in Figure 7, the bulk of EPROM consumption in 1988 was for versions with access times slower than 150ns. With demands of processor speeds soaring past 15 and 20 MHz, however, sub-150ns EPROMs will become the dominant versions by 1992.

© 1989 Dataquest Incorporated April

Figure 6

Military/Aerospace EPROM Consumption
by Density

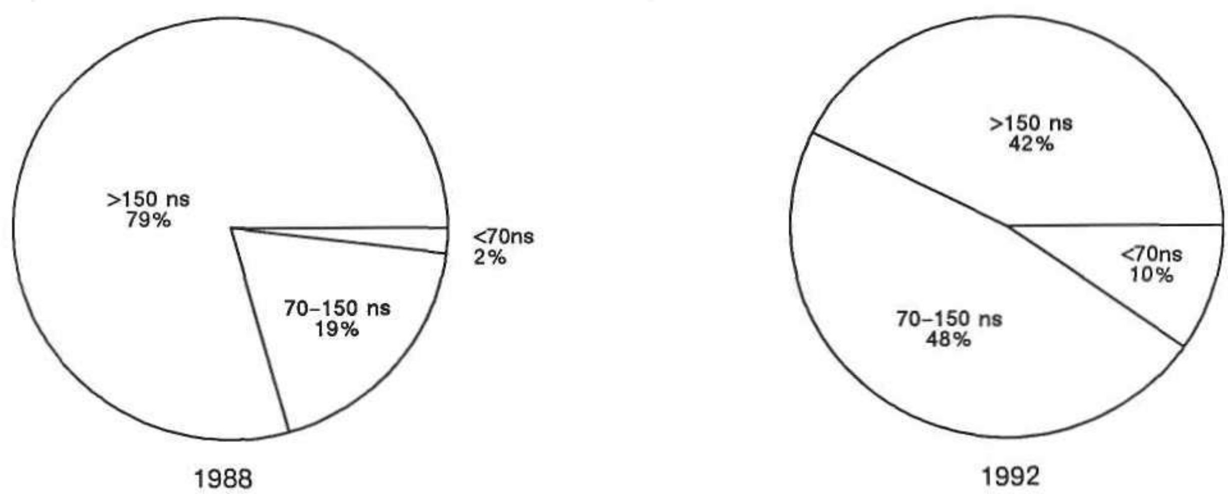


0003412-6

Source: Dataquest
April 1989

Figure 7

Military/Aerospace EPROM Consumption
by Performance



0003412-7

Source: Dataquest
April 1989

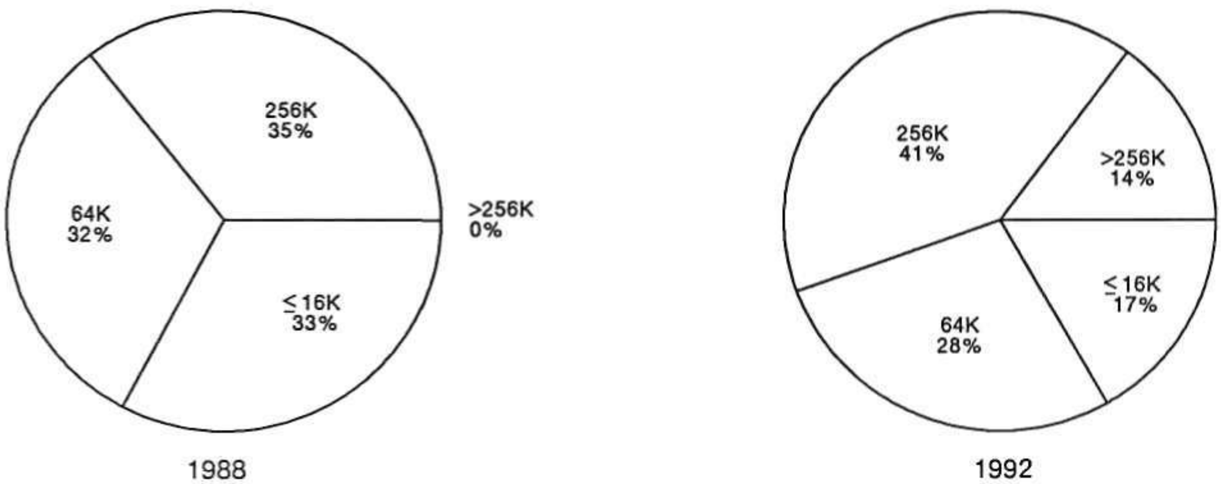
© 1989 Dataquest Incorporated April

EEPROM

Figure 8 illustrates the consumption of electrically erasable programmable read only memory (EEPROM) devices by density. The dominant densities for EEPROM usage in military/aerospace markets in 1988 were split between the 64K and 256K levels, accounting for an estimated 67 percent. With continued demand for EEPROM main memory (and backup) for reprogrammable missile guidance, electronic warfare, and a myriad of adaptable control applications, 256K densities or greater will absorb the bulk of the growth through 1992. As in the EPROM case, the sub-150ns access time domain will absorb the bulk of growth in applications as well.

Figure 8

Military/Aerospace EEPROM Consumption by Density



0003412-8

Source: Dataquest April 1989

PROM

The other major nonvolatile memory categories used in military/aerospace applications are programmable read only memory (PROM) devices—both bipolar and the newer CMOS replacement versions. Applications requiring sub-70-second performance use PROMs. DSP, bit-slice architectures, and fast general-purpose processors (especially ones operating faster than 20 MHz) have continued needs for PROMs. We estimate that 16K is the most popular density, with 64K becoming equally so by the early 1990s. The sub-25ns market is currently dominated by bipolar (TTL and ECL I/O). In general, the CMOS versions (often EPROMs with a PROM pin-out) are replacing the bipolar versions in the 35ns and greater market.

© 1989 Dataquest Incorporated April

Flash Technology

We expect the demand for Flash technology to emerge for applications not requiring frequent reprogramming (less than 10K write/erase cycles). This is the case for many threat-related changes in avionics, for example. Optimized to either EPROM or EEPROM versions, we accordingly count the Flash market in with those two categories. With its price per bit falling somewhere between EPROMs and EEPROMs, Flash technology provides an attractive alternative in an increasingly cost-conscious environment.

Product and Technology Trends

Table 2 presents a comparison of the various nonvolatile memory technologies available. Besides the programmability methods, the major technology parameters include density, performance, cost per bit, and write/erase cycles for in-circuit programmable versions.

Table 2

**Nonvolatile Memory
Product Trade-Offs 1989**

	Mask ROM	Bipolar PROM	Fast EPROM	OTP ROM	UV EPROM	Flash EPROM	Flash EEPROM	EEPROM	NVRAM	FERRAM
User Programmable	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reprogrammable	No	No	Yes/No	No	Yes	Yes	Yes	Yes	Yes	Yes
Programming Voltage	N/A	21V	12V	12V	12V	12.5V	5-12.5V	5V	5V	5V
In-Circuit	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
Write/Erase Cycles	N/A	N/A	N/A	N/A	N/A	100K-1K	1K-10K	10K-100K	10K-100K	1.00E+15
Performance	150ns	35ns	35ns	150ns	150ns	150ns	170ns	35-200ns	200ns	80ns
Highest Density	16Mb	128K	1Mb	1Mb	4Mb	1M	4M	1M	16K	256 bit
Millicents/Bit	0.4	N/A	N/A	1.3	1.7	N/A	N/A	43.2	N/A	N/A
Plastic Package	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Transistor	N/A	N/A	2-T	1-T	1-T	1-T	1-T	1&2-T	2&4-T	4to6-T

N/A = Not Applicable

Source: Dataquest
April 1989

© 1989 Dataquest Incorporated April

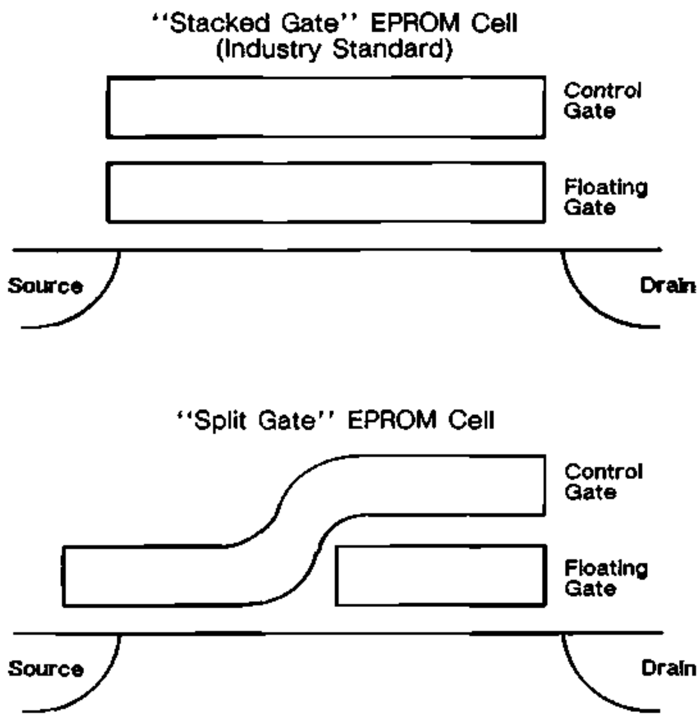
EPROM

The principal trends in EPROM technology, as in the other nonvolatile memories, is toward higher densities but, perhaps more importantly, also toward higher speeds. As processors move to higher frequencies, say greater than 20 MHz, the corresponding EPROMs need to move below 70ns and even 50ns.

Figure 9 shows two typical EPROM technologies. The stacked-gate type is optimized toward higher densities, whereas the split-gate technology, as pioneered by Wafer Scale Integration, is optimized toward speed.

Figure 9

EPROM Technology



0003412-9

Source: Waferscale Integration

© 1989 Dataquest Incorporated April

EEPROM

From 1973 through 1980, the first EEPROM devices pioneered by NCR and known as EAPROMs (electrically alterable programmable ROMs), were built exclusively around a P-channel MNOS (metal-nitride oxide silicon) process, which used trapped charges at the nitride interface for bit storage. The technology then passed through several other stages in the late 1970s, including N channel versions and a version known as silicon nitrox (SNOS), which could operate at +5 volts. In 1980, Intel introduced its floating-gate technology, known as FLOTOX, which was an extension of its EPROM technology. Xicor, founded in 1978, introduced the first nonvolatile shadow RAM (NOVRAM), followed closely by its 16K EEPROM. Xicor also introduced the first full-featured 16K EEPROM that had 5-volt programming as well as functions required for in-system programming. Other entrants at this time were AMD, Hughes, Motorola, National, SEEQ, and Siemens.

By the end of 1983, Xicor's X2816A emerged as a de facto standard in the EEPROM market; by the end of 1984, Exel, SEEQ, Tristar, and Xicor were all shipping functionally compatible 16K products. With further second sourcing, production volumes of 64K and 256K devices have validated the market viability of standard EEPROMs.

In general, the aspects that comprise a full-featured EEPROM are the following:

- Complete 5-volt operation, including the erase/write cycle
- On-board clocks
- Latched data and address

A recent trend is in Flash technology. This lower-cost version typically has fewer features and less write/erase cycle capability. Some versions are optimized to compete with EPROMs and some with EEPROMs for applications where the data is changed or updated infrequently. Dataquest believes that Flash technology will be suitable for the military/aerospace applications requiring infrequent data changes and/or for applications where higher densities (512K to 1Mb) are needed (e.g., control programs). Intel, National, SEEQ, and Toshiba currently offer Flash technology.

PROM

Traditionally offered in bipolar technology, CMOS versions have appeared on the market with comparable speed and density features. In addition, the CMOS versions (often EPROM derivatives) are UV erasable with packaged windows.

There are 128K bipolar versions entering the market with speeds as fast as 35ns. New introductions also are occurring for very high speed 10ns versions in the low-density ranges of 1K to 8K. In addition, 15ns 64K versions are available. New features include registered outputs.

 © 1989 Dataquest Incorporated April

Memory

Pursuing the demand from high-speed applications such as radar and image signal processing, we expect the speed-density envelope to continue pushing out. The 1 to 3ns advanced ECL and GaAs versions will most likely be available by 1992. CMOS technology will continue to be applied to all but the very fastest versions, for the advantage of power reduction.

Other Nonvolatile Technologies

Many other nonvolatile semiconductor memory technologies exist. However, two relatively well-known technologies—magnetic bubble and ferroelectric RAM (FERRAM)—are making a comeback with fresh research and applications.

FERRAM. FERRAM technology entails the application of ferroelectric material to the dielectric of a capacitor, in turn, using the capacitor in a memory cell. As the capacitor containing the dielectric is charged, the bipolar (+ on one end, - on the other) molecules in the ferroelectric material align themselves with the electric field. If the capacitor is discharged, these molecules stay aligned. If subsequent voltage is applied in the opposite direction to the first voltage, these molecules have to align themselves in the opposite direction and high current flows. If, on the other hand, the second voltage is applied in the same direction as the first voltage, only a small current flows because the bipolar molecules already are aligned in that direction. The capacitors can be applied to SRAMs or to DRAMs to make them nonvolatile when the power is turned off.

Recently, several key breakthroughs have brought FERRAMs under further scrutiny. One is the use of ferroelectric material in semiconductor technology rather than in coincident wire technology (for memories). Secondly, with proper processing, this ceramic-like material has been found to be robust and compatible with semiconductor processing. Finally, the deposition techniques have advanced to the point where it is possible to reliably deposit thin films of this material.

FERRAMs have several potential advantages. One is the much greater write/erase cycles permissible in comparison with today's electrically erasable technology, on the order of 10^{15} cycles. Radiation hardness is also an advantage, with initial test data indicating dose rate capability of 1 to 2 x 10^{11} rads/sec, total dose of 4 million to 5 million rads, and very little susceptibility to single-event upset (SEU). Another potential advantage is cost; with further development, FERRAMs could be on a par with EEPROMs by the early 1990s.

Today, small experimental parts with access times of 80ns exist, and projects to develop 256K densities are under way. Densities of 1Mb will be feasible in the early 1990s. Two start-up companies in the United States—Krysalis of Albuquerque, New Mexico, and Ramtron of Colorado Springs, Colorado—are the principal developers of the technology to date.

Magnetic Bubble. In bubble memory, data is stored in tiny magnetic domains in a garnet epitaxial thin film over a gallium-gadolinium-garnet (GGG) substrate. Structures of permalloy form input/output tracks and storage loops for the bubbles. There are circuits for writing, moving, and reading the 1 and 0 information as denoted by the presence of a magnetic bubble.

© 1989 Dataquest Incorporated April

Memory

Although currently not price competitive at the IC level, bubble memory systems have other advantages for military data storage use. They are extremely resistant to radiation and have effectively infinite write/read cycle capability. Currently, production technology is at the 4Mb phase, with 16Mb in early introduction.

Hitachi, Fujitsu, Magnesys, and MemTek Technology (former Intel technology) are the principal suppliers of magnetic memory ICs. Magnesys has developed a series of cartridge-based storage units. A 720-Kbit IC version with an extended temperature range (-20° to +70°C) has an average access time of 30ns and a cost of $800.

 © 1989 Dataquest Incorporated April

Analog

INTRODUCTION

The following sections discuss key analog functions and their various market and technology features as they pertain to military and aerospace consumption.

AMPLIFIERS

Market Segmentation

Dataquest's analysis of the market cuts across two dimensions—product segments and technology. We will address the current status of each of these dimensions and the implications for future growth.

The first dimension is product segments. Dataquest divides amplifiers into three categories—general-purpose, precision, and high-speed devices. These segments refer to amplifier performance characteristics. General-purpose products are broadest in their usage focus. Precision and high-speed devices meet high-performance application needs.

The amplifier market is dominated by general-purpose products. This type of product meets the broadest distribution of applications and amounts to approximately 61 percent of the total amplifier market. The precision market is the next largest and meets high-accuracy needs. Precision amplifiers accounted for 16 percent of the total market. The high-speed category is the next largest category and amounts to approximately 15 percent of the market. For a visual illustration of the composition of the market, please refer to Figure 1.

Figure 1

Estimated Amplifier Market by Product Segment

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Amplifier Technology

There are many types of amplifiers that meet both general-purpose and special-purpose applications. The following text discusses amplifiers in a broad sense, including special-purpose types such as video and audio amplifiers. Amplifiers of a general application nature are referred to as operational amplifiers. Estimated amplifier market share by technology is shown in Figure 2.

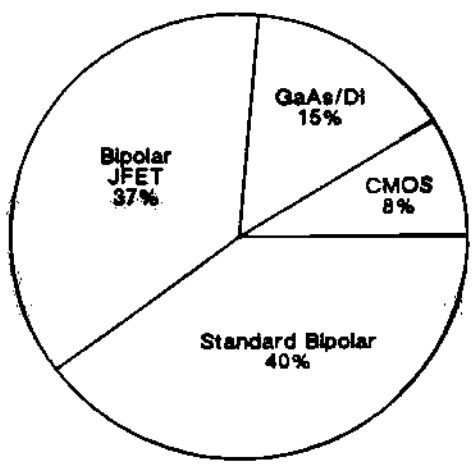
Operational Amplifiers

An operational amplifier (op amp) is a gain block that performs well with a DC or AC signal. The main function of the circuit, as with all amplifiers, is to amplify without introducing errors.

One of the characteristic features of the op amp is the ability to set the signal gain by the ratio of external resistors. High gain or open-loop gain is desired not only to increase the signal, but for feedback to reduce errors. Any amplifier that has high gain, however, also has a strong tendency to oscillate. Yet the ideal op amp is unconditionally stable. To keep the op amp from oscillating, a capacitor is added for "compensation." The need for compensation has led to the development of two major types of op amps: those that are "internally compensated" and those that are "externally compensated." Internally compensated op amps (where the capacitor is in the chip) meet the objective of simplicity, but at some sacrifice in performance, such as slew rate or unity gain bandwidth. Externally compensated op amps are compensated through use of outside capacitors.

Figure 2

Estimated Amplifier Market by Technology



Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

The ideal op amp provides a linear output voltage that is proportional to the voltage difference across the two input terminals. Ideal op amps have the following characteristics:

- Differential gain = infinite
- Common-mode gain = 0
- Input resistance = infinite
- Output resistance = 0
- Bandwidth = infinite
- Offset and drift = 0

Although we would like to deal with ideal op amps, in reality there are no such perfect circuits. Designers must make decisions based on primary performance requirements. A broad array of specialized circuits have been developed over the years to optimize certain product features.

The specialization of op amps to meet various needs has given rise to a number of product classifications. These variations include the following:

- General purpose
- Higher precision/accuracy
- Higher speed
- Lower power
- Multiples (duals and quads)
- Single or dual power supply

General Purpose. This is the largest category of operational amplifiers. General-purpose circuits meet most usage requirements; they generally are specified as follows:

- Input offset voltage—5mV
- Input bias current—500nA
- Slew rate—1 V/usec

High Precision. High precision or accuracy means that less correction must be used for errors in the op amps, such as offset voltage or drift. These circuits generally are classified as follows:

- Input offset voltage—<1mV
- Input bias current—< ±50nA
- Open-loop gain—>100,000 (minimum); 500,000 (typical)

High Speed. High speed refers either to the speed of frequency response, called gain bandwidth, or to the speed of the slew rate. These circuits generally are classified as follows:

- Slew rate—≥10V/usec
- Gain bandwidth—>4 MHz

©1990 Dataquest Incorporated August

Low Power. Low power refers to the power consumption of the op amp. Some versions have been designed specifically for battery operation and generally are classified as follows:

- Supply-current drain—<300 uA per amplifier
- Supply voltage range—can go to ±1.2 volts or ±2.5 volts (typical)

Multiples. Multiples refer to the number of op amps in a chip. Two circuits per chip are referred to as "dual," and four circuits per chip are called "quad."

Power Supply. Op amps typically are operated from a positive and a negative power supply, typically ±15 volts, to allow the input and output to swing above and below ground. Newer applications usually are run on a single-ended supply, although a dual power supply also can be used.

Audio Amplifiers

Audio amplifiers are designed to operate with AC signals within the audio spectrum, which is 20Hz to 20,000Hz. There are two basic types of audio amplifiers: preamplifiers and power amplifiers.

Video Amplifiers

Video amplifiers are concerned with amplifying very high-frequency AC signals. These signals frequently range between 1 MHz and 100 MHz or higher. The DC characteristics of the circuit are not important. Typically, the input and output are differential rather than single ended, meaning that the circuit amplifies the difference between the two input terminals and provides an output to two terminals. The amplifier ignores any signal common to the two input terminals.

Amplifier Suppliers

The principal amplifier suppliers are listed in Table 1.

Table 1

Principal Suppliers of Mil/Aero Amplifier ICs

	General Purpose	High Speed	High Voltage	Low-Bias Current	Low Drift	Low Power	Wide-Band	GaAs
Alpha Industries								X
ANADIGICS								X
Analog Devices	X	X	X	X	X			
AT&T	X	X						
Avantek								X
Ball Aerospace								X

(Continued)

Table 1 (Continued)

Principal Suppliers of Mil/Aero Amplifier ICs

	General Purpose	High Speed	High Voltage	Low-Bias Current	Low Drift	Low Power	Wide-Band	GaAs
Burr-Brown	X	X	X	X	X	X		
Datel	X	X						
Elantec	X	X						
Exar	X	X	X					
Fujitsu	X							
Harris (GE)	X	X	X	X	X	X	X	X
Hitachi	X	X	X					
Holt	X					X		
Honeywell								X
ITT								X
Linear Technology	X	X	X					
Litton								X
M/A COM								X
Maxim	X							
McDonnell Douglas								X
Microlinear								
Micro Power	X	X	X	X				
Microwave Semi.								X
Mitsubishi	X							
Modular Devices								
Motorola	X	X	X	X	X			
National	X	X	X	X	X	X	X	
NEC	X	X						
Pacific Monolithic								X
Philips-Signetics	X	X	X					
Plessey								
PMI	X	X	X	X				
Raytheon	X	X						
Rockwell								X
SGS-Thomson	X	X						
Silicon General	X	X						
Siliconix	X							
Sipex Data Linear								
Solitron	X							
Teledyne	X	X	X					
Texas Instruments	X	X						
Toshiba	X							
TriQuint								X
TRW Space and Def.								X
Varian								X
VTC	X							
Westinghouse								X

Source: Dataquest (August 1990)

COMPARATORS

Market Segmentation

Dataquest's analysis of the market cuts across two dimensions—product segments and technology. We will address the current status of each of these dimensions and discuss the implications for future growth.

The first dimension is product segments. Dataquest divides the comparator market into two categories—low and medium speed, and high speed. Low- and medium-speed comparators function at greater than 25 nanoseconds. High-speed comparators operate at 25 nanoseconds or less.

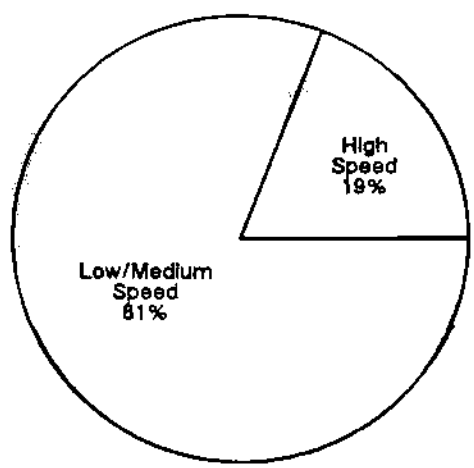
The largest volume of products is currently in the low- to medium-speed range. In the future, the high-speed range is expected to grow in size because of the importance of the speed function and an increased focus from suppliers. Comparator speed is very important in relaying operational information to dependent system circuitry. Speed is especially critical in automatic test equipment and instrumentation applications. Figure 3 illustrates the current status of speed segmentation.

Of the products segmented by speed in Figure 3, we note that the low to medium range is the largest category at 81 percent. The high-speed area is currently quite small, at 19 percent of the total market. This area is expected to grow strongly in the future, however, because of high-speed performance requirements coming from applications such as instrumentation.

Bipolar is the predominant technology, as in other analog product areas. Bipolar technology accounts for 88 percent of the comparator market. MOS technology accounts for 9 percent of the market. BiCMOS is currently a small portion of the comparator market at 3 percent. As a single function, comparators are subject to displacement. Multifunction chips may absorb comparators, or the circuits may evolve into cell libraries. With these directions in mind, MOS and BiCMOS will be the favored technologies.

Figure 3

Estimated Comparator Market by Speed Segment



Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Comparator Technology

The purpose of a comparator is to compare two inputs, one of which usually is at a fixed reference voltage, and to give a digital output based on the comparison of the two inputs. The output of the circuit is determined by which input has the highest voltage—the reference or the compared input. This is a very common function, and it is the basic conversion function of analog to digital. The typical application for this circuit is for comparing some varying signal, such as temperature or light intensity, to a reference. A "1" or "0" is given as the output signal when the compared input signal goes above or below the point of reference. Another use of a comparator is to "clean up" digital signals that have deteriorated over a long line or through a circuit, such as in a radio receiver.

The comparator is very similar to an op amp, except the output snaps between the digital states rather than varying continuously. The input impedance, gain, and output voltage swing requirements often are somewhat lower for a comparator than for an op amp.

Because a comparator output switches between the two output states of "1" and "0," the voltage gain requirement is less, as feedback is not used to improve linearity. To interface with digital circuits, the required output swing levels range from 3 to 5 volts, and a voltage gain of 1,000 is usually sufficient. The input offset and bias current requirements of a comparator are comparable to those of an op amp.

Several significant parameters define the usage of a comparator. The primary focus of the parameters are speed and the reduction of errors.

Response speed is a critical parameter for most comparator applications. The comparator is required to switch between two output states in a minimum amount of time subsequent to an appropriate level change, and the circuit should exhibit fast rise and fall times in its output. The comparator also is required to have a rapid recovery from cutoff to saturation as a condition of the input or output.

A direct measure of the speed capabilities of a circuit is its "response time." Response time is defined as the time interval between the application of a predetermined step input and the time it takes for the output to cross the corresponding logic state threshold. The input step drives the comparator from some initial saturated input condition to an input level in excess of that required to cause the output to switch states. This excess voltage is called the "overdrive." The comparator response speeds up as the overdrive increases. For comparison purposes, response times normally are stated with a 100mV total input step change and a 5mV overdrive.

Errors can be introduced through a comparator in a number of ways, including through the input offset voltage and input offset current. Input offset voltage refers to the voltage difference needed on the comparator input in order to change the output. Most of the popular comparators range from 2MV to 3MV in input offset voltage. A closely associated issue is the input offset current. This is the difference in the two input bias currents that can cause a change in the output. Input offset current is typically 20nA to 3uA.

The characteristics of the circuit application also are important in selecting a comparator. Part selection should take into consideration the nature of the differential input and the power supply.

Other than speed, the major variance in comparators lies in either features or how many devices there are to a package. The significant features include programmability and the ability to be strobed. Comparators usually are offered in combinations of two, four, or six per package.

©1990 Dataquest Incorporated August

Comparator Suppliers

Table 2 lists principal comparator suppliers.

Table 2

Principal Suppliers of Mil/Aero Comparator ICs

	Low/Medium Speed (>25ns)	High Speed (<25ns)
Advanced Linear	X	X
Analog Devices	X	X
AT&T	X	
Elantec	X	
Fujitsu	X	
Harris (GE)	X	
Hitachi	X	
Holt	X	
Honeywell		X
Linear Technology	X	X
Mitsubishi	X	X
Motorola	X	
National	X	
NEC	X	
Philips-Signetics	X	X
Plessey		X
PMI	X	X
Raytheon	X	X
SGS-Thomson	X	X
Silicon General	X	X
Siliconix	X	
Tektronix		X
Texas Instruments	X	X
Toshiba	X	
VTC	X	X

Source: Dataquest (August 1990)

VOLTAGE REGULATOR/REFERENCES

Market Segmentation

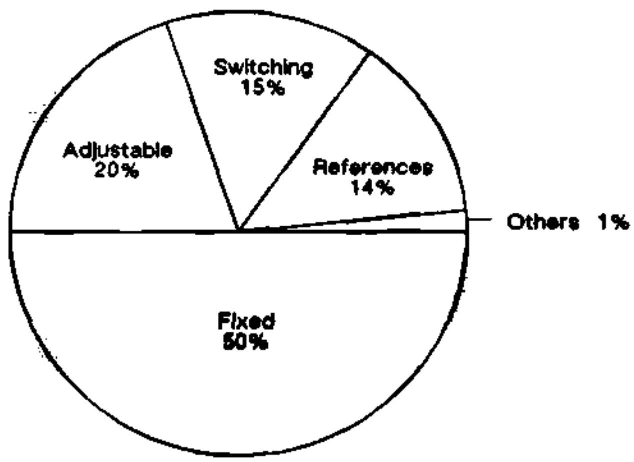
Dataquest's analysis of this market cuts across two dimensions—product segments and technology. We will address the current status of each of these dimensions and the implications for future growth.

The first dimension is product segments. Dataquest divides this market into five categories—fixed, adjustable, and switching regulators, references, and others. The fixed and adjustable categories represent linear types of regulation in contrast to switchmode regulation. References are also lumped into the regulator category. References provide a stable voltage comparison to the output signal.

In this combined area of regulators and references, we note the fixed type of regulators to be the largest subcategory at 50 percent. Next in volume are adjustable regulators at 20 percent. References and switching regulators are close in value at 14 percent and 15 percent, respectively. For a visual illustration of the composition of the market, please refer to Figure 4.

Figure 4

Estimated Regulator/References Market by Product Segment



Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Voltage Regulator Technology

The basic function of a voltage regulator is to provide power to other circuits at a specified DC voltage. Typically, the power source may not provide the appropriate voltage or be able to maintain the output voltage over the range of current the load demands. The purpose of a regulator is to provide a specified constant DC voltage to a load over a wide range of variations in input voltage and output current. Later versions of regulator integrated circuits (ICs) have added the function of protection from failure due to excess current or temperature.

There are two ways of providing regulation—linear and switchmode. With linear regulation, the regulator absorbs the difference between the input and the desired output. For example, if 5 volts is the desired output and the input is 8 volts, the regulator will absorb the 3-volt difference. Although circuits providing linear regulation can provide excellent performance, their efficiency can be very low. Using the example already illustrated, at 1 ampere, the load would absorb 5 watts and the regulator would have to dissipate 3 watts, resulting in an efficiency of 62.5 percent. The efficiency of most linear regulators is between 30.0 and 70.0 percent.

In switchmode, the regulator connects and disconnects the power source at a rapid rate (20 kHz to 1 MHz) and varies the ratio of the on-time to off-time to provide regulation. Although the circuit is more complex and requires careful selection of components, the switchmode or switching regulator offers efficiencies of between 70 and 80 percent and size and weight reductions in power supply applications of about 80 percent compared with linear regulators.

Of the three types of regulators illustrated in Figure 4, the fastest growth is in the switching and adjustable areas. Of these two segments, the switching regulator is the fastest-growing area. Switching regulators offer many benefits in the way of power supplies and will show very strong growth in the future. Because of the benefits of the technology enhancement, we expect this segment to represent a much more significant portion of the market in the future.

From a technology standpoint, the market is dominated by bipolar technology. We note the distribution to be 97 percent bipolar and 3 percent MOS. We expect regulators to go the way of other analog products, with more focus on MOS and BiCMOS technology in the future.

Table 3 shows some of the operating characteristics of the various types of regulators, including fixed 3-terminal, adjustable, and switching regulators.

Table 3

Comparisons of Various Types of Regulators

Type	Input Voltage	Output Current	Output Voltage
Fixed 3-Terminal	35V-40V	100mA-20A	2V-24V
Adjustable	36V-40V	100mA-3A	1.2V-57V
Switching	1V-40V	40mA-1.5A	Drives transistor
Fixed Negative	35V-40V	100mA-5A	2V-36V

Source: Dataquest (August 1990)

Regulator/Reference ICs

Table 4 lists the principal regulator/reference IC suppliers.

Table 4

Principal Suppliers of Mil/Aero Voltage Regulator and Reference ICs

	Regulators Fixed	Adjust.	Switching	Reference
Analog Devices				X
AT&T	X			X
Burr-Brown				X
Cherry	X		X	
Exar	X	X	X	
Fujitsu	X		X	
Harris (GE)		X	X	X
Hitachi	X	X	X	
ITT	X			X
Linear Technology	X	X	X	X
Maxim		X	X	X
Micro Power				X
Mitsubishi	X	X	X	X
Motorola	X	X	X	X
National	X	X	X	X
NEC	X	X	X	X
Philips-Signetics		X	X	
Plessey				
Raytheon	X	X	X	X
Rifa			X	X
SGS-Thomson	X	X		X
Silicon General	X	X	X	X
Siliconix			X	
Sipex Data Linear				
Solitron	X	X		
Teledyne				X
Texas Instruments	X	X	X	
Toshiba	X	X	X	
VTC				X

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

INTERFACE ICs

Market Segmentation

Dataquest's analysis of the market cuts across two dimensions—product segments and technology. We will address the current status of each of these dimensions and the implications for future growth.

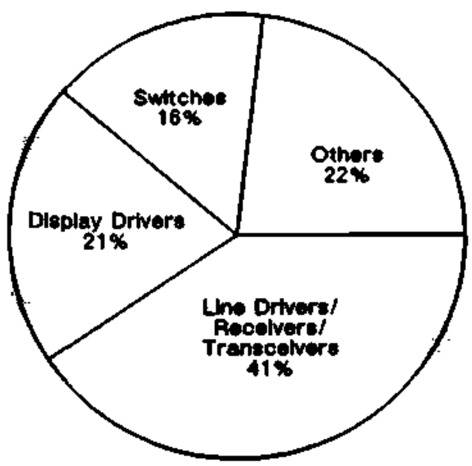
The first dimension is product segments. Dataquest divides interface ICs into four categories—line drivers, receivers, and transceivers; display drivers; switches; and other. Line drivers, receivers, and transceivers transmit data. Line drivers send data, line receivers receive data, and transceivers both send and receive data. Display drivers send data to display terminals, and switches control circuit function.

The largest of these categories is the combined segment of line drivers, receivers, and transceivers. This category amounts to a market value of 41 percent of total interface IC sales. Next in size is the display driver sector, contributing 21 percent of the market. Switches account for 16 percent of sales. For a visual illustration of the composition of the interface IC market, please refer to Figure 5.

Interface product growth has ups and downs that are associated with digital products. We expect all of these product segments to flourish with the need to connect systems and peripheral products.

Figure 5

Estimated Interface IC Market by Product Segment



Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Of the general-purpose analog products, the interface IC market currently shows the greatest diversity in technology. The interface IC sector comprises 72 percent bipolar, 21 percent CMOS, and 7 percent BiCMOS. We expect much more growth from MOS, specifically CMOS and BiCMOS, in the future. CMOS technology offers advantages of low-power consumption and allows higher integration over bipolar parts. BiCMOS technology offers the lower power consumption of MOS with the speed and output drive advantages of bipolar.

Interface IC Technology

Interface circuits are used to connect the digital world, which typically runs at 5 volts DC, with the outside world, which operates at much higher voltages. Functionally, this involves the flow of data over lines, power boosting and handling capabilities to drive other functions, and analog signal switching. These functions are handled respectively by line drivers, receivers, and transceivers; power drivers, including display drivers; and analog switches.

To have a good transmission system, it is important that certain basic requirements are fulfilled initially. The requirements of a component system include the following:

- Speed—Most systems must be capable of handling speeds up to 10 MHz. The speed of operation is often expressed in bits per second (bps).
- Power supplies—The most common power supply is 5 volts, although others also may be used.
- Logic compatibility—TTL-level compatibility is the norm, although some devices also can be used with ECL and high-voltage CMOS.
- Drivers—These circuits must be able to drive low-impedance transmission lines and to withstand line voltages up to V_{cc} supply levels.
- Receivers—These circuits must have good input sensitivity, generally less than 500mV, and must be able to provide immunity to various forms of noise.
- Lines—Lines must have uniform impedance characteristics over their length, allowing correct termination of high-speed transmission without error.

Line Drivers/Receivers/Transceivers

Line drivers and receivers handle the sending of a digital signal back and forth over a cable that might attenuate the signal level below logic levels. Transceivers combine the function of sending and receiving signals in one circuit.

Line interface circuits, drivers, receivers, and transceivers are available in single-ended or differential modes. The advantage to the differential transmission includes high common-mode noise voltage rejection, reduced line radiation, improved speed, and longer line driving. Their disadvantages compared with single-ended transmission include their slightly higher costs and the fact that they must be used with balanced transmission lines, such as twisted pair. Single-ended circuits generally offer simple use and connection, have a low cost, and require only one power supply. Applications of single-ended circuits are limited, however, by line length and data transmission rate concerns, as well as by noise affiliated with this configuration.

 ©1990 Dataquest Incorporated August

Both single-ended and differential circuits are available for general-purpose applications or for special interface standards. A number of standards have developed for specialized applications, including RS-232, RS-422/423, RS-485, IBM 360/370, and IEEE 488.

Power Drivers

Power drivers increase the voltage or power controlled by a digital circuit so that the output may do some useful work, such as drive a printer or a display. Power drivers also come in specialized application variations, such as memory drivers, motor drivers (direct drive), power semiconductor drivers, and display drivers. We will discuss display drivers in more depth.

Display Drivers. Display drivers are a significant portion of the interface market. These circuits are used to drive various types of display products. Because of varied requirements in the specific end applications, these circuits are very specific with respect to the display medium. There also are several ways that data are entered to control the display. Table 5 describes the major display types and their key characteristics.

Because display drivers are application oriented, we will discuss some of the attributes of various types of display systems and their associated driver needs.

LED Display Drivers. Light-emitting diodes (LEDs) are available in a variety of sizes and operating currents. It is common for a display to require 5 to 20mA forward current per light source for normal brightness levels. To minimize the number of drivers required to drive the display, time-multiplex techniques often are used.

Electroluminescent Display Drivers. EL displays have evolved into a product that is thin, durable, and compact in screen size, and has low power requirements. X-Y matrix panels also can offer line resolutions of up to 100 lines per inch, with up to 500 lines per axis. This display medium is available in a variety of forms including segmented characters, dot matrix characters, large X-Y matrix, and custom shapes. In an X-Y configuration, a panel requires both row and column drivers. A slightly different control is used for each of these drivers.

Table 5

Display Drive Characteristics

Display Type	Format	Voltage
Light-Emitting Diode (LED)	Bar graphs, dot matrix, multiple segment	Low
Liquid Crystal Display (LCD)	Bar graphs, dot matrix, alphanumeric	Low
Electroluminescent (EL)	Dot matrix	High
Vacuum Flourescent	Segment, digit	High
DC Plasma (Gas Discharge)	Segment, digit	High

Source: Dataquest (August 1990)

 ©1990 Dataquest Incorporated August

Vacuum Flourescent Display Drivers. The vacuum flourescent display emits a bright, clear, blue-green light. It comes in a variety of sizes and configurations of dot matrix, segment, and dot character. Its panel construction is flat, it operates on relatively low voltage, and it consumes relatively low power. The size of the display, its application, and timing determines the selection of an appropriate display driver.

DC Plasma (Gas Discharge) Display Drivers. The DC plasma medium offers a very bright display that is especially suitable for panel meters and test equipment. The most common configuration is the 7-digit array, which most drivers are designed to meet.

Switches

The function of an analog switch is to isolate or connect two sections of an electrical circuit. The ideal switch has the following characteristics:

- On resistance—0
- Off resistance—infinite
- Turn-on/turn-off times—instantaneous

Although an analog switch is not perfect because it has many parasitic elements, it can still come very close. On resistance can be as low as 10 ohms; off resistance can be as high as 90dB at 1 MHz; and switching speeds can be as fast as 75ns for a CMOS device. Other technologies are even faster.

The most critical consideration when using a switch is to avoid altering the analog signal input. A wide range of products are available from which to select the many varied product applications. Compromises must be made in selecting a product. Careful consideration should be given to on resistance, off resistance, linearity, voltage range, and speed.

Interface IC Suppliers

Table 6 lists the principal interface IC suppliers.

©1990 Dataquest Incorporated August

Table 6

Principal Suppliers of Mil/Aero Interface ICs

	Line Driver	Line Receiver	Line Trans-ceiver	Trans-mitters Receivers	Display Drivers	Switches	Memory Drivers	Periph. Drivers
AMD	X		X				X	
Analog Devices						X		
AT&T	X	X	X			X		
Cherry								X
Dallas				X			X	
Elantec								X
Exar	X	X	X		X	X	X	X
Fujitsu							X	X
Harris (GE)	X			X	X	X		X
Hitachi	X	X	X		X	X	X	X
Holt					X			
Hughes					X			
Intel				X			X	X
ITT						G		X
Linear Technology	X		X			X	X	
M/A COM						G		
MEDL				X				
Maxim	X		X		X	X		
Micro Power						X		
Microwave Semi.						G		
Mitel					X			
Mitsubishi	X	X			X	X		
Motorola	X	X	X	X		X	X	X
National	X	X	X	X	X	X	X	X
NEC				X	X	X	X	
Oki				X	X			
Pacific Monolithic						G		
Philips-Signetics	X	X	X	X	X	X	X	X
Plessey	X	X				G		
PMI							X	
Rifa								X
S-MOS Systems					X			
SGS-Thomson	X	X	X	X	X	X		X
Siemens					X			X
Silicon General		X					X	X
Silicon Systems							X	
Siliconix					X	X	X	X
SMC				X				X
Solitron					X	X		X
Sprague		X			X	X		X
Supertex					X			X

(Continued)

Table 6 (Continued)

Principal Suppliers of Mil/Aero Interface ICs

	Line Driver	Line Receiver	Line Transceiver	Transmitters Receivers	Display Drivers	Switches	Memory Drivers	Periph. Drivers
Tachonics						G		
Teledyne		X			X	X,G		
Telefunken	X	X			X			
Texas Instruments	X	X	X	X		X,G	X	X
Topaz						X		
Toshiba				X	X	X		X
TriQuint						G		
TRW Space & Def.						G		
Universal						G		
Unitrode	X	X						
Varian						G		
VLSI Tech.				X			X	X
Westinghouse						X		

G = GaAs
Source: Dataquest (August 1990)

DATA CONVERTERS

Market Segmentation

Dataquest's analysis of the data converter market cuts across two dimensions—product segments and technology. We will address the current status of each of these dimensions.

The first dimension is product segments. Dataquest divides data converters into several categories—analog to digital (A/D) converters, digital to analog (D/A) converters, multiplexers, sample and hold circuits, voltage to frequency (V/F) and frequency to voltage (F/V) converters, and other types. To review the functions, A/D and D/A converters translate analog signals to digital signals and vice versa. V/F and F/V converters translate an analog voltage to a stable frequency for long distance transmission and vice versa. The other products are used with data converters. Multiplexers isolate one signal from multiple signals for processing, and sample and hold circuits sample the value of a changing signal and hold it constant until it can be converted.

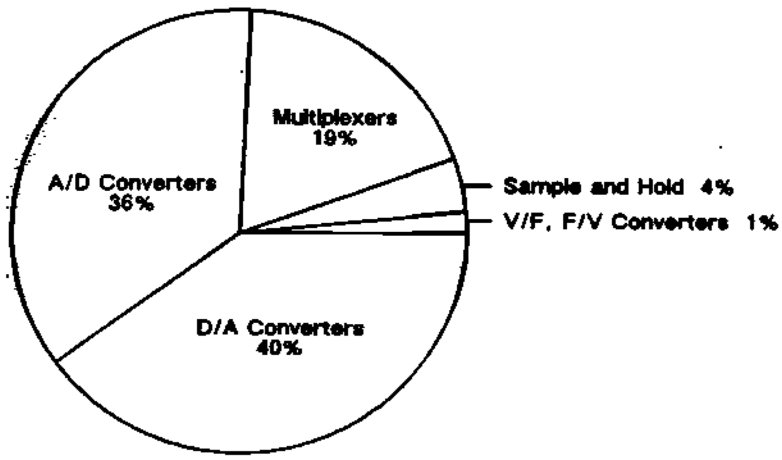
The D/A converter segment is the largest segment at 40 percent of the total versus 36 percent for the A/D segment. Multiplexer circuits are values of 19 percent and 4 percent, respectively. V/F, F/V, and other types of converters have a small portion of this market. For a visual illustration of the composition of the market, please refer to Figure 6.

The A/D converter market is split as 55 percent in the 10-bit or less sector and 40 percent in the greater than 10-bit sector. The focus for strong future growth will be in the high end of the market. D/A converters have approximately 49 percent of the market is in the greater than 10-bit range.

©1990 Dataquest Incorporated August

Figure 6

Estimated Data Converter Market by Product Segment



Source: Dataquest (August 1990)

Data converters show a very healthy mix of CMOS technology at 45 percent. BiCMOS is also currently being pursued and accounts for 5 percent. Bipolar technology accounts for the lion's share of the market, with 50 percent. We expect to see much more activity in BiCMOS and also CMOS technologies in the future. BiCMOS combines the benefits of CMOS' high-density and low-power consumption with the superior speed, high current, and low noise features of bipolar. The ability to combine both bipolar and CMOS features on a chip will drive this technology in the future.

Data Converter Technology

Multiplexers (MUXs)

The function of a MUX is to use digital control to select one signal from several inputs. It is the electronic equivalent of the rotary switch. MUXs are classified by the number of inputs that they can select and by whether they are singled-ended or differential. If many inputs are to be selected, the devices can be "stacked" or arranged in a combination that quickly multiplies the number of inputs.

Key product developments with MUXs include improving switching times, lower FET on resistance, and reduced crosstalk.

Sample and Hold (S&H)

The function of the S&H is to take a snapshot of the signal or a sample at some specific instant in time and hold the voltage constant until otherwise instructed. To do the job effectively, the circuit must not affect the signal being measured (input impedance), it must be fast, and it must not lose the value of the signal over time, e.g., "droop."

 ©1990 Dataquest Incorporated August

Although some ICs are used solely as S&Hs, there is a tendency to incorporate the function on the A/D converter when adequate performance can be achieved.

Analog to Digital (A/D) Converter

There are many ways of doing conversion, and Table 7 shows some of the relative trade-offs involved. The product development trends are for faster conversion times, less error, and greater resolution (bits).

Digital to Analog (D/A) Converter

The basic function of the D/A converter is to convert a digital input code to a specific value of voltage on the analog output. Although the output is viewed as analog because it can take values between "1" and "0," the output is varied in discrete steps, depending upon the resolution. The typical implementation of D/A conversion is to control the switching of weighted values of resistors or capacitors.

There is one other popular D/A converter—the multiplying DAC. Because the output of the converter is based on a series of divided steps from a reference voltage, if the reference varies, then the output is the product of the analog reference voltage and the digital code. One popular use is in a digitally controlled gain control.

New product developments include coupling RAM and DAC functions for graphics, greater resolution, shorter settling time, and reduced linearity error.

Data Conversion IC Suppliers

Table 8 lists the principal data conversion IC suppliers.

Table 7

Various Types of A/D Converters and Their Characteristics

Converter Type	Conversion Time	Error	Resolution
Single-Slope	Slow (ms)	High ± 1 LSB	Medium-high (8-14 bits)
Dual-Slope	Slow (ms)	High ± 1 LSB	High (10-18 bits)
Successive-Approximation	Medium (us)	Low-medium ± 0.5 LSB	Medium-high (8-16 bits)
Flash	Fast (us)	Low-medium ± 0.25 LSB	Low-medium (4-8 bits)

Source: Texas Instruments *Linear and Interface Circuit Applications*, Volume 3, 1987, pp. 11-14

©1990 Dataquest Incorporated August

Table 8

Principal Suppliers of Mil/Aero Data Conversion ICs

	A/D	D/A	Multiplx.	Sample and Hold	V/F, F/V
Addacon	X	X			
Advanced Linear		X			
Aeroflex	X	X			
AMD	X	X		X	
ANADIGICS	G				
Analog Devices	X	X	X	X	X
Brooktree	X	X			
Burr-Brown	X	X	X	X	X
Crystal	X				X
Datel	X	X	X	X	X
Exar		X			
Fujitsu	X	X			
Harris	X	X	X	X	
Hitachi	X	X	X		
Honeywell	X	X			
IDT	X	X			
Inmos		X			
ITT	G				
Linear Technology	X	X	X	X	
Maxim	X	X	X		
McDonnell Douglas	G				
MEDL	X	X			
Micro Power	X	X	X		
Microlinear	X	X			
Microwave Semi.	G	G			
Mitsubishi	X	X	X		
Modular Devices	X	X			
Motorola	X	X	X		
National	X	X	X	X	X
NEC	X	X	X	X	
Oki	X				
Philips-Signetics	X	X	X	X	
Plessey	X,G	X			
PMI	X	X	X	X	
Raytheon	X	X	X	X	X
Rockwell	G	G			
RTC			X		
SGS-Thomson	X		X	X	X

(Continued)

©1990 Dataquest Incorporated August

Table 8 (Continued)

Principal Suppliers of Mil/Aero
Data Conversion ICs

	A/D	D/A	Multiplx.	Sample and Hold	V/F, F/V
Siemens	X	X			
Sierra		X			
Silicon Systems		X	X	X	
Siliconix	X	X	X		
Sipex Datalinear					
Solitron			X		
Sprague			X		
Supertex			X		
Tektronix	X	X			
Teledyne	X		X	X	X
Texas Instruments	X	X			X
Topaz			X		
Toshiba	X		X		
TriQuint	G	G			
TRW-LSI	X,G				
Universal					
VTC	X	X			
Westinghouse	X	X	X		

G = GaAs
Source: Dataquest (August 1990)

INTELLIGENT POWER ICs

Overview

Intelligent power technology entails the coupling of digital logic with the power handling capabilities of analog circuitry. Its most common usage is for microprocessor-controlled power switches and assorted motor, solenoid, and actuator control applications. It is competing with existing solutions such as electromechanical switches, hybrids composed of combined logic and power functions, and discrete MOSFETs, which accept TTL gate signals. Dataquest expects the cost competitiveness of integrated intelligent power ICs to improve as volume applications appear in the early 1990s. Aircraft bus architectures and fly-by-wire systems are expected to be two of the major beneficiaries of this technology.

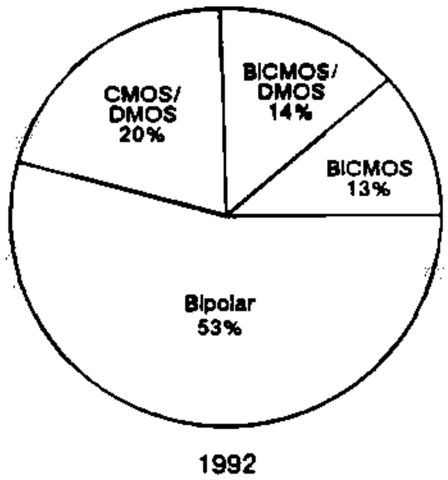
Market Segmentation

Figure 7 presents our estimated technology breakdown of the intelligent power IC market. Bipolar implementations currently dominate with 80 percent of the market. However, by 1992, various mixed CMOS, BiCMOS, and DMOS versions are expected to complement the bipolar versions. Compatibility with the CMOS microprocessor-controlled buses and the ever-present need to reduce power consumption will drive the growth of the MOS versions.

©1990 Dataquest Incorporated August

Figure 7

Intelligent Power Technologies



Source: Dataquest (August 1990)

There are at least 20 companies that make up the supply base for various approaches to intelligent power ICs. The market leaders to date are Motorola, National, SGS-Thomson, and Texas Instruments. Dataquest expects some consolidation of this marketplace in the future, but its application-specific nature will allow many suppliers to exist in various niches.

Applications

The applications of intelligent power to military/aerospace systems are many. An abbreviated list of those applications follows:

- Aircraft bus architectures (e.g., Pave Pillar)
  - Actuator control (such as rudders and elevators)
  - Engine control
  - Radar power control
  - Countermeasure power control
  - Cockpit controls and displays
- Spacecraft and launch vehicle control
- Missile, torpedo, and smart weapon control
- Shipboard radar, sonar, and countermeasures control
- Tank and armored vehicle system control
- Rugged computers peripheral control (such as printers and disks)

©1990 Dataquest Incorporated August

Technology

Available and emerging technologies for intelligent power ICs actually represent a spectrum of various approaches. It ranges from the emergence of smart discrete MOSFETs, which can accept TTL gate commands from a microprocessor, to wholly integrated solutions with several hundred gates of logic and numerous sense, feedback, and protection capabilities.

Figure 8 presents a generic diagram of an intelligent power IC. Applications range from such specific standard functions as high-side switches, 3-phase brushless and full-bridge motor control, and computer peripheral control to switchmode converters for DC/DC conversion. ASIC approaches also are emerging as many features are incorporated into core libraries, allowing a relatively quick turnaround time for tailored product features. These libraries can be customized to specific microprocessor and load-dependent purposes.

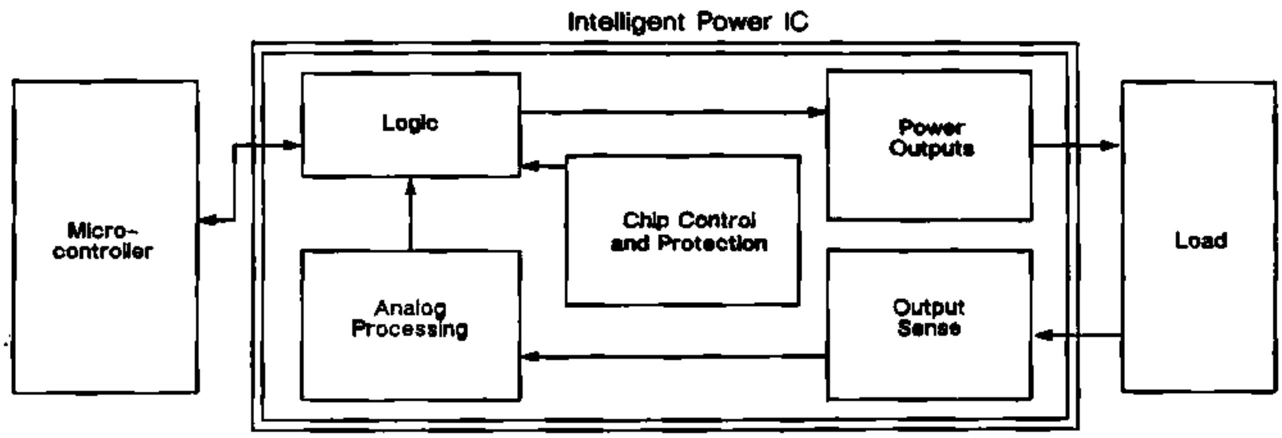
The technology in its various forms has been energized by breakthroughs in isolation of high (power) and low voltages (digital control). Self-isolation and junction-isolation techniques are two approaches to isolation. The current product spectrum includes a range from 50-amp to 50-volt devices to 500-volt to 2-amp devices.

Military temperature range (-55°C to 125°C) use has been hampered by the lack of adequate packaging standards. However, proposals under review by JEDEC are intended to correct this situation, including a 15-pin hermetic, T0-204 style package with conventional glass/metal lead sealing.

As high-volume applications such as computer peripherals and automotive controls develop, this factor should help drive the cost of these ICs down the classic learning curve. Currently at the $10 to $20 range for commercial temperature range versions, intelligent power ICs will most likely be in the $2 to $3 range by the early 1990s.

Figure 8

Generic Intelligent Power IC



Source: Texas Instruments

©1990 Dataquest Incorporated August

Other Analog IC Suppliers

Table 9 lists some other analog IC suppliers.

Table 9

Principal Suppliers of Mil/Aero Other Analog ICs

	Signal Gener.	PLL	Timers	Sensors	Motor Control	Filter	Other MMIC Functions
Adams-Russell							X
Advanced Linear			X				
ANADIGICS							X
Analog Devices	X			X			
ANEC		X	X				
ATT						X	
Avantek							X
Cal. Micro Devices			X	X		X	
Cherry					X		
Exar	X	X	X			X	
Ford Micro.							X
Fujitsu		X					
Gould						X	
Harris	X	X	X	X	X	X	X
Hitachi			X				
Honeywell				X		X	X
Hughes		X					
IC Sensors				X			
IMI		X					
Integrated Power	X						
Intel						X	
ITT							X
Linear Technology				X			
Maxim			X				
Mitel						X	
Mitsubishi	X		X		X		
Motorola	X	X	X	X	X	X	
M/A COM							X
National	X	X	X	X	X	X	
Nova Sensor				X			
Pacific Monolithic							X

(Continued)

Table 9 (Continued)

Principal Suppliers of Mil/Aero
Other Analog ICs

	Signal Gener.	PLL	Timers	Sensors	Motor Control	Filter	Other MMIC Functions
Philips-Signetics	X	X	X		X		
Plessey	X	X	X				
Raytheon	X	X	X			X	
Rifa			X				
Sensym				X			
SGS-Thomson			X	X	X	X	
Siemens		X		X			
Silicon Systems						X	
Sprague		X	X	X	X		
STI		X					
Tachonics							X
Teledyne			X				
Telefunken	X	X	X				
Texas Instruments	X	X	X	X		X	
Toshiba		X	X	X			
TriQuint							X
Unitrode		X			X		

Source: Dataquest (August 1990)

ANALOG GaAs ICs

Overview

Analog GaAs ICs, including microwave monolithic ICs (MMICs), are causing a major evolution in systems, pushing performance to record heights. The concept embodied in the first single-chip K-band radar module has revolutionized the design and functionality of radar systems. The TVRO downconverter MMIC pioneered by Pacific Monolithics proved that GaAs MMICs can be worst-case designed for production costs of less than $10 for certain applications.

Technology

Analog GaAs ICs offer the same types of advantages over hybrid devices as is the case in silicon technology, namely the following:

- Lower manufacturing costs via batch processing
- Improved quality and reliability through fewer wire bonds and discrete components

©1990 Dataquest Incorporated August

- Reduced size, weight, and power
- Circuit design flexibility, with potential for new functions

The first MMIC patent was filed in 1966. Since that time, MMIC amplifiers have led the evolution of GaAs and other III-V compound technology toward ever-increasing levels of integration.

A good example of the advantages of GaAs MMICs over hybrid MICs is found in electronic warfare (EW) applications. MMICs allow designers to place high-density threat detection and jamming capability into heretofore inaccessible places in aircraft structures, such as in wingtips, nosecones, and leading edges of flying surfaces.

Emerging Technology

The emerging technologies influencing analog GaAs ICs include scaling through refined photolithography and related processing, adoption of standard cell design methodology, increased complexity of functions on a single chip, and integration of electronic and photonic functions on the same die. The DOD millimeter-microwave IC (MIMIC) initiative is expected to intensify many of these activities.

Scaling and Performance. The relatively low volume of wafers processed by a MMIC fab line allows working to tighter specifications than is usual for silicon fab. A "loose" GaAs MMIC process as of late 1988 has 0.6u minimum geometries. However, this would be considered difficult to control in most silicon fab areas. Next-generation GaAs processes will use 0.25u or tighter minimum gate lengths. As a result, transistor cutoff frequencies are being pushed beyond 100 GHz in new GaAs processes, and performance continues to climb dramatically.

Standard Cell Designs. Shortly after Pacific Monolithics announced the industry's first extensive GaAs MMIC standard cell family in 1986 (comprising more than 30 cells), others joined the bandwagon. Now several suppliers are claiming standard-cell MMIC capability, and more announcements are expected soon. This approach is very cost effective for many designs.

MIMIC Program. The DOD MIMIC initiative, which also is discussed in the "Systems Markets" section, represents a major effort to incorporate the advantages of compound semiconductors into a variety of military applications. These applications include:

- Ultrareliable radar for the Air Force ATF
- Shared-aperture radar for the Navy ATA
- MILSTAR network communications terminals
- Smart munitions
- Wideband jammers
- Antiradiation missiles
- Other "brilliant" weapons

 ©1990 Dataquest Incorporated August

Products

GaAs analog and linear ICs may be categorized as including the following types of products:

- Amplifiers—Transimpedance, preamps, AGC amps, op amps
- Converters—A/D, D/A, sample and holds, phase-locked loops
- Analog signal conditioners—Mixers, tuners, switches, doublers
- Oscillators
- Comparators

The product and process improvements in analog GaAs ICs are accelerating. A cross-section of activities in this field is presented in Table 10. Papers were presented by each of the companies shown at major conferences and seminars in 1988.

As in the case of silicon technology, GaAs IC products are available in standard, ASIC, and custom forms. The particular approach used typically depends on the design constraints of function, performance, cost, and availability. At the end of 1988, about 30 companies were serving the merchant market for GaAs analog ICs. More than a dozen foundries are available to serve the growing customer base for GaAs analog ASICs and custom products.

Markets

Typical applications of analog GaAs ICs include the following:

- Military/government—Radar, lidar, satellite communications, ECM and EW equipment, fiber-optic links
- Communications—TVRO, commercial satellite, cellular phones
- Instrumentation—Spectrum analyzers, microwave testers
- Consumer—CDs, videodiscs, VCRs
- Automotive—Collision-avoidance radar, radar detectors

Suppliers

The companies listed in Table 11 were serving the GaAs analog/linear merchant market at the end of 1988. There also are many captive suppliers, some of which are teamed in support of the DOD MIMIC initiative.

©1990 Dataquest Incorporated August

Table 10

Product Concepts in Analog GaAs ICs

Company	Product Concept
Alpha/Aerojet/GAMMA Monolithics	Monolithic Ka-band VCO (voltage-controlled oscillator)
ANADIGICS	7-Gbps decision circuit IC
ATR (Osaka)	Broadband active inductor
COMSAT Labs	60-GHz MMIC LNAs
Ford/COMSAT Labs/Pacific Monolithics	ASMMIC (application-specific MMIC) cell library
GAMMA Monolithics	35-GHz MMIC LNA
General Electric	Wideband MMIC variable gain amplifiers
Hughes Aircraft	V-band MMIC transmit-receive switch
ITT	MMIC IF upconverter
LEP/TRT (France)	MMIC for FM continuous wave radars
Matsushita	15-GHz single-stage divider
Mitsubishi	HEMT fabricated with focused ion beam lithography
NEC Corporation	9.5-GHz prescaler
NTT	Uniplanar MMICs
Pacific Monolithics	6- to 18-GHz MMIC amplifiers
Raytheon	14- to 37-GHz power amplifier MM-wave monolithic IMPATT VCO 3-bit K/Ka-band MMIC phase shifter
Texas Instruments	0.5- to 4-GHz true logarithmic amplifier 60-GHz CW IMPATT oscillator X-band monolithic LNA 3-watt X-band variable gain amplifier Ka-band monolithic power amplifier modules X- and Ka-band MMIC variable attenuation limiters
TRW Inc.	GaAs HBT log IF amplifier Q-band monolithic 3-stage amplifier
Varian	MMIC Ka-band HEMT LNA
Westinghouse	6- to 18-GHz analog phase shifter

Source: Aztek Associates

©1990 Dataquest Incorporated August

Table 11

Analog/Linear GaAs IC Suppliers by Region

Western Europe	Japan	United States
Philips	Fujitsu	Alpha Industries
Plessey 3-5	Hitachi	ANADIGICS
Siemens	Mitsubishi	Avantek
Thomson-CSF	NEC (CA Eastern Labs)	COMSAT Labs
	Toshiba (Matcom)	Ford Microelectronics
		Harris
		Hittite
		Hughes
		ITT GTC
		M/A-COM
		Microwave Monolithics
		MicroWave Technology
		Narda
		Pacific Monolithics
		Sanders
		Teledyne
		TI
		TriQuint
		Varian
		Westinghouse

Source: Dataquest (August 1990)

GaAs Analog Partnerships, Joint Ventures, and Alternate Sources

The following are typical examples of the many supplier companies' interrelationships in this industry segment:

- Pacific Monolithics/TriQuint
- Pacific Monolithics/COMSAT Labs
- Rockwell/IBM
- MicroWave Technology/Monolithic Microsystems
- TRW/TriQuint
- Ciba-Geigy/Spectra-Physics
- Amoco/Spectra Diode/Kodak/Litton Airtron
- Thorne-EMI/Varian

©1990 Dataquest Incorporated August

- Ford ASMMIC Team
  - Ford Aerospace/Communications Corp.
  - Ford Microelectronics, Inc.
  - Singer Dalmo Victor Division
  - IBM Federal Systems Division
  - COMSAT
  - Pacific Monolithics
  - TriQuint

Issues

The user issues involved in the use of GaAs analog ICs include the following:

- Design considerations:
  - Monolithic versus hybrid trade-offs
  - Decreasing the risk of system obsolescence
  - Transmission line environment considerations
  - Design tolerance of parametric variations
  - Test problems due to lack of high-performance equipment
- Export controls
- Frequency spectrum crowding
- Product availability and cost
  - Impact of international competition
  - Impact of industry structural changes
- Safety issues, including potential radiation hazards

©1990 Dataquest Incorporated August

Discrete Semiconductors

SUMMARY

Dataquest breaks the discrete market into seven separate categories: small signal and power transistors; small signal, power, and zener diodes; thyristors; and other discretes. The principal growth areas for discretes are in the GaAs microwave/millimeter and power categories.

TECHNOLOGY OVERVIEW

The term "discrete" refers to a packaged semiconductor device having a single function. This may mean that one or several functioning circuits are in the package. Technically, optoelectronic devices belong in this category, but for the purpose of this section, we are treating them separately. Dataquest identifies several classes of devices within the discrete category. They include transistors, diodes, thyristors, and other discretes. These devices are discussed in the following paragraphs.

Transistors

Transistors may be manufactured in bipolar or MOS technology. The characteristics of their structure differ according to the technology and their design function. We will first discuss the characteristics of a basic bipolar transistor.

A basic bipolar transistor consists of a "sandwich" of doped silicon layers, either PNP or NPN. The transistor has three electrical connections: the base, emitter, and collector. Each of these areas provides access to one of the doped regions. The transistor can act as a current-amplifying device or a switch. In the current-amplifying application, a small change in a small current flowing between the base and the emitter can cause a large change in a proportionally larger current flowing between the collector and the emitter. In a switch function, a sufficiently large voltage applied to the base will cause the maximum amount of collector current to flow; this is referred to as saturation. If the voltage applied to the base returns to zero, the collector current drops to nearly zero. In this way, the presence or absence of a voltage between base and emitter can initiate or interrupt the flow of current in the collector circuit.

Field-effect transistors (FETs) differ from most bipolar transistors in that they are voltage-controlled rather than current-controlled devices. FETs are available in two types: junction types, or JFETs, and metal oxide types, or MOSFETs. The electrical connections to a FET are source, drain, and gate, which are somewhat similar to the emitter, collector, and base of a bipolar transistor.

JFETs have a gate/source junction through which only a very small amount of current can flow. This feature makes JFETs good for applications requiring low noise and input sensitivity. MOSFETs have no gate/source junction. The source and drain connections are made to two physically separated but similarly doped areas of silicon that are located in the surface regions of a substrate of silicon that is doped oppositely. The gate electrode is an area of oxidized silicon, which is an insulator.

A MOSFET may function in an enhanced mode or in a depletion mode; that is, the source-drain channel may be used to conduct or not conduct current, respectively. Both of these modes are used as amplifiers and switches. The low-leakage current and high degree of electrical isolation

©1990 Dataquest Incorporated August

between the insulated gate input and the drain output make MOSFETs extremely sensitive and excellent for high-frequency performance.

Power dissipation is another criterion for evaluating transistors. Transistors are generally classified into the categories of small signal and power.

Small-signal transistors dissipate power of less than 1 watt. The range of applications for these devices is large and increasing. They are used in small servo circuit controls to drive disks, magnetic tape drives, and videotape recorders. Other applications include front-end signal acquisition for communications, radar, sonar, and electronic warfare.

Power transistors dissipate power of 1 or more watts. Power transistors are used in applications of switch-mode power suppliers, power inverters, regulators, and motor controls. Historically, the realm of power transistors has been dominated by bipolar technology. In power-switching applications, the range above 1,000 volts is dominated by the bipolar power transistor, whereas power MOSFETs are strong in the 500- to 600-volt range. Whether bipolar or MOSFET, power transistors must operate within their safe operating area (SOA). The SOA is the maximum voltage and current to which the device should be exposed while in operation. If this maximum is exceeded, the device will be destroyed.

Diodes

Diodes are two-terminal devices that conduct current in one direction only. A PN junction forms the diode; the P section of the junction is analogous to the anode of a vacuum tube and the N section is analogous to the cathode. Primary types of diodes are signal diodes, power diodes or rectifiers, Schottky barrier diodes, and zener diodes.

Signal diodes are diodes with a forward current of less than 100 milliamperes (0.1 amperes). The sides of the silicon chip are metallized and encapsulated in a tubular glass package. These diodes are used as rectifiers in low-current power supplies, for detectors in lower-frequency circuits such as in televisions and radios, and for steering computer signals, an application for which integrated electronics has not been employed.

Power diodes operate at 0.1 or greater amperes. They are large-area PN junction diodes. In some applications, these rectifiers can be as large as 2 or 3 inches in diameter and handle hundreds of amperes of current. Some applications include radar and sonar power circuits.

A Schottky barrier diode is characterized by a junction of thin layered metals, usually platinum and p-type silicon. Schottky diodes can turn on and off very quickly in response to high-frequency alternating signals, but they are limited by low reverse breakdown voltage ratings. As high-speed, low-loss switching diodes, these devices are used in power supplies for computers and peripheral equipment.

Zener diodes are used for voltage regulators, overvoltage protection, voltage references, and level shifters. The conventional reference diode is an Okasis transistor with the zener avalanche occurring at the surface of the emitter—the base junction. This breakdown is noisy and the long-term stability is usually about 0.5 percent. Some improvement can be obtained by connecting a junction diode to an axial zener diode to obtain a more stable temperature-compensated system. Buried zeners are used with integral temperature stabilizers in applications including voltage regulators, operational amplifiers, digital-to-analog converters, multipliers, and dividers.

©1990 Dataquest Incorporated August

Thyristors

Thyristors consist of a four-layer slice of silicon. The device is characterized by continuous switching. Once a thyristor has been triggered into conducting current, it will continue to conduct current until the main current falls to zero. Large amounts of power can be controlled with very little gate power.

The name thyristor is used in a generic sense to include silicon-controlled rectifiers (SCRs), triacs, and diacs. A modification of the SCR—the gate turnoff SCR (GTO)—can be turned off with a negative voltage applied to the gate terminal. The solid-state relay (SSR) is a contactless switch with components (triacs, thyristors, resistors, capacitors, and an optical coupler) that are molded in compact models designed to dissipate heat efficiently. This switch is made possible by using an optical coupler (isolator) to link the power device and the control-signal source. This isolation prevents the output noise from feeding back into IC or LSI control circuits.

GaAs

Technology

In the early stages of the development and application of GaAs devices, individual small-signal transistors were used to build hybrid amplifiers and other functions. As integrated circuitry progressed through the development of the integrated inductor, it became possible to replace many hybrid functions with GaAs IC chips, thus slowing the growth of the transistor market. However, some applications still require the use of discrete transistors to accomplish the required tolerance control on such characteristics as low noise and gain-bandwidth.

Products

Discrete GaAs devices are broadly categorized as low-noise, low-power, and high-power. The distinction between low- and high-power transistors is usually made at a power level in the range of 0.5 watt to 1.0 watt.

Small-Signal Transistors. GaAs small-signal transistors are usually referred to as low-noise amplifiers (LNAs), although this term has also been used to describe one class of MMIC chips. Small-signal transistors are available for operation to frequencies as high as 120 GHz; NEC's NE04500G is one such device available in chip form. Mitsubishi offers several LNAs for operation at up to 100 GHz. Raytheon and several other companies market devices that operate above 60 GHz.

NEC has applied HFET technology to produce devices with 1dB noise figure and 12dB associated gain at 12 GHz. Fujitsu and others are developing HEMT devices as a means of improving low-noise performance in the microwave frequency range. One example of a supplier serving this market with innovative products is Gould, which has a product line that includes 18-GHz HEMT devices. Other suppliers of LNA products include Amperex (Philips), California Eastern Labs (NEC), Fujitsu, Harris, MSC (Siemens), Mitsubishi, Narda, Toshiba, and Varian.

©1990 Dataquest Incorporated August

Power FETs. The replacement of discrete transistors with ICs that has occurred in small-signal GaAs devices has not progressed as rapidly in power FETs, primarily due to the physical constraint of power dissipation. Discrete power FETs still represent a growing niche to the responsive supplier. Thus a market remains for suppliers such as Avantek, Fujitsu, Hughes, Gould, M/A-COM, MSC (Siemens), NEC, Philips, Raytheon, Thomson-CSF and TRW, and for several captive sources.

Hall-Effect Devices. Siemens has taken advantage of a developing market for high-temperature Hall-effect devices. GaAs provides a semiconductor capability to operate at temperatures more than 150°C higher than the maximum temperature achievable with silicon. Such products are useful for engine sensors, disk-brake rate-of-rotation sensors, and other very high-temperature applications.

Other Discretes. This category includes microwave diodes, varactor tuning diodes, and tunnel diodes. These devices have a wide variety of applications.

Discrete Semiconductor Suppliers

Tables 1 and 2 list the principal discrete suppliers.

©1990 Dataquest Incorporated August

Table 1

Principal Suppliers of Mil/Aero Diodes

	Transient Switching	Regulator Suppress.	Reference	RF Rectifier	Microwave
American Power Devices			X		
Alpha Industries					X
BKC International	X		X	X	
CODI			X	X	
Compensated Devices			X		
Diodes			X	X	
General Instrument	X	X		X	
General Semiconductor		X			
Germanium Power Devices					X
Harris (GE)	X				X
Hewlett-Packard	X				
Hughes					X
International Rectifier				X	
ITT	X		X	X	
Knox Semiconductor			X		
Microsemi	X	X	X	X	
Mitsubishi	X	X	X	X	X
Motorola			X	X	X
M/A-Comm	X				X
National Semiconductor	X			X	
NEC	X	X	X	X	X
Philips	X		X	X	X
Plessey					X
Powerex				X	
SGS-Thomson					X
Semicon Components		X	X	X	
Semtech				X	
Sensitron				X	
Siemens					X
Solid State Devices				X	
St. Semicon		X		X	
Teledyne				X	
Toshiba	X	X	X	X	X
Unitrode	X	X	X	X	
Varian					X

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Table 2

Principal Suppliers of Mil/Aero Transistor and Other Discretes

	Transistors						
	Low-Power Bipolar	Power Bipolar	Silicon FET/JFET	MOSFET	GaAs	Thyristor	Others
API Electronics	X	X	X				X
Avantek					X		
Fujitsu					X		
General Semiconductor	X	X					
Germanium Power Devices	X	X					X
Harris (GE)	X	X	X	X	X	X	
Hughes					X		
Interfet			X				
International Rectifier				X			
Lansdale	X	X					
M/A Comm	X				X		
Microsemi	X	X					
Mitsubishi	X	X	X	X	X	X	
Motorola	X	X	X	X		X	X
Narda					X		
National Semiconductor	X	X		X			X
NEC	X	X	X	X	X	X	
New England Semi.		X					
Pacific Monolithic					X		
Philips	X					X	X
Powerex						X	
PPC Products		X					
Power Tech.		X					
Raytheon	X	X	X			X	X
SGS-Thomson					X		
Sensitron		X					
Siemens					X		
Siliconix			X	X			
Silicon Transistor	X	X					
Solid Power		X					
Solid State Devices	X	X					X
Teledyne	X	X					
Toshiba					X		
Unitrode	X	X		X		X	X
Varian					X		

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Optoelectronics

SUMMARY

Dataquest breaks the optoelectronics market into four separate categories: LED lamps, LED displays, optoelectronic couplers, and other optoelectronic devices. Optoelectronics growth is being fueled by the communication and computer applications, which use light as a medium for communication. Emerging technology includes the development of optoelectronic ICs that combine optical and electronic processing on the same IC.

TECHNOLOGY OVERVIEW

Optoelectronics is a field that combines the technologies of optics and electronics. Visible devices, including LED lamps and LED displays, are the market segment concerned with the interactions between light-emitting and filtering devices and electronics. LEDs are the largest area of the opto market and are considered to be commodity products. Optocouplers and other opto areas are more customized products. Both of these are growing at a faster pace than LEDs. Other opto includes products such as photodiodes and phototransistors, solar cells, infrared lamps, and lasers.

LED Lamps and Displays

LED lamps and displays are based on the light-emitting diode. This device is a pinhead-size pn junction formed from combinations of gallium, arsenic, and phosphorus. Light emission is the result of hole-electron recombinations that take place near the junction of the p-doped and n-doped regions. As the electrons in the n region of the diode travel through the area near the junction, they recombine with a hole. As a result of this recombination between an electron and an atom, light in the form of photons is produced. The wavelength or color of the light is determined by the difference in energy levels.

The most common materials used to manufacture LEDs are gallium-arsenide-phosphide (GaAsP), which emits light in the 650-nanometer (nm) red light region of the visible spectrum, and gallium-phosphide (GaP), which can, with appropriate doping, be made to emit light in the 565nm green region. Mixing GaAsP and GaP in various substrate combinations can result in various color variations, including orange-red, amber, yellow, or bright greens. Blue is obtainable with ZnSe technology.

Light from LEDs is proportional to current, and altering the drive current modulates the light output. The eye cannot detect small changes in light intensity, however. The electrical requirements needed to operate an LED are current from 0.5mA to 20.0mA and voltage from 1.6V to 2.0V.

Individual LED dice may be bonded to metal lead frames or substrates of ceramic or fiberglass-epoxy laminate to form discrete numerical modules or multidigit displays. Seven separate dice are used to form a discrete seven-segment display module—an eighth die is used for the decimal point. Each of the seven dice illuminates a segment, or bar, used to form numbers from 1 to 10 and the letters A through F.

©1990 Dataquest Incorporated August

It is generally believed that visible LEDs have entered the maturity stage. They are used as light sources for reading facsimile machines and in duplicating machine erasers, printers, and outdoor displays. Additionally, applications in alarms and signals have been studied for some time. It is expected that LEDs will be used for automotive taillights in the future.

Optocouplers

Optocouplers or optoisolators consist of an LED separated from a photodetector by a transparent, insulating, dielectric layer, all mounted in an opaque package. A current pulse in the LED causes a radiation pulse to flow across the dielectric layers to the photodetector, which gives a current pulse at the output. The input and output circuits are coupled with high standoff voltage isolation. One important application for this coupler is to provide the isolation protection needed for triggering power semiconductors with delicate logic circuits.

The coupler can also be used as a linear input/output device. The input current signal can be varied about the bias current level, and the output will be a linear function of the input. Sensors or devices called optointerrupters and optoreflectors consist of couplers in which the space between the LED and the photodetector is arranged to accommodate a moving screen, a slotted disk, or a rotating reflector that modulates the radiation to the detector. These sensors are used as data encoders in computer peripheral equipment, as position sensors, and in some electronic games.

The current transfer ratio (CTR) is used to rate the efficiency of the coupler. Therefore, it is important to match the radiation wavelength of the LED to the absorption band of the detector. A considerable variety of couplers is available currently. Although diode couplers have the higher speed, transistor couplers (to 250 KHz) have higher sensitivity. Photo-Darlington couplers are available for high transfer ratios and increased current with speeds up to 25 KHz. The phototriac driver output coupler provides high-voltage (line-voltage) isolation protection for logic-triggering circuits.

The optocoupler is used in high-performance relays, position sensors, optical encoders, and voltage isolators for connecting logic circuits to power devices. Another growing market is for short quartz fiber links (less than 2km) for connecting sensors, computers, and terminals in a building. These links would operate in the visible (0.7u) or the near infrared. The couplers would use LED emitters and PIN photodiode detectors. The parabolic graded-index fiber would be used to prevent mode noise in short links. These links would have a bandwidth capacity of 70 MHz.

Other Optoelectronics

Other opto products include photodiodes and phototransistors, solar cells, lasers, and other optical sensing devices. Focal plane arrays are not covered in this category. Following is a short discussion of the characteristics of these products.

Photodiodes and Phototransistors

Photodiodes are used in CD ROM storage and in remote control devices and other products. Phototransistors are used as sensors in facsimile and photocopier machines. The demand for phototransistors is approximately three times that for photodiodes.

©1990 Dataquest Incorporated August

In optical communications, demand for silicon photodiodes is large. Silicon photodiodes are used for short-wavelength LEDs and in simple digital links. Growth in the production of digital links is expected to bring strong demand for silicon photodiodes.

Solar Cells

Solar cells are used mainly in electrical power and space-saving applications. In the consumer category, their use has been confined mainly to calculators. Although there was a strong initial demand in this market, no new applications have evolved. As to the other applications, the dropping price of oil has made solar cells less attractive from a price standpoint, and other forms of power are more efficient. Solar cells in the consumer environment are expected to show relatively low growth. Their other applications may have a somewhat higher growth rate.

Semiconductor Lasers

Semiconductor lasers are categorized according to their oscillation wavelength into 1.55-micrometer (um) band, 1.30um band, 0.85um band, and 0.78um band. The 1.55um band is the laser that is believed to have the greatest possibility for use as a light source in long distance optical communications. Currently, however, this wavelength is used only in a very few measuring instruments for optical communications. Semiconductor lasers of the 1.30um and 0.85um bands are being widely used for optical communications. The 1.30um band laser is used in long-distance optical communications and is expected to have high growth potential. Semiconductor lasers of the 0.78um band are widely used in CD ROM drives, optical videodiscs, and laser printers.

Optoelectronic Suppliers

Table 1 lists the principal optoelectronic suppliers.

©1990 Dataquest Incorporated August

Table 1

Principal Suppliers of Mil/Aero Optoelectronics

	LEDs	LED Lasers	Opto-Couplers	GaAs Photodetectors
Amperex		X		
Fujitsu		X		
General Optronics		X		
Harris (GE)		X		X
Hewlett-Packard	X			
III-V				X
Lasertron		X		
Lytel		X		
Micropac Indus.	X		X	
Mitsubishi	X	X	X	
Motorola		X	X	X
M/A Comm		X		X
NEC		X		X
Oki				
Optek	X	X	X	
Opto-Electronic		X		
Ortel		X		
Philips-Signetics		X		
PlessCor		X		X
Plessey				
Quality Semiconductor	X	X		
Siemens		X		
Spectra Diode Labs		X		
Stantel		X		
Telefunken	X	X		
Texas Instruments			X	
SGS-Thomson		X		X
Toshiba	X	X	X	

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Radiation Tolerance

OVERVIEW

Radiation tolerance or hardness addresses the continued correct performance of electrical equipment and inclusive semiconductors during and after exposure to various forms of radiation. The radiation can be generated by natural or man-made sources. As more data have been gathered on the subject in recent years, the effect of radiation on semiconductors has been recognized as a major design issue for space-based systems and other systems that potentially could be hampered or destroyed by radiation. Accordingly, radiation-hardened and radiation-tolerant semiconductors are increasingly being specified for a growing percentage of military and aerospace systems.

BACKGROUND

Definitions

Radiation resistance, along with the technology to implement it, is a complicated and somewhat controversial subject. To understand it, however, one needs to start with an understanding of the terminology. The following are some of the commonly used terms in radiation resistance:

- Radiation—Radiation is most commonly defined in four basic forms.
  - Neutron—component of atom
  - Alpha—helium nuclei
  - Beta—electrons
  - Gamma—high-energy, short-wave length photons
- Rad (Si) (radiation absorbed dose)—This is the quantity of any type of radiation that will impart 100 ergs of energy into one gram of silicon.
- Ionizing Radiation—Ionizing radiation has sufficient energy to dislodge electrons from atoms or molecules, thereby creating ions.
- Burst Radiation (prompt dose or pulse radiation)—This is radiation transmitted for a short period in pulse form.
- Total Dose—The amount of gamma radiation accumulated by the irradiated material during the total time of exposure is the total dose.
- Postirradiation Effects—These are changes in the device characteristics after the irradiation has ceased.
- Single-Event Upset (SEU)—An SEU involves the loss of data due to a single ionic particle. This event usually applies to memory devices.
- Transient Upset—This is the temporary corruption of data or severe degradation of a device during or immediately following a radiation exposure in excess of the device's dose rate tolerance.
- Latchup—Latchup occurs when a device enters a nonoperative condition and can be returned to operation only through removal and reapplication of the power supplies.

- Strategic Rad-Hard—Although many opinions abound, we define it as devices that remain functional during and after exposure to 10^5 rads (Si) total dose and 10^{12} neutrons/cm^2. A more restrictive definition addresses the electrical parametrics and operation within prescribed ranges.
- Tactical Rad-Tolerant—Given the definition of rad-hard, this would include all devices that remain functional from 5 x 10^3 to 10^5 rads (Si) total dose and 2 x 10^{12} neutrons/cm^2.

Table 1 summarizes the various types of radiation, their sources, and the sensitivity of various systems. Figure 1 presents further details regarding the natural radiation effects—in particular, single-event upsets—on avionics in high-altitude situations. This problem is of concern to both military and civilian avionics designers. The conclusion here is that there is a growing concern about aircraft data systems errors as these systems become more complex, incorporating denser submicron componentry.

Table 1

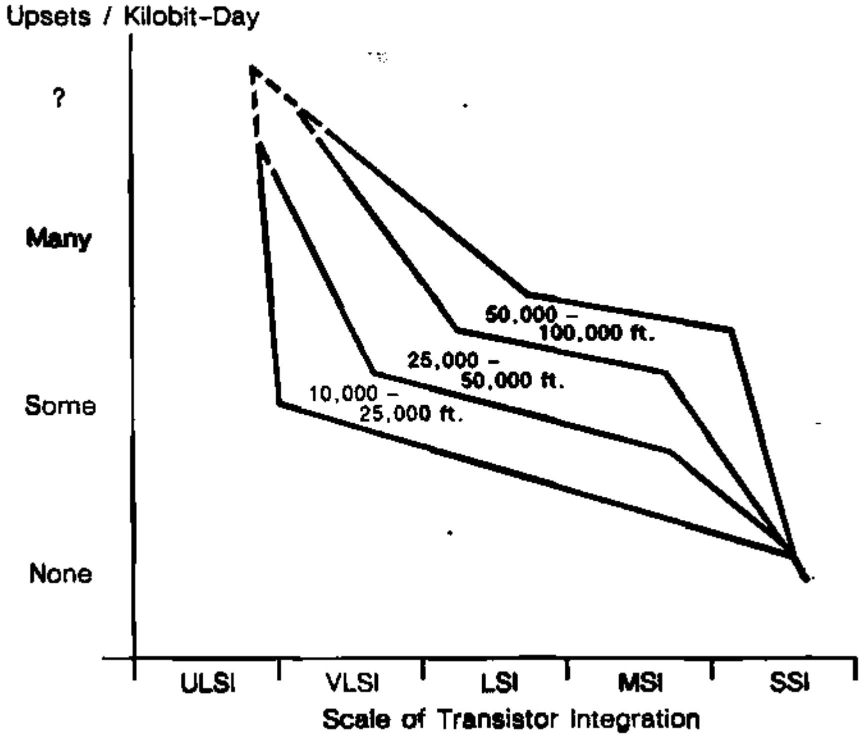
Types of Radiation and System Sensitivity to Radiation

		System			
Environment	Radiation Source	ICBM	Strategic Bomber, Cruise Missile	Space Space Vehicle	Tactical Shipboard, Ground
Electrons, Protons, Cosmic Rays, etc.	Space	X		X	
Particles	Electrons emitted by fission fragment	X		X	
X-Rays	Blackbody radiation	X		X	
Neutrons	Radiation emitted during the fission and fusion processes	X	X	X	X
Prompt Gamma Rays	Radiation emitted during the fission and fusion processes	X	X	X	X
Delayed Gamma Rays	Fission fragment radiation	X	X	X	X
Electromagnetic Pulse (EMP)	Generated by electrons stripped from air atoms by prompt gamma rays	X	X		X
System-Generated EMP	Radiation bombardment of metallic bodies	X		X	
Thermal	Thermal energy radiated by fireball	X	X		X
Blast	Shock wave generated in air by explosion	X	X		X

Source: *Defense Science & Electronics*

Figure 1

SEU Susceptibility in Avionics Semiconductors



Source: ICS Radiation Technologies, Inc.

Standards

The definition of what constitutes a rad-hard device is confusing, to say the least. However, the MIL-M-38510 standard (see Table 2) does as good a job as any other definition in detailing the device radiation-hardness requirements as applicable to the US military, NASA, and many NATO programs. The current prevailing opinion is that the device meets the radiation-hardness assurance (RHA) level specification if its function continues properly. Another more restrictive view specifies that all data sheet parameters must be adhered to during testing.

In addition to the JAN RHA standards, the MIL-STD-883 Group E QCI tests specify test procedures for total dose and neutron tolerance. Dose rate tests are being considered for the future. The MIL-HDBKS-279 and 280 standards provide a good source of educational and guideline information. In addition, the JEDEC 13.4 committee also helps define issues of importance to standards.

The Defense Nuclear Agency maintains a database on radiation tolerance for industry components at the Electronic Radiation Response Information Center (ERRIC).

©1990 Dataquest Incorporated August

Table 2

MIL-M-38510 Radiation-Hardness Requirements

Radiation-Hardness Assurance Level	Total Dose Rads (Si)	Neutron (n/cm^2)
M	3×10^3	2×10^{12}
D	1×10^4	2×10^{12}
R	1×10^5	10^{12}
H	1×10^6	10^{12}

Source: Dataquest (August 1990)

PRODUCTS AND TECHNOLOGY

The Problems

At the system level, radiation can cause transient problems, data loss, soft errors, degraded performance, and permanent failures. Problems caused by radiation in solid-state componentry include atom displacement damage and ionization. Atom displacement damage is caused by heavy charged particles and neutrons; bipolar devices typically are more sensitive to its effect than CMOS devices. Ionization is caused by gamma radiation and high-speed particles. In some cases, this physical damage can heal itself—a process known as annealing.

The parametric effects of this damage can be permanent degradation of circuit performance, device burnout, or temporary degradation or failure caused by latchup and leakage currents.

Radiation-Hardening Technology

Radiation hardness can be accomplished by a rad-hard system-level design that employs radiation-tolerant components or by less rigid system-level design practices and the use of fully rad-hard components. Often, combinations of the two approaches are used.

At the system/subsystem level there are various shielding, filtering, and clamping techniques available to protect the operation of the equipment. Often, when significant system-level techniques are used, tactical radiation components are considered satisfactory to fulfill design requirements. Commonly, tactically tolerant components are fabricated with the same process technology as the commercial product. Semiconductor companies planning to do much military/aerospace business often develop processes designed to account for radiation tolerance. However, there are engineering trade-offs with the extra weight and power consumption that system-level techniques require. When system-level techniques are not feasible or need to be complemented, strategically hard components instead of tactically tolerant components are employed to a greater degree.

Device radiation hardening can be accomplished through a combination of circuit design techniques and process technologies. Those techniques include the following:

- The use of silicon-on-insulator (SOI) or silicon-on-sapphire (SOS) technology to enhance the immunity of CMOS to SEU and dose rate effects (Simox technology, which uses preprocessed wafers with an implanted silicon dioxide layer, is gaining in popularity.)

©1990 Dataquest Incorporated August

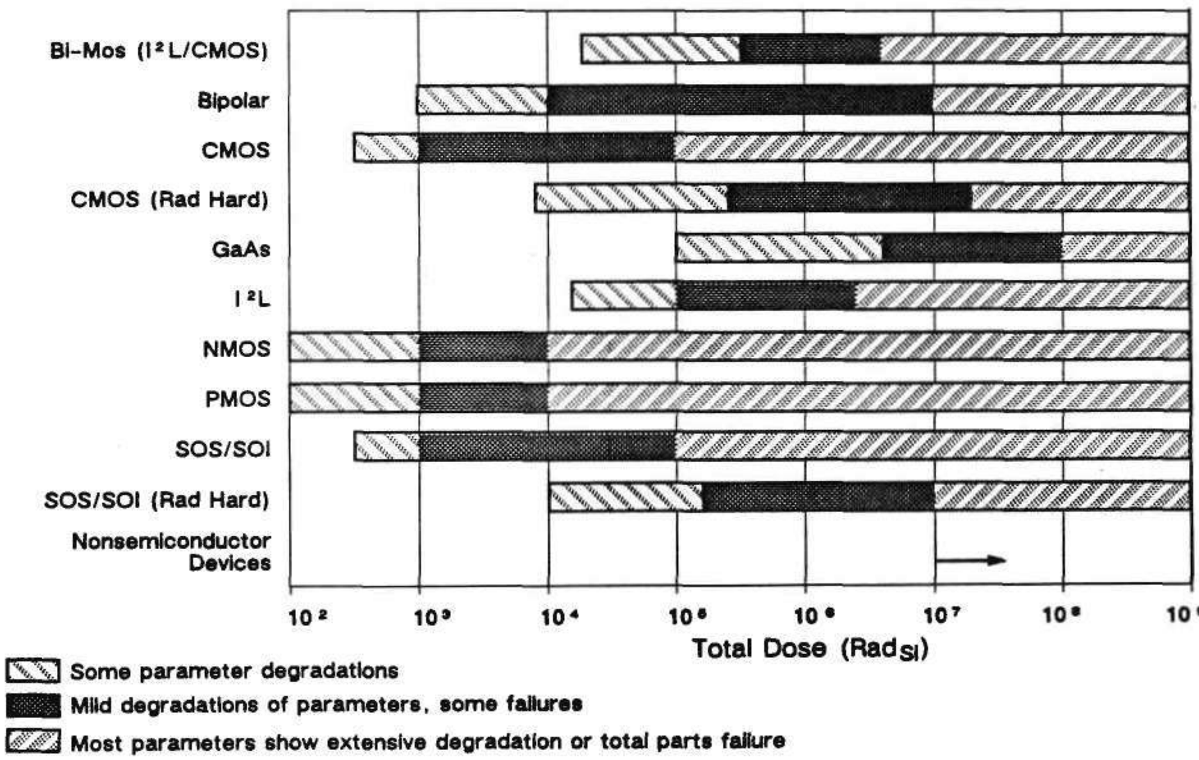
- Assorted techniques including the dielectric isolation, shunting elements, circuit biasing, guard bands, and fan-out considerations
- The use of epitaxial layers and thick oxides with bulk CMOS
- Tight process monitoring to ensure consistency to rad-hard process parameters

Figures 2 through 4 present typical radiation resistance capabilities for various classes of semiconductor technology. Depending on the radiation type, certain technologies are more resistant than others. For total dose, GaAs and bipolar technologies are inherently more rad hard. When special rad-hard considerations are applied, however, CMOS can also operate in the megarad total-dose range.

For neutron damage resistance, the MOS technologies are 50 to 100 times more resistant than bipolar. For dose rate effect resistance, GaAs, bipolar and some BiCMOS tend to perform better than bulk MOS technologies.

Figure 2

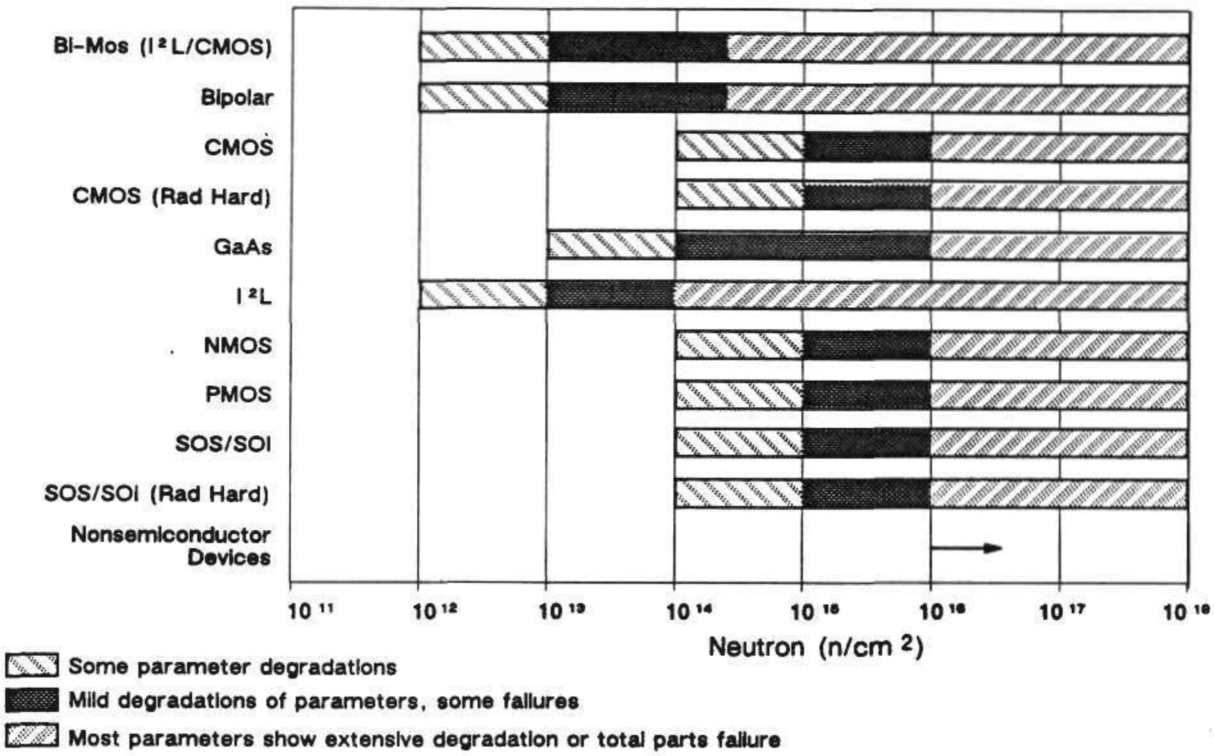
Total Dose Hardness Levels for Selected Technologies



Source: ICS Radiation Technologies, Inc.

Figure 3

Neutron Hardness Levels for Selected Technologies

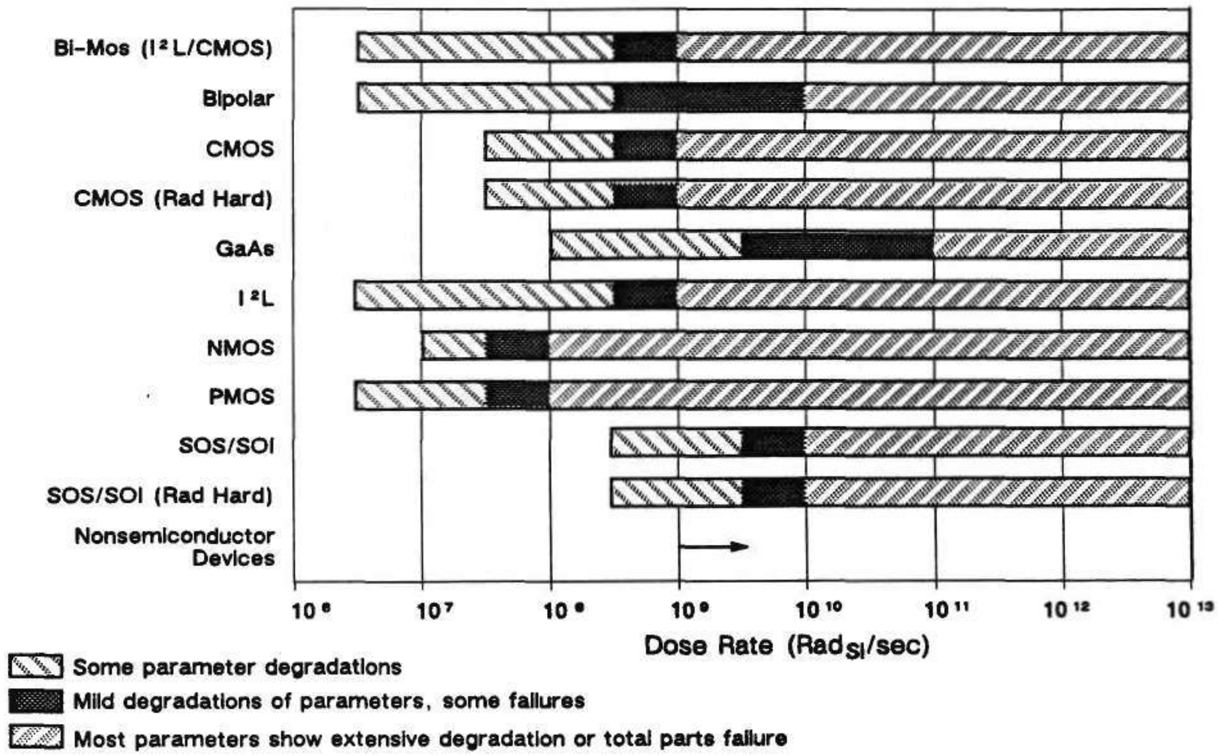


Source: ICS Radiation Technologies, Inc.

©1990 Dataquest Incorporated August

Figure 4

Dose Rate Hardness Levels for Selected Technologies



Source: ICS Radiation Technologies, Inc.

Radiation Testing

Radiation testing of components requires very specialized knowledge and is very complicated and time consuming; therefore, it is expensive. The most common use for testing is to establish a body of characteristic data for a particular product, family, or technology. Testing can be the responsibility of the supplier, the OEM, or the government. Testing by an outside contractor and accompanying documentation can cost from $40,000 to $50,000 and take six months or longer with a cooling-off period.

The equipment involved is expensive and typically can include X-Ray, cobalt-60, strontium-90, and cesium-137 sources as well as particle accelerators. Aracor offers an in-process X-ray test system for wafer testing. Sandia National Laboratory in Albuquerque, New Mexico, is available as a national rad-hard engineering and testing resource and as a supplier of components. The Defense Nuclear Agency maintains a database of test results.

©1990 Dataquest Incorporated August

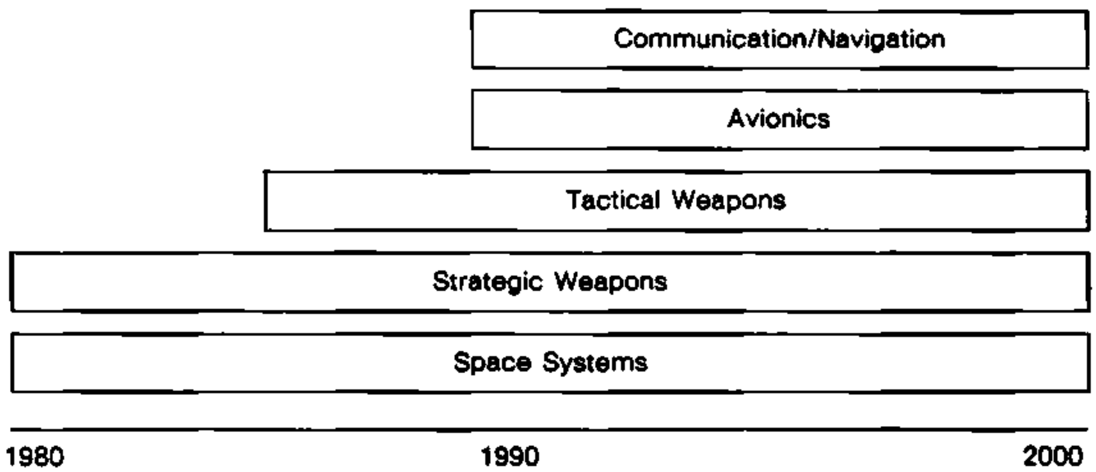
MARKET FORECAST

The demand for rad-hard-characterized components, as specified, is increasing faster than the average demand for ordinary components in the overall military and aerospace market. This situation is due to the fact that space systems are growing faster than the average market and due to the continued rapid penetration of rad-hard components into tactical missiles, communication systems, and avionics (see Figure 5).

Table 3 presents the overall North American and Western European demand for rad-hard-characterized semiconductors. Dataquest expects demand to grow at a CAGR of 13.6 percent, from $435.0 million in 1989 to $822.4 million in 1994. The fastest-growing categories are expected to be microcomponents, ASICs, and memories because they offer the more highly integrated VLSI solutions required in space-constrained platforms. We also expect MOS (primarily CMOS) to continue as the technology of predominance over the same time period (see Figure 6). Tables 3 through 5 present our detailed forecast by product category and geographic area.

Figure 5

Building Applications for Rad-Hard Semiconductors



Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Table 3

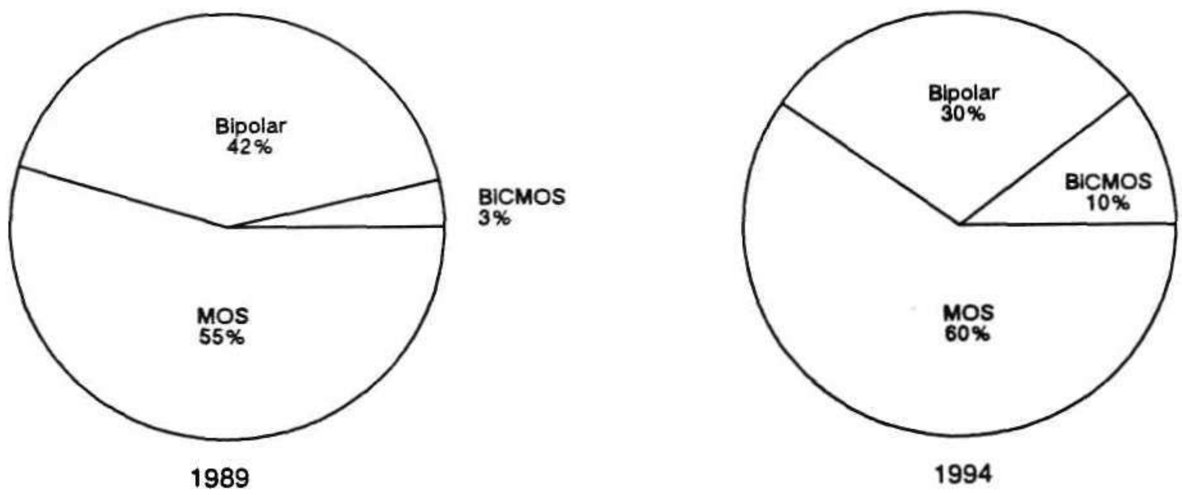
Rad-Hard Semiconductor Consumption North America and Western Europe (Millions of Dollars)

	1989	1994	CAGR 1989-1994
IC	352.5	696.1	14.6%
Standard Logic/PLD	44.4	55.8	4.7%
ASIC	74.7	185.3	19.9%
Microcomponent	50.3	116.7	18.3%
Memory	87.1	182.2	15.9%
Analog	95.9	156.1	10.2%
Discrete	68.3	102.0	8.3%
Optoelectronic	14.2	24.4	11.4%
Total Semiconductor	435.0	822.4	13.6%

Note: Rad-hard is defined as functional to 10^5 rads (Si) total dose and 10^{12} neutrons/cm^2
Source: Dataquest (August 1990)

Figure 6

Rad-Hard Semiconductor Technology Breakout



Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Table 4

Rad-Hard Semiconductor Consumption North America
(Millions of Dollars)

	1989	1994	CAGR 1989-1994
IC	307.2	611.6	14.8%
Standard Logic/PLD	38.8	49.1	4.8%
ASIC	64.4	162.0	20.3%
Microcomponent	43.5	101.2	18.4%
Memory	77.8	163.5	16.0%
Analog	82.7	135.7	10.4%
Discrete	59.0	87.3	8.1%
Optoelectronic	11.9	20.6	11.7%
Total Semiconductor	378.1	719.5	13.7%

Note: Rad-hard is defined as functional to 10^5 rads (Si) total dose and 10^{12} neutrons/cm^2
Source: Dataquest (August 1990)

Table 5

Rad-Hard Semiconductor Consumption Western Europe
(Millions of Dollars)

	1989	1994	CAGR 1989-1994
IC	45.3	84.5	13.3%
Standard Logic/PLD	5.6	6.7	3.5%
ASIC	10.3	23.3	17.7%
Microcomponent	6.8	15.5	17.8%
Memory	9.3	18.7	15.0%
Analog	13.2	20.4	9.0%
Discrete	9.3	14.7	9.6%
Optoelectronic	2.3	3.8	10.1%
Total Semiconductor	56.9	103.0	12.6%

Note: Rad-hard is defined as functional to 10^5 rads (Si) total dose and 10^{12} neutrons/cm^2
Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

SUPPLIERS

Table 6 presents suppliers of radiation tolerant semiconductors by technology and product type.

Table 6

Suppliers of Radiation Tolerant ICs

	CMOS SOS/SOI/Trench					
	Standard Logic (TD)	Gate Array (TD, GC)	Cell IC Custom (TD, TC)	MPU/MPR (TD)	SRAM (TD, Size)	Analog (TD)
AMD						
Allied Signal						
Analog Devices						$.5x10^5$
Elantec						
Gigabit Logic						
GM/Hughes		10^6,25K	10^6,1.1u			
Harris	10^5	10^5,1.2K	10^5,3.0u	10^5	10^5,16K	
Honeywell						D,64K
IDT	10^5	$5x10^4$				
Linear Technology						
LSI Logic						
Marconi	10^5	10^6,4K	10^6,2.5u	10^6	10^6,64K	10^5
Micrel						
National						
PMI						
Raytheon						
Rockwell			10^6,1.6u		10^6,16K	
Signetics						
Silicon General						
Siliconix						
Sipex						
Texas Instruments					10^6,64K	
Thomson		D	D		D	
TriQuint						
TRW LSI						
TRW						
UTMC						
Unitrode						
Universal						
Vitesse						
VTC						

(Continued)

©1990 Dataquest Incorporated August

Table 6 (Continued)

Suppliers of Radiation Tolerant ICs

	Bulk CMOS					
	Standard Logic (TD)	Gate Array (TD, GC)	Cell IC Custom (TD, TC)	MPU/MPR (TD)	SRAM (TD, Size)	Analog (TD)
AT&T					D,256K	
AMD						
Allied Signal			10^5,1.2u	10^5	10^5,64K	
Analog Devices			10^4,2.0u	10^5		10^4
Elantec						
GE Microelectronic	10^6	10^6,13K	10^6,1.2u			
Gigabit Logic						
GM/Hughes		$5x10^5$,40K	10^5,1.1u			$3x10^5$
Harris	10^6	10^6,8K	10^6,2u	10^6	10^6,64K	10^6
Honeywell		10^6,15K	10^6,1.2u		10^6,64K	
IBM					D,64K	
IDT	10^5			$5x10^4$		
Linear Technology						
LSI Logic		10^6,100K	10^6,1.5u			
Marconi						
Micrel	10^6					
National	10^6	10^5,2.4K	10^5.1.0u	10^6		
PMI						10^5
Raytheon						
Rockwell						
Signetics				$2.5x10^5$		
Silicon General						
Siliconix						
Sipex						
Texas Instruments						
Thomson						
TriQuint						
TRW LSI	$5x10^5$		10^5,1.5u			
TRW		10^6,20K	10^6,1.0u	10^6	10^6,16K	
UTMC	10^6	10^6,11K	10^6,1.2u	10^6	10^6,64K	$3x10^5$
Unitrode						
Universal	10^6	10^6,2.4K	10^6,1.5u			
Vitesse						
VTC					10^6,16K	

(Continued)

©1990 Dataquest Incorporated August

Table 6 (Continued)

Suppliers of Radiation Tolerant ICs

	Bipolar, GaAs				
	Standard Logic (TD, N)	**ASIC (TD, N)**	**MPU/MPR (TD, N)**	**SRAM (TD, N)**	**Analog (TD, N)**
AMD	$10^6,10^{14}$				
Allied Signal					
Analog Devices					$10^5,10^{12}$
Elantec					$10^6,10^{13}$
Gigabit Logic				G,10^8	
GM/Hughes					
Harris		G		G	G
Honeywell	$10^6,10^{12}$				$10^6,10^{12}$
IDT					
Linear Technology					$10^5,10^{12}$
LSI Logic					
Marconi					
Micrel					
National	$10^6,10^{12}$	106,10^{14}	$10^5,10^{13}$		$10^5,10^{12}$
PMI					$10^6,10^{13}$
Raytheon		108,10^{14}			$10^5,10^{12}$
Rockwell	G	G	G	G	G
Signetics	$10^6,10^{12}$	$10^7,10^{15}$	$10^6,10^{12}$	$10^7,10^{14}$	
Silicon General		$10^6,10^{14}$			$10^6,10^{14}$
Siliconix					$10^6,10^{12}$
Sipex					available
Texas Instruments					G
Thomson					
TriQuint		G,$5x10^7$			G,$5x10^7$
TRW LSI	$10^6,10^{14}$		$10^6,10^{14}$		$10^6,10^{14}$
TRW	$5x10^4$		$5x10^4$		
UTMC					
Unitrode					$5x10^5$
Universal					
Vitesse		G,10^8	G,10^8	G,10^8	
VTC					

D = Development
G = GaAs
TD = Total dose rads(Si)
N = Neutrons/cm^2
GC = Gate count
TC = Technology
Source: Defense Science 1989, Dataquest (August 1990)

©1990 Dataquest Incorporated August

Technology Usage in Systems

Technology Usage in Systems

The following is list of the material in this section:

- System Semiconductor Utilization

System Semiconductor Utilization

OVERVIEW

Overall, military and civil aerospace equipment in production today is utilizing mature and multisourced semiconductor technology. This fact is a result of very long development and production lifetimes of the majority of both military systems and commercial aircraft. We estimate that 45 percent of the semiconductor technology currently built into these systems was initially available ten years ago or before.

The following megatrends affect the future application of semiconductor solutions to military and aerospace equipment:

- Continued aggressive footprint, functional density, and power reduction on all platform-oriented systems
- Increased use of commercial grade and/or plastic packaging for components, as environmental needs are better segregated and as improvements in packaging technology emerge
- A procurement system that is better oriented toward ASICs and VLSI
- Improved hierarchical design and simulation software creating more transparency from the actual semiconductor implementation, quickening the rate of acceptance of new technologies, and reducing problems with interoperability and obsolescence
- Availability of advanced compiler technology on microprocessor products, allowing easier and maintainable programming
- Continued replacement of SSI/MSI-era system designers with VLSI/ULSI-era designers
- Eventual phased-in implementation of a procurement system oriented toward commercial buying practices and more toward commercial technology life cycles
- Further requirements for radiation-hardened (rad-hard) semiconductors in some aircraft, naval, and ground systems and most missiles and space systems

Figures 1 through 20 and Tables 1 through 12 present detailed semiconductor end-use information. Based on the factors listed above, we believe that the following trends will continue or develop in the demand for semiconductors in military and aerospace electronic equipment:

- In meeting the goals of integration and power consumption, CMOS will continue to be the technology of broad choice, but its growth will be tempered, as long system design and production cycles prevail.
- ASICs will continue to be designed-in as replacements for discrete logic and, in an increasing number of situations, as custom chip sets and processor engines.
- Microcomponents, including digital signal processing (DSP) MPUs, 16- and 32-bit MPUs, and functional chip sets, will continue gaining acceptance in areas such as electronic warfare, secure communication, integrated aircraft architectures, and intelligent weapons.

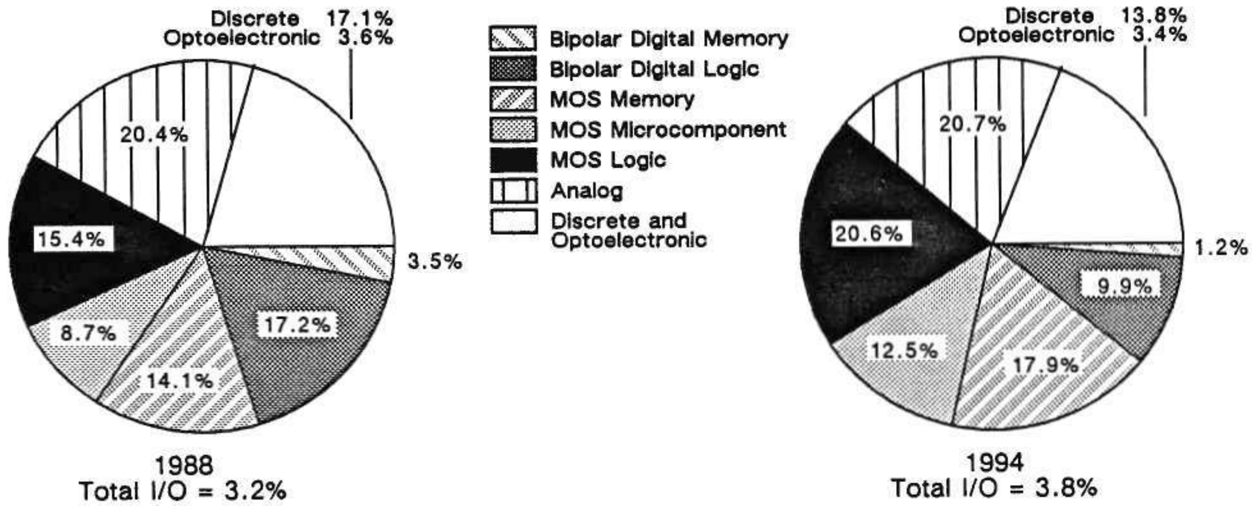
©1990 Dataquest Incorporated July

- Increasing microcomponent applications will drive new uses for volatile and nonvolatile memory products.
- Aggressive high-frequency, high-density, low-noise, and rad-hard requirements on all front-end processing will demand both gallium arsenide monolithic microwave and millimeterwave IC (MMIC) technology and sophisticated DSP techniques.
- Smaller, cooler, more efficient power supplies, switches, and controls will drive demand for intelligent power and MOSFETs.
- Fiber-optic data conduits on aircraft and ships will demand transmitters/receivers and other optoelectronics.

©1990 Dataquest Incorporated July

Figure 1

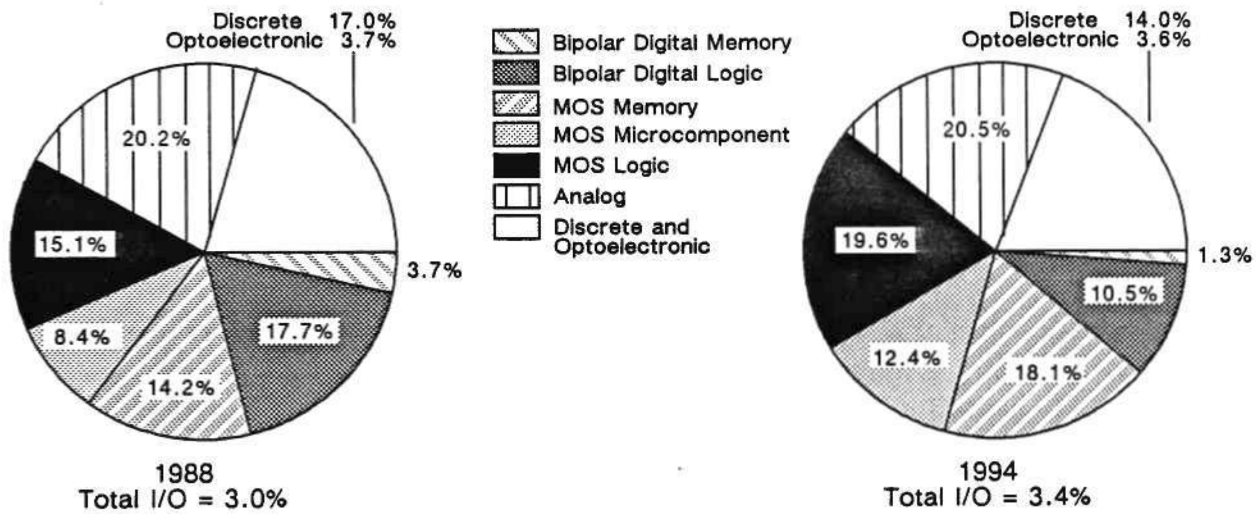
Estimated Total Military/Aerospace Semiconductor Consumption



Source: Dataquest (July 1990)

Figure 2

Estimated Military Semiconductor Consumption

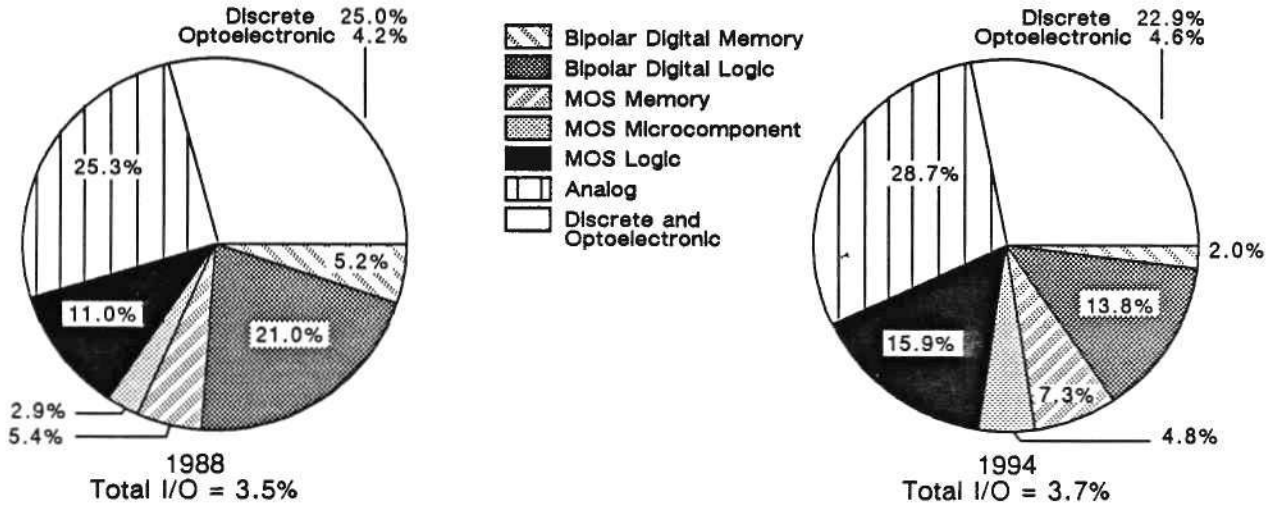


Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Figure 3

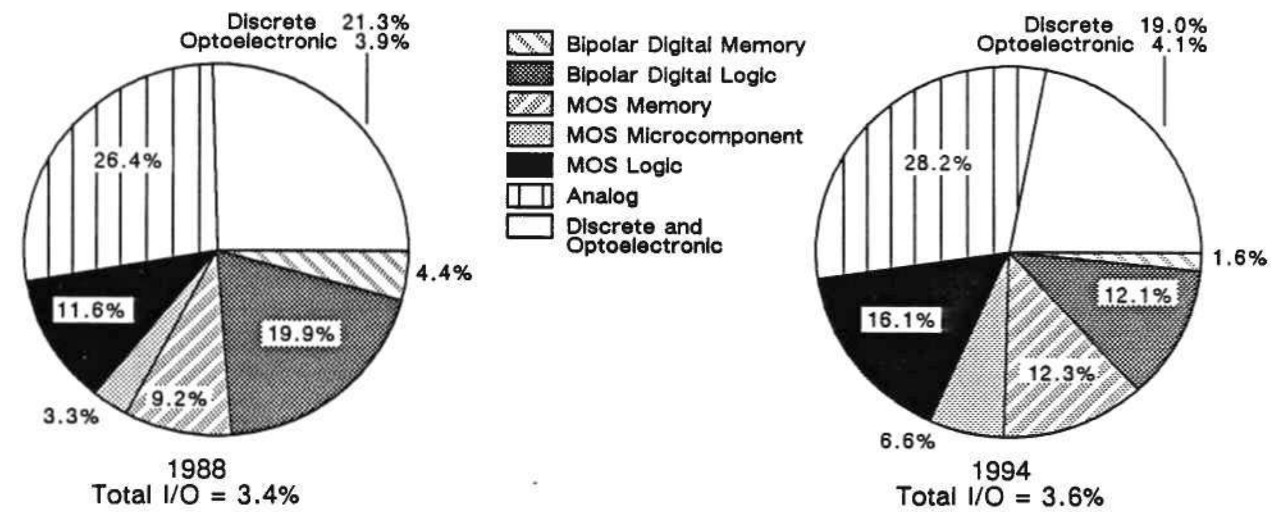
Estimated Military Radar Semiconductor Consumption



Source: Dataquest (July 1990)

Figure 4

Estimated Military Sonar Semiconductor Consumption

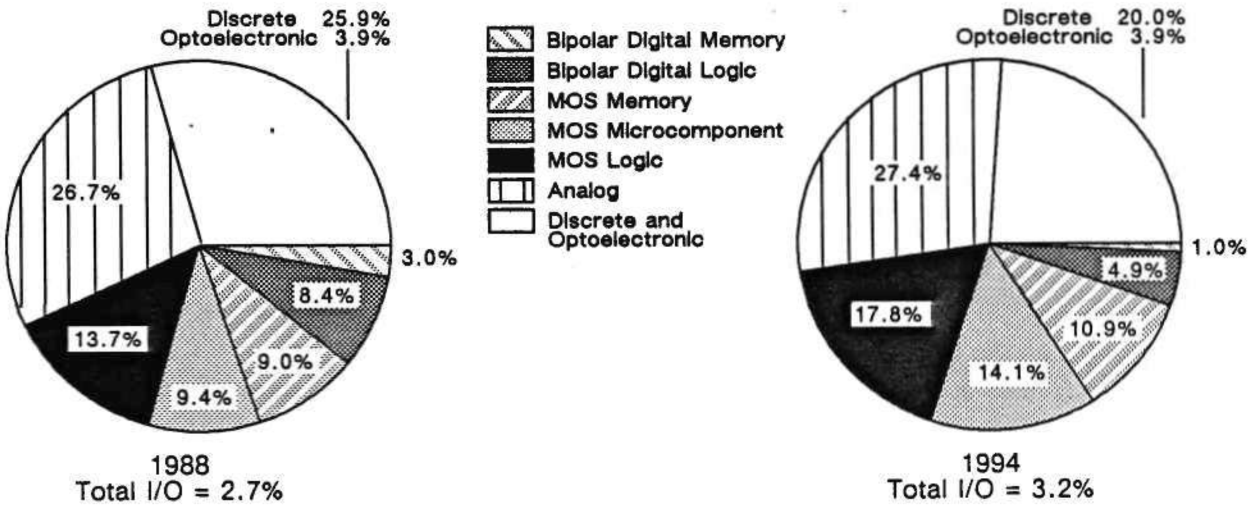


Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Figure 5

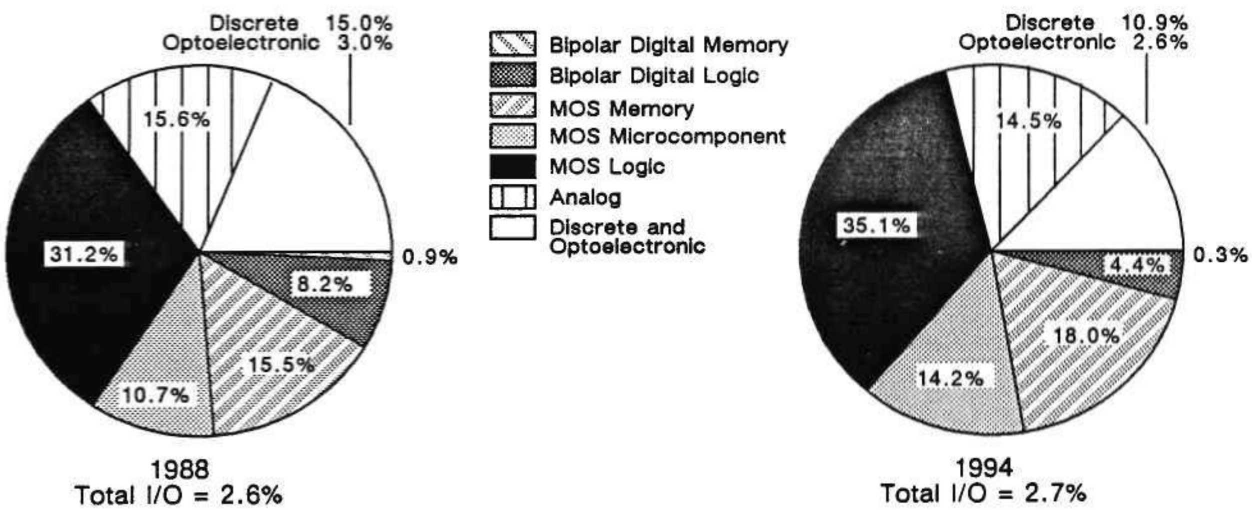
Estimated Missile and Weapon Semiconductor Consumption



Source: Dataquest (July 1990)

Figure 6

Estimated Military Space Semiconductor Consumption

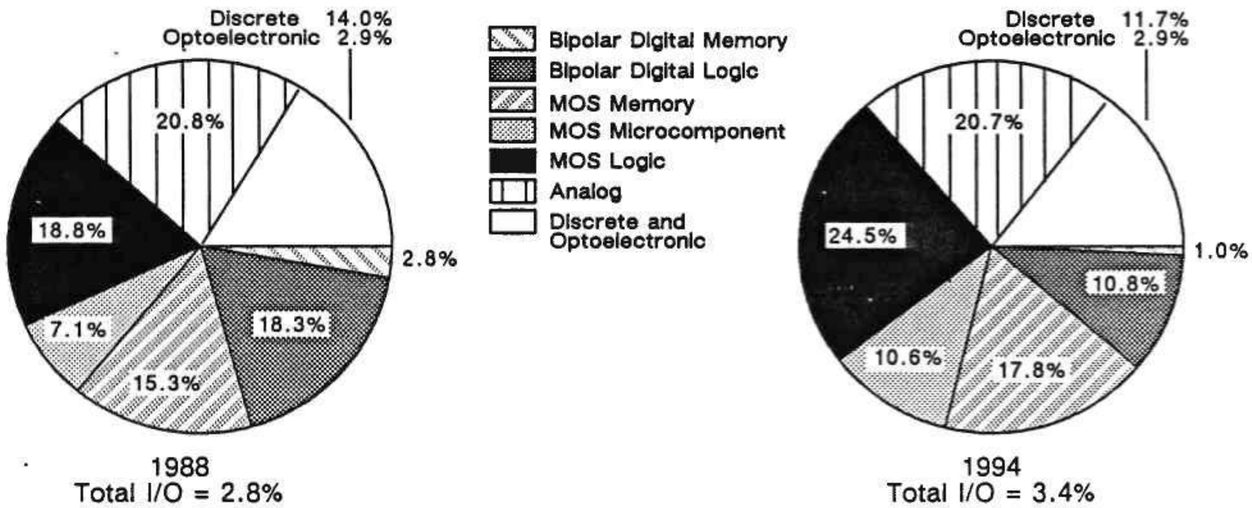


Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Figure 7

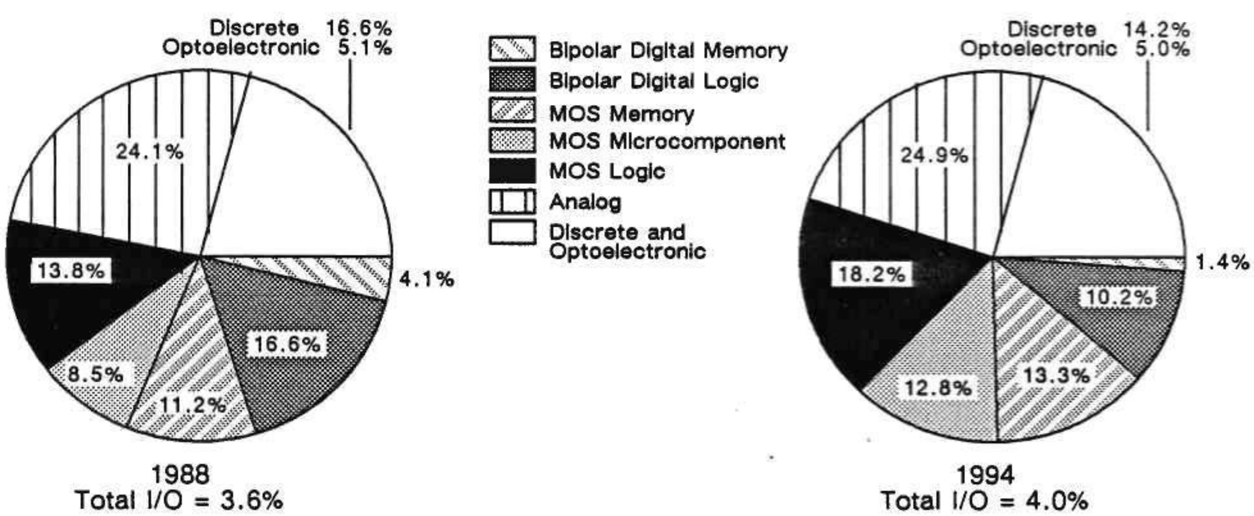
Estimated Military Navigation Semiconductor Consumption



Source: Dataquest (July 1990)

Figure 8

Estimated Military Communications Semiconductor Consumption

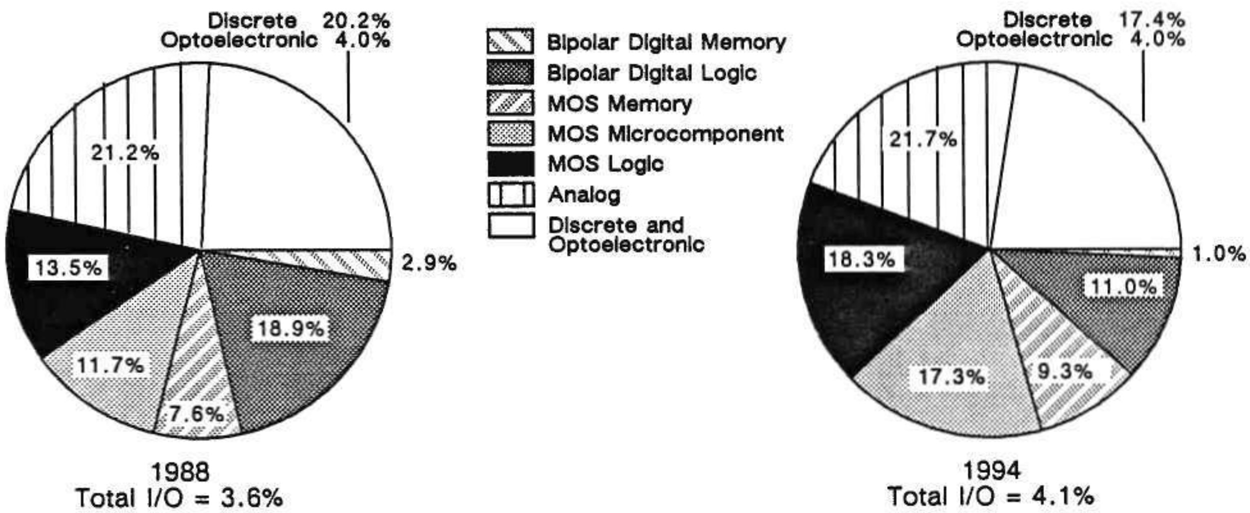


Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Figure 9

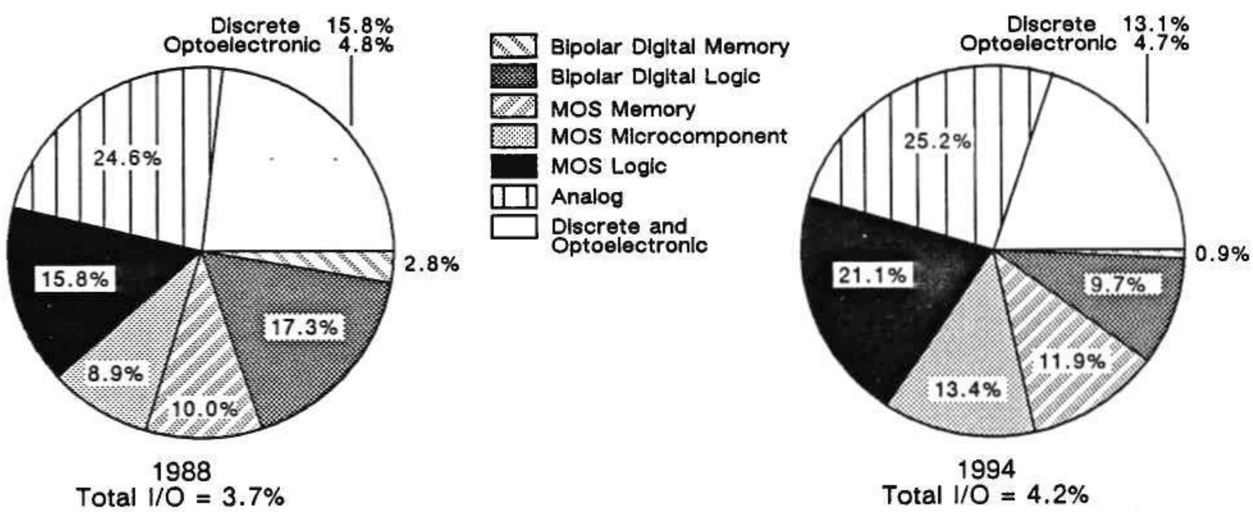
Estimated Electronic Warfare Semiconductor Consumption



Source: Dataquest (July 1990)

Figure 10

Estimated Reconnaissance Semiconductor Consumption

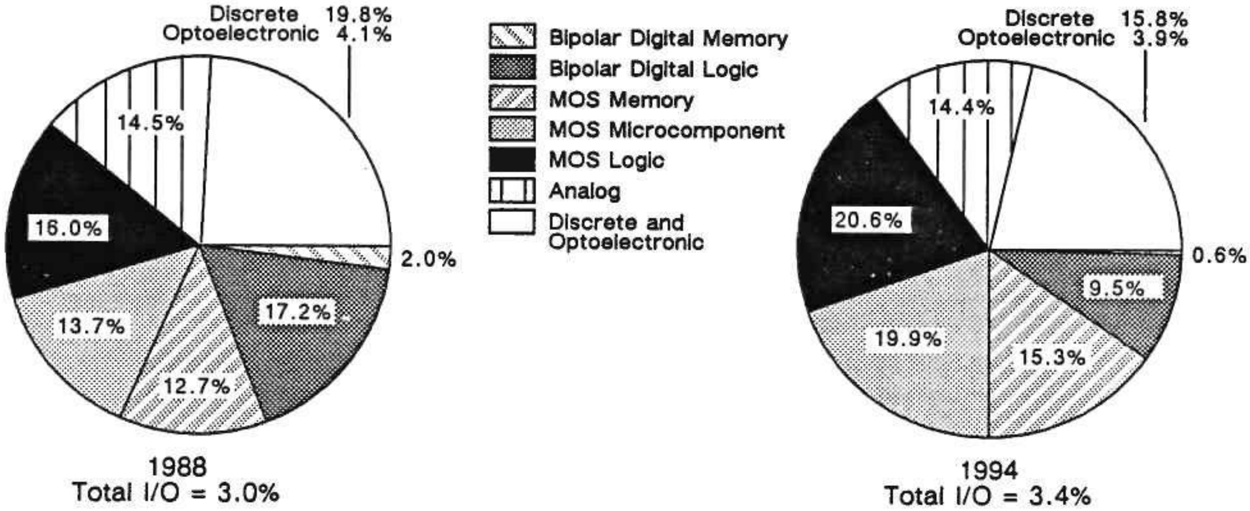


Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Figure 11

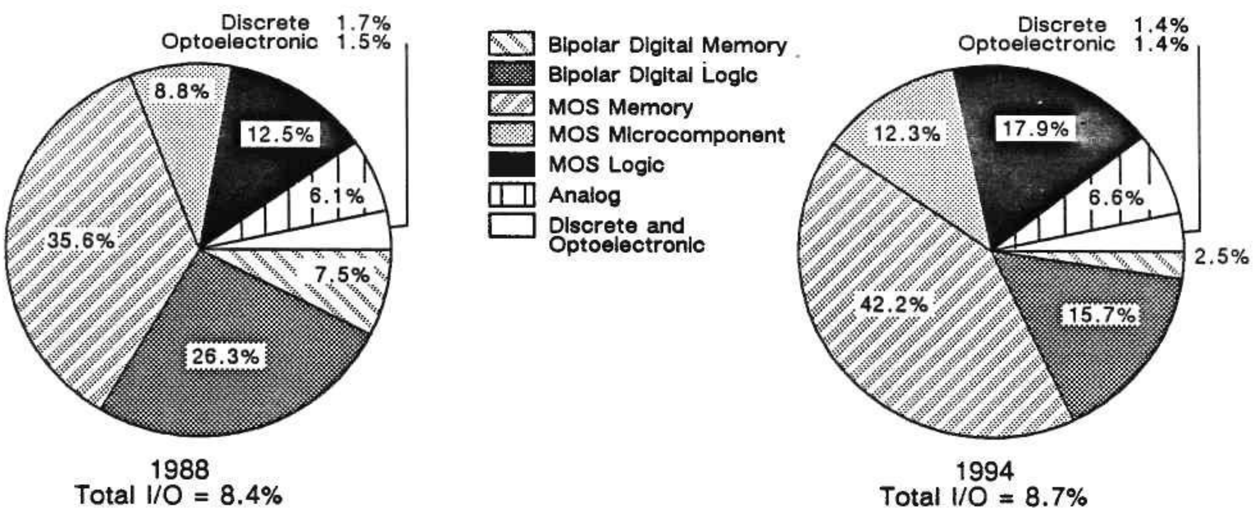
Estimated Military Aircraft Systems Semiconductor Consumption



Source: Dataquest (July 1990)

Figure 12

Estimated Military Computer Systems Semiconductor Consumption

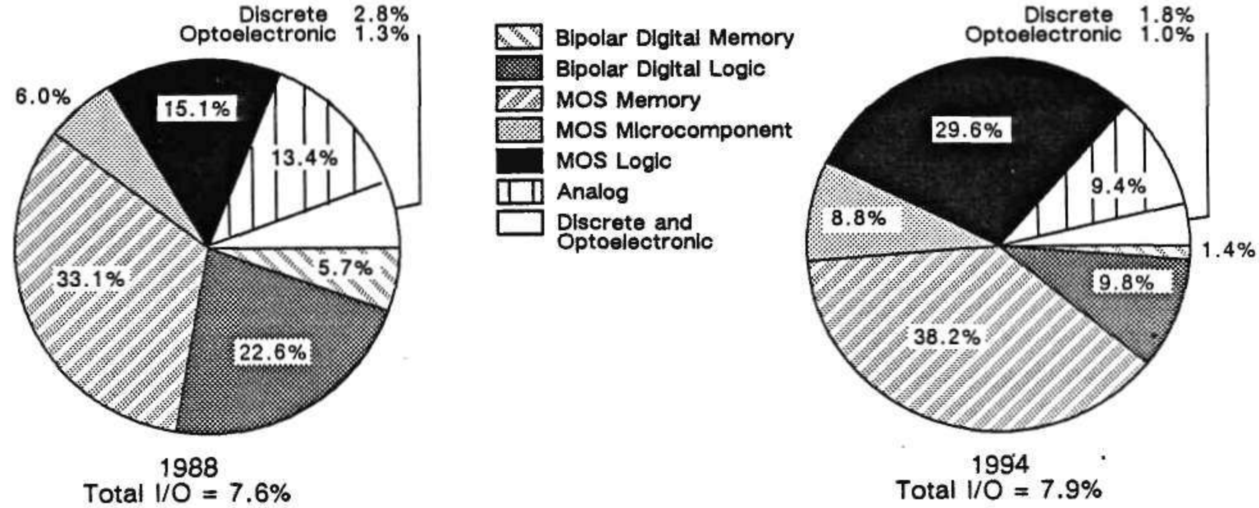


Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Figure 13

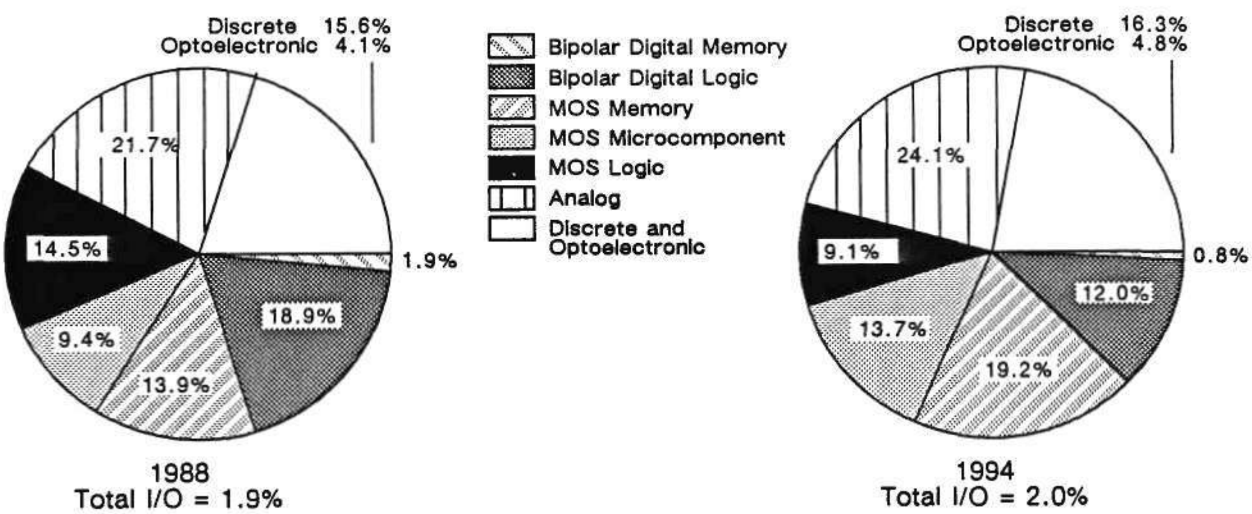
Estimated Military Simulation and Training Semiconductor Consumption



Source: Dataquest (July 1990)

Figure 14

Estimated Military Miscellaneous Equipment Semiconductor Consumption

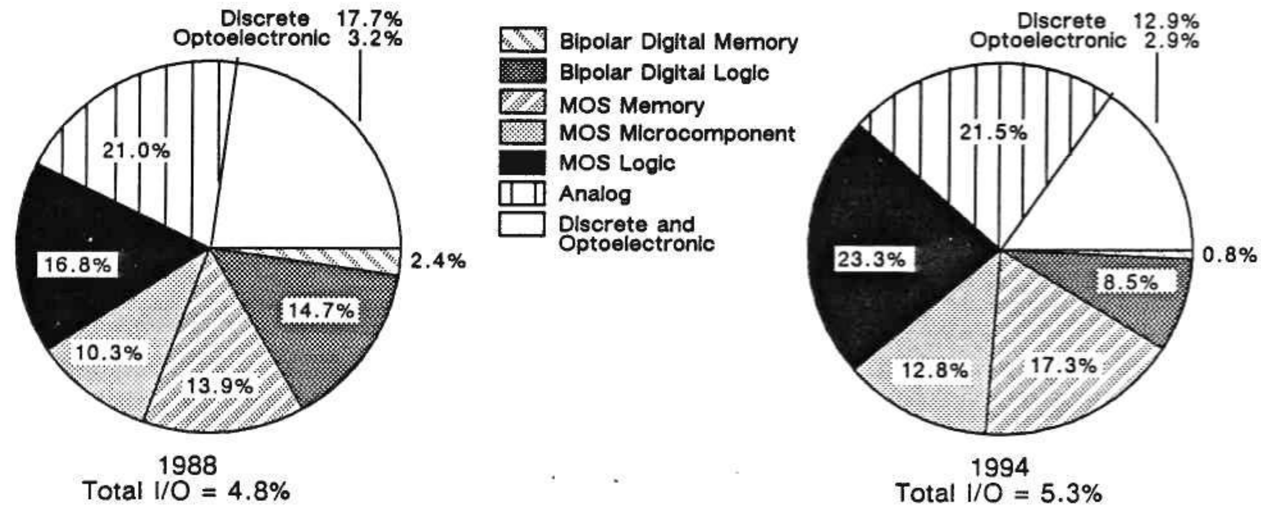


Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Figure 15

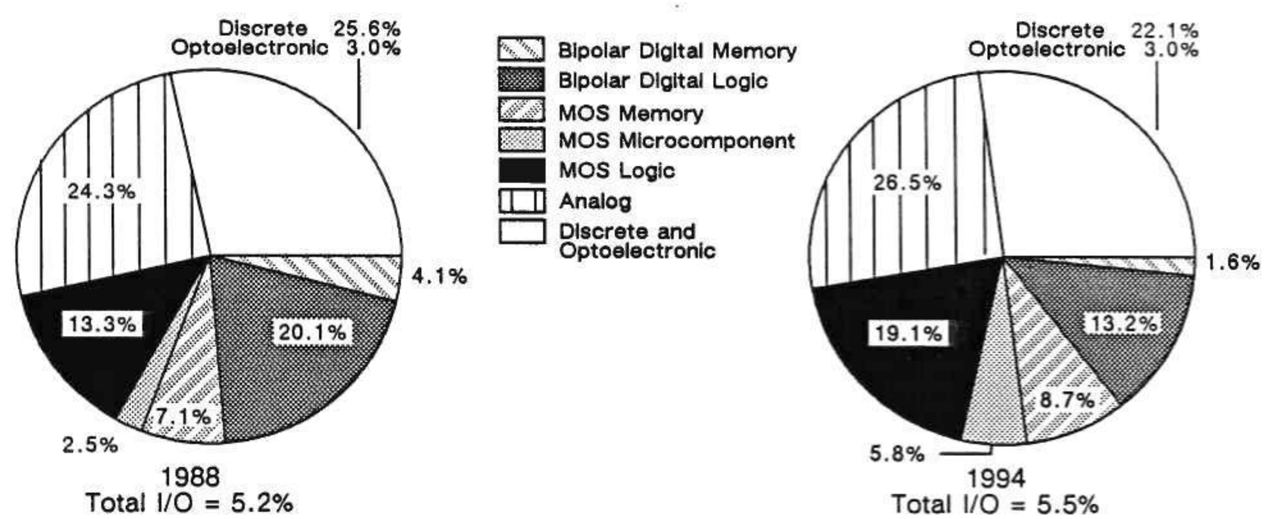
Estimated Total Civil Aerospace Semiconductor Consumption



Source: Dataquest (July 1990)

Figure 16

Estimated Civil Aerospace Radar Semiconductor Consumption

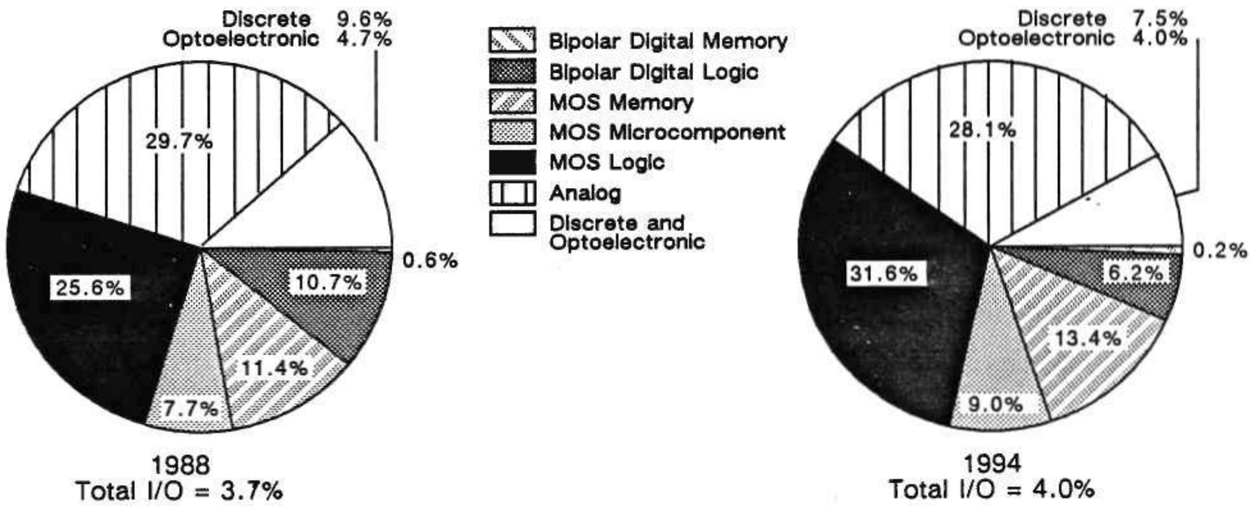


Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Figure 17

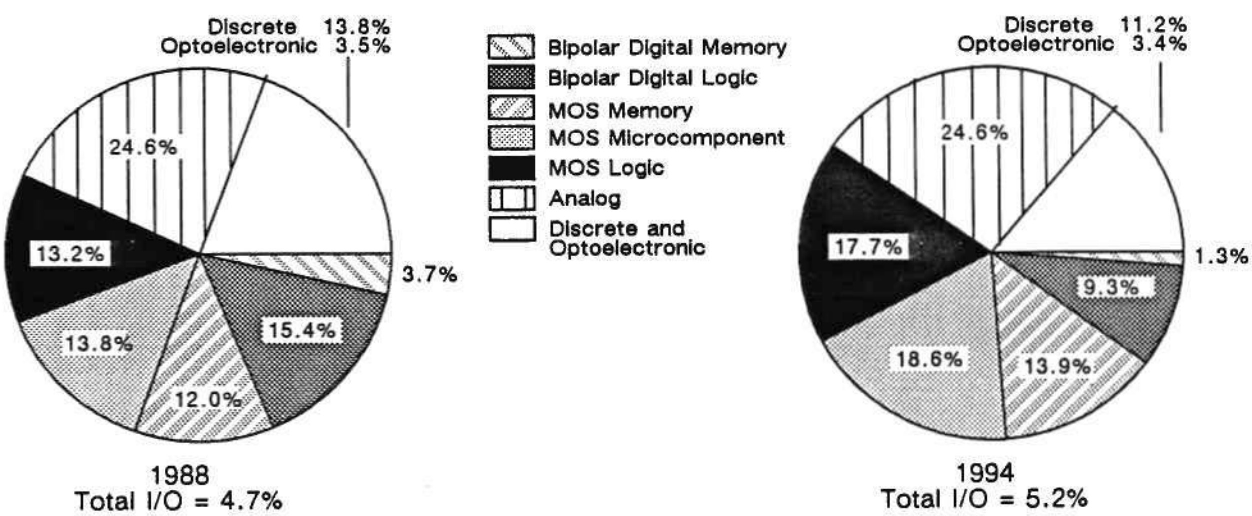
Estimated Civil Space Semiconductor Consumption



Source: Dataquest (July 1990)

Figure 18

Estimated Civil Aerospace Communication/Navigation Semiconductor Consumption

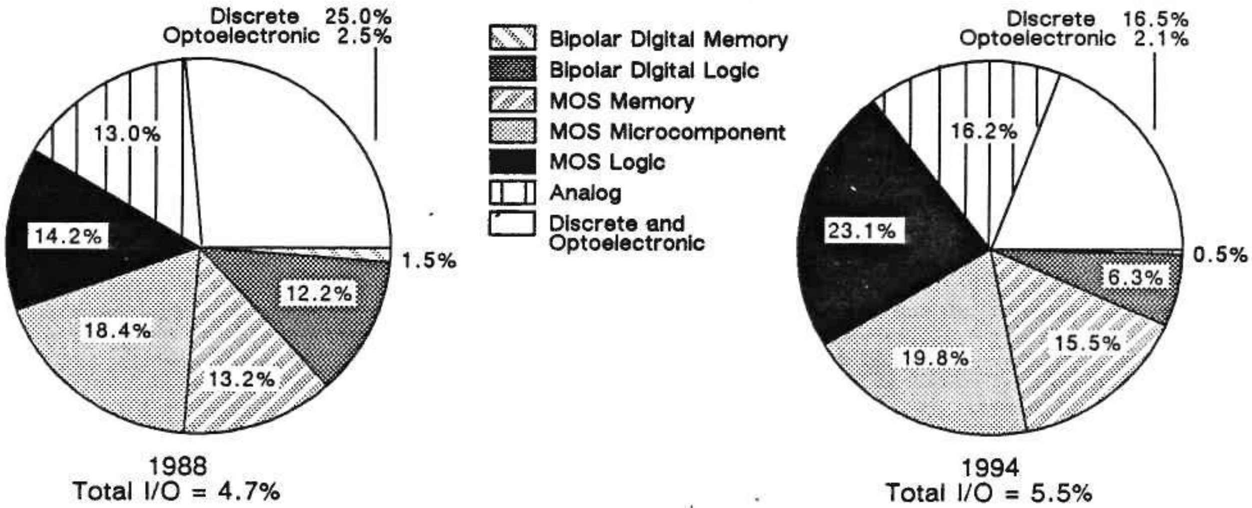


Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Figure 19

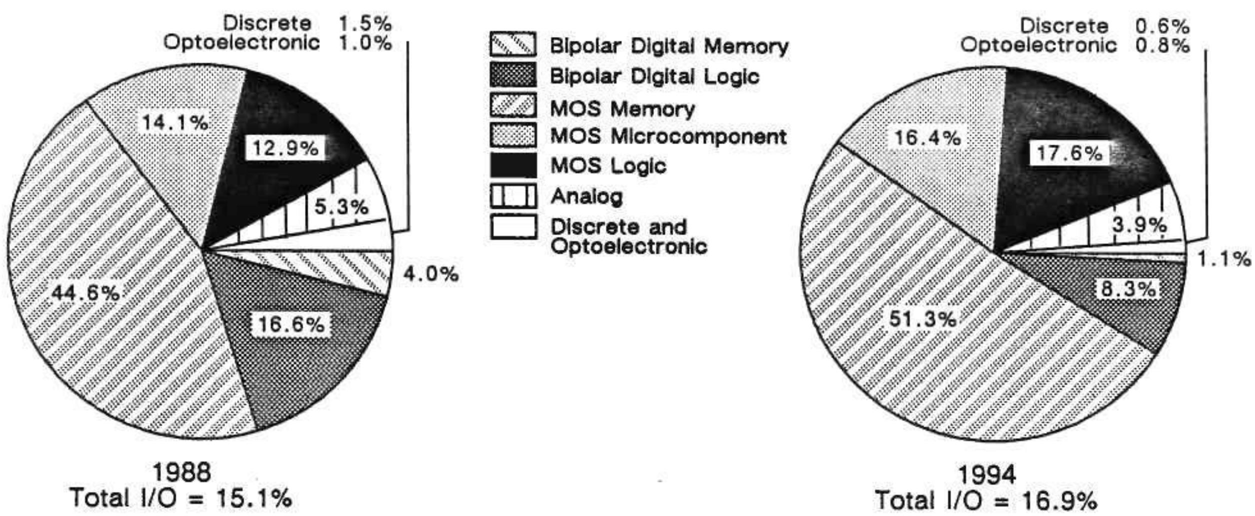
Estimated Civil Flight Systems Semiconductor Consumption



Source: Dataquest (July 1990)

Figure 20

Estimated Civil Simulation and Training Semiconductor Consumption



Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 1

Estimated Worldwide Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	2,775.5	2,873.7	3,023.3	3,191.3	3,410.8	3,669.5	3,964.3	6.6%
IC	2,190.0	2,301.6	2,436.4	2,584.3	2,778.0	3,007.4	3,271.7	7.3%
Digital Bipolar	574.4	554.2	527.9	489.1	455.6	425.4	395.6	(6.5%)
Memory	96.2	85.4	75.2	65.9	58.3	52.9	48.5	(10.7%)
Microcomponent	59.1	58.6	60.1	60.2	60.1	60.1	60.3	0.6%
Logic	419.0	410.2	392.7	363.0	337.2	312.4	286.8	(6.9%)
Standard (S/MSI)	259.5	234.5	227.2	211.5	194.1	177.4	157.5	(7.7%)
ASIC	159.5	175.7	165.4	151.5	143.1	134.9	129.3	(5.9%)
Digital MOS	1,037.2	1,176.0	1,314.7	1,470.7	1,658.9	1,865.8	2,092.2	12.2%
Memory	385.1	448.2	496.9	554.4	623.8	698.9	778.3	11.7%
Microcomponent	246.5	269.7	302.9	339.7	382.0	431.6	489.1	12.6%
MOS Logic	405.5	458.1	515.0	576.5	653.1	735.3	824.7	12.5%
Standard (S/MSI)	88.0	92.3	96.2	98.3	100.6	103.2	107.7	3.1%
ASIC	317.5	365.8	418.8	478.2	552.5	632.1	717.0	14.4%
Analog	578.5	571.4	593.7	624.5	663.6	716.2	783.9	6.5%
Discrete	478.9	469.0	480.9	498.0	517.9	538.2	558.8	3.6%
Optoelectronic	106.6	103.1	106.0	109.0	114.9	123.9	133.8	5.3%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 2

Estimated Worldwide Military Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	2,258.3	2,284.1	2,347.4	2,425.0	2,540.7	2,690.9	2,865.5	4.6%
IC	1,778.4	1,827.4	1,888.9	1,957.3	2,058.5	2,192.0	2,348.8	5.1%
Digital Bipolar	481.0	462.1	437.7	401.8	369.2	340.2	314.0	(7.4%)
Memory	83.4	75.5	66.7	58.8	52.0	46.9	42.8	(10.8%)
Logic	397.6	386.6	371.0	343.0	317.2	293.3	271.2	(6.8%)
Digital MOS	837.7	921.6	1,006.3	1,100.4	1,213.6	1,344.6	1,490.1	10.1%
Memory	315.8	358.4	391.6	426.7	469.0	519.0	575.9	10.0%
Microcomponent	196.4	209.6	227.4	249.3	276.3	306.2	338.6	10.1%
Logic	325.5	353.6	387.3	424.4	468.4	519.4	575.7	10.2%
Analog	459.7	443.7	445.0	455.0	475.7	507.3	544.7	4.2%
Discrete	393.9	376.4	378.9	386.0	395.1	405.7	416.5	2.0%
Optoelectronic	86.0	80.3	79.6	81.7	87.1	93.2	100.2	4.5%

Source: Dataquest (July 1990)

Table 3

Estimated Worldwide Civil Aerospace Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	517.2	589.6	675.9	766.3	870.1	978.6	1,098.8	13.3%
IC	411.6	474.2	547.5	627.0	719.5	815.3	923.0	14.2%
Digital Bipolar	93.4	92.1	90.3	87.3	86.4	85.2	81.7	(2.4%)
Memory	12.8	9.9	8.5	7.1	6.3	6.0	5.7	(10.3%)
Logic	80.6	82.2	81.8	80.2	80.1	79.2	75.9	(1.6%)
Digital MOS	199.5	254.4	308.4	370.2	445.3	521.2	602.1	18.8%
Memory	69.3	89.8	105.3	127.7	154.8	179.9	202.4	17.7%
Microcomponent	50.1	60.1	75.5	90.4	105.8	125.4	150.5	20.1%
Logic	80.0	104.5	127.7	152.1	184.7	215.9	249.1	19.0%
Analog	118.8	127.7	148.8	169.5	187.9	208.9	239.2	13.4%
Discrete	85.0	92.6	102.0	112.0	122.7	132.6	142.2	9.0%
Optoelectronic	20.6	22.8	26.4	27.3	27.8	30.7	33.6	8.0%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 4

Estimated North American Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	2,000.2	2,058.6	2,135.1	2,235.5	2,379.3	2,554.1	2,756.1	6.0%
IC	1,585.1	1,651.0	1,721.4	1,808.0	1,933.1	2,086.2	2,265.8	6.5%
Digital Bipolar	432.0	419.5	396.7	365.0	337.1	312.8	288.4	(7.2%)
Memory	74.6	64.1	55.8	48.8	42.9	38.7	35.4	(11.2%)
Microcomponent	40.4	39.5	40.6	41.4	42.0	42.8	43.6	2.0%
Logic	317.0	315.9	300.3	274.8	252.1	231.3	209.4	(7.9%)
Digital MOS	756.1	845.1	929.7	1,028.9	1,155.4	1,295.7	1,449.2	11.4%
Memory	288.3	326.9	357.3	395.5	442.8	494.1	548.4	10.9%
Microcomponent	175.8	191.9	213.2	237.9	268.4	304.1	345.8	12.5%
MOS Logic	292.0	326.3	359.2	395.5	444.2	497.4	555.0	11.2%
Analog	397.0	386.4	395.1	414.2	440.6	477.8	528.2	6.5%
Discrete	341.0	335.3	340.6	352.7	367.0	381.8	396.7	3.4%
Optoelectronic	74.1	72.3	73.0	74.8	79.2	86.0	93.6	5.3%

Source: Dataquest (July 1990)

Table 5

Estimated North American Military Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	1,668.9	1,679.4	1,716.2	1,765.8	1,842.9	1,946.3	2,069.1	4.3%
IC	1,313.3	1,338.1	1,374.4	1,417.4	1,483.9	1,574.9	1,684.3	4.7%
Digital Bipolar	368.1	356.1	336.2	309.0	284.3	262.6	243.0	(7.4%)
Memory	65.8	57.9	50.5	44.2	38.8	35.0	32.1	(11.1%)
Logic	302.3	298.2	285.7	264.8	245.5	227.6	211.0	(6.7%)
Digital MOS	618.9	670.5	726.7	790.7	867.6	955.4	1,054.0	9.5%
Memory	241.1	267.8	290.6	315.3	345.2	381.5	423.4	9.6%
Microcomponent	140.9	149.8	161.8	176.3	194.9	215.3	237.9	9.7%
Logic	236.9	252.9	274.4	299.1	327.5	358.6	392.7	9.2%
Analog	326.3	311.5	311.5	317.7	332.0	356.9	387.3	4.5%
Discrete	292.5	281.4	282.8	287.9	294.5	302.5	310.6	2.0%
Optoelectronic	63.1	59.9	59.0	60.5	64.4	68.9	74.1	4.3%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 6

Estimated North American Civil Aerospace Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	331.3	379.2	418.9	469.7	536.5	607.8	687.0	12.6%
IC	271.8	312.9	347.0	390.6	449.2	511.3	581.4	13.2%
Digital Bipolar	63.9	63.4	60.5	56.0	52.8	50.2	45.4	(6.5%)
Memory	8.8	6.2	5.3	4.6	4.1	3.6	3.3	(11.6%)
Logic	55.1	57.2	55.3	51.4	48.7	46.5	42.1	(6.0%)
Digital MOS	137.2	174.6	202.9	238.2	287.8	340.3	395.2	17.7%
Memory	47.2	59.1	66.7	80.3	97.6	112.7	125.0	16.2%
Microcomponent	34.9	42.1	51.4	61.5	73.5	88.8	107.9	20.7%
Logic	55.1	73.4	84.8	96.4	116.7	138.8	162.3	17.2%
Analog	70.7	74.9	83.6	96.4	108.6	120.8	140.9	13.5%
Discrete	48.5	53.9	57.8	64.8	72.5	79.4	86.0	9.8%
Optoelectronic	11.0	12.4	14.0	14.3	14.8	17.1	19.6	9.5%

Source: Dataquest (July 1990)

Table 7

Estimated European Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	632.9	647.1	695.8	733.9	776.8	826.2	881.5	6.4%
IC	484.4	506.4	548.2	581.9	619.7	663.5	713.0	7.1%
Digital Bipolar	116.9	108.3	105.5	99.5	95.3	91.5	88.1	(4.0%)
Memory	16.2	15.6	14.2	12.3	10.9	10.0	9.2	(10.0%)
Microcomponent	16.5	16.9	17.1	16.5	15.8	15.3	14.8	(2.7%)
Logic	84.1	75.8	74.2	70.7	68.6	66.2	64.1	(3.3%)
Digital MOS	224.8	256.0	292.3	326.1	361.8	400.4	443.1	11.6%
Memory	72.7	87.7	100.1	111.5	124.1	138.0	153.5	11.9%
Microcomponent	58.6	63.4	71.3	79.3	87.8	97.7	109.1	11.5%
MOS Logic	93.4	105.0	120.9	135.3	149.8	164.7	180.5	11.4%
Analog	142.8	142.1	150.4	156.3	162.7	171.5	181.8	5.1%
Discrete	118.9	113.4	118.5	122.0	125.8	129.7	133.7	3.3%
Optoelectronic	29.6	27.3	29.1	30.1	31.2	33.0	34.8	5.0%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 8

Estimated European Military Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	495.2	495.7	509.3	526.0	551.4	582.6	616.2	4.4%
IC	384.6	395.2	408.4	423.4	445.9	473.9	504.1	5.0%
Digital Bipolar	93.8	86.4	82.4	75.3	68.7	62.7	57.2	(7.9%)
Memory	13.6	13.4	12.0	10.8	9.7	8.7	7.9	(10.1%)
Logic	80.2	73.0	70.4	64.5	59.0	54.0	49.4	(7.5%)
Digital MOS	181.3	202.3	220.0	240.3	265.0	294.5	325.5	10.0%
Memory	57.8	67.8	73.2	79.4	87.0	95.3	103.8	8.9%
Microcomponent	47.7	50.6	54.9	60.7	67.3	74.7	82.2	10.2%
Logic	75.8	83.9	91.9	100.1	110.7	124.5	139.4	10.7%
Analog	109.5	106.5	106.0	107.9	112.2	116.7	121.3	2.6%
Discrete	89.6	82.5	82.9	84.2	85.9	87.7	89.6	1.7%
Optoelectronic	21.0	18.0	18.0	18.5	19.6	21.0	22.6	4.7%

Source: Dataquest (July 1990)

Table 9

Estimated European Civil Aerospace Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	137.7	151.4	186.5	207.9	225.3	243.5	265.3	11.9%
IC	99.8	111.2	139.8	158.5	173.9	189.6	209.0	13.4%
Digital Bipolar	23.1	21.9	23.1	24.2	26.6	28.8	30.9	7.1%
Memory	2.6	2.2	2.2	1.5	1.2	1.3	1.4	(9.5%)
Logic	20.5	19.7	20.9	22.8	25.4	27.5	29.5	8.5%
Digital MOS	43.5	53.7	72.3	85.8	96.8	105.9	117.6	17.0%
Memory	14.9	19.9	26.9	32.1	37.1	42.8	49.6	20.1%
Microcomponent	10.9	12.8	16.4	18.7	20.5	23.0	26.9	16.0%
Logic	17.6	21.1	29.1	35.1	39.2	40.2	41.1	14.3%
Analog	33.3	35.6	44.4	48.4	50.5	54.9	60.5	11.2%
Discrete	29.3	30.9	35.6	37.8	39.9	42.0	44.1	7.4%
Optoelectronic	8.6	9.3	11.1	11.6	11.6	11.9	12.2	5.6%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 10

Estimated Japanese/Rest of World Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	142.4	167.9	192.4	221.9	254.7	289.2	326.6	14.2%
IC	120.5	144.1	166.7	194.4	225.2	257.7	292.9	15.2%
Digital Bipolar	25.5	26.4	25.7	24.7	23.2	21.1	19.1	(6.3%)
Memory	5.4	5.7	5.3	4.9	4.5	4.2	3.9	(7.5%)
Microcomponent	2.2	2.2	2.3	2.3	2.2	2.1	2.0	(2.1%)
Logic	17.9	18.5	18.1	17.5	16.5	14.8	13.2	(6.5%)
Digital MOS	56.3	74.8	92.7	115.7	141.8	169.7	199.9	21.7%
Memory	24.1	33.6	39.5	47.4	56.9	66.8	76.5	17.9%
Microcomponent	12.1	14.4	18.4	22.5	25.9	29.7	34.2	18.9%
MOS Logic	20.1	26.8	34.8	45.8	59.1	73.2	89.2	27.2%
Analog	38.7	42.9	48.3	54.1	60.3	66.9	73.9	11.5%
Discrete	19.0	20.3	21.8	23.4	25.0	26.7	28.4	7.0%
Optoelectronic	2.9	3.5	3.8	4.1	4.5	4.9	5.3	8.6%

Source: Dataquest (July 1990)

Table 11

Estimated Japan/Rest of World Military Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	94.2	109.0	121.9	133.2	146.4	162.0	180.2	10.6%
IC	80.5	94.1	106.1	116.5	128.7	143.2	160.3	11.2%
Digital Bipolar	19.1	19.6	19.1	17.6	16.2	14.9	13.7	(6.9%)
Memory	4.0	4.2	4.2	3.8	3.5	3.1	2.8	(7.8%)
Logic	15.1	15.4	14.9	13.7	12.7	11.8	10.9	(6.7%)
Digital MOS	37.5	48.8	59.5	69.5	81.1	94.7	110.6	17.8%
Memory	16.9	22.8	27.8	32.0	36.8	42.3	48.7	16.4%
Microcomponent	7.8	9.2	10.7	12.3	14.1	16.1	18.4	14.9%
Logic	12.8	16.8	21.0	25.2	30.2	36.3	43.5	21.0%
Analog	23.9	25.7	27.5	29.4	31.5	33.7	36.0	7.0%
Discrete	11.8	12.5	13.2	13.9	14.7	15.5	16.3	5.5%
Optoelectronic	1.9	2.4	2.6	2.8	3.0	3.3	3.5	8.0%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

Table 12

Estimated Japan/Rest of World Civil Aerospace Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	48.2	58.9	70.5	88.7	108.2	127.2	146.4	20.0%
IC	40.0	50.0	60.6	77.9	96.5	114.4	132.6	21.5%
Digital Bipolar	6.4	6.8	6.7	7.1	7.0	6.2	5.4	(4.5%)
Memory	1.4	1.5	1.1	1.0	1.1	1.1	1.1	(6.7%)
Logic	5.0	5.3	5.6	6.1	5.9	5.1	4.3	(3.9%)
Digital MOS	18.8	26.0	33.2	46.2	60.7	75.0	89.3	28.0%
Memory	7.2	10.8	11.7	15.4	20.1	24.5	27.8	20.8%
Microcomponent	4.3	5.2	7.7	10.2	11.8	13.7	15.8	24.9%
Logic	7.3	10.0	13.8	20.6	28.8	36.9	45.7	35.5%
Analog	14.8	17.2	20.8	24.6	28.8	33.2	37.9	17.1%
Discrete	7.2	7.8	8.6	9.4	10.3	11.2	12.1	9.1%
Optoelectronic	1.0	1.1	1.2	1.3	1.5	1.6	1.8	9.9%

Source: Dataquest (July 1990)

©1990 Dataquest Incorporated July

(Page intentionally left blank)

©1990 Dataquest Incorporated July

System Semiconductor Utilization

OVERVIEW

Overall, military and civil aerospace equipment in production today is utilizing mature and multisourced semiconductor technology. This fact is a result of very long development and production lifetimes of the majority of both military systems and commercial aircraft. We estimate that 45 percent of the semiconductor technology currently built into these systems was initially available 10 years ago or before.

The following megatrends affect the future application of semiconductor solutions to military and aerospace equipment:

- Continued aggressive footprint, functional density, and power reduction on all platform-oriented systems
- Increased use of commercial grade and/or plastic packaging for components, as environmental needs are better segregated and as improvements in packaging technology emerge
- A procurement system that is better oriented toward ASICs and VLSI
- Improved hierarchical design and simulation software creating more transparency from the actual semiconductor implementation, quickening the rate of acceptance of new technologies, and reducing problems with interoperability and obsolescence
- Availability of advanced compiler technology on microprocessor products, allowing easier and maintainable programming
- Continued replacement of SSI/MSI-era system designers with VLSI/ULSI-era designers
- Eventual phased-in implementation of a procurement system oriented toward commercial buying practices and more toward commercial technology life cycles.
- Further requirements for radiation-hardened (rad-hard) semiconductors in some aircraft, naval, and ground systems and most missiles and space systems.

Figures 1 through 20 and Tables 1 through 80 present detailed semiconductor end-use information. Based on the factors listed above, we believe that the following trends will continue or develop in the demand for semiconductors in military and aerospace electronic equipment:

- In meeting the goals of integration and power consumption, CMOS will continue to be the technology of broad choice, but its growth will be tempered, as long system design and production cycles prevail.
- ASICs will continue to be designed-in as replacements for discrete logic and, in an increasing number of situations, as custom chip sets and processor engines.

© 1988 Dataquest Incorporated August

System Semiconductor Utilization

- Microcomponents, including digital signal processing (DSP) MPUs, 16- and 32-bit MPUs, and functional chip sets, will continue gaining acceptance in areas such as electronic warfare, secure communication, integrated aircraft architectures, and intelligent weapons.

- Increasing microcomponent applications will drive new uses for volatile and nonvolatile memory products.

- Aggressive high-frequency, high-density, low-noise, and rad-hard requirements on all front-end processing will demand both gallium arsenide monolithic microwave and millimeterwave IC (MMIC) technology and sophisticated DSP techniques.

- Smaller, cooler, more efficient power supplies, switches, and controls will drive demand for intelligent power and MOSFETs.

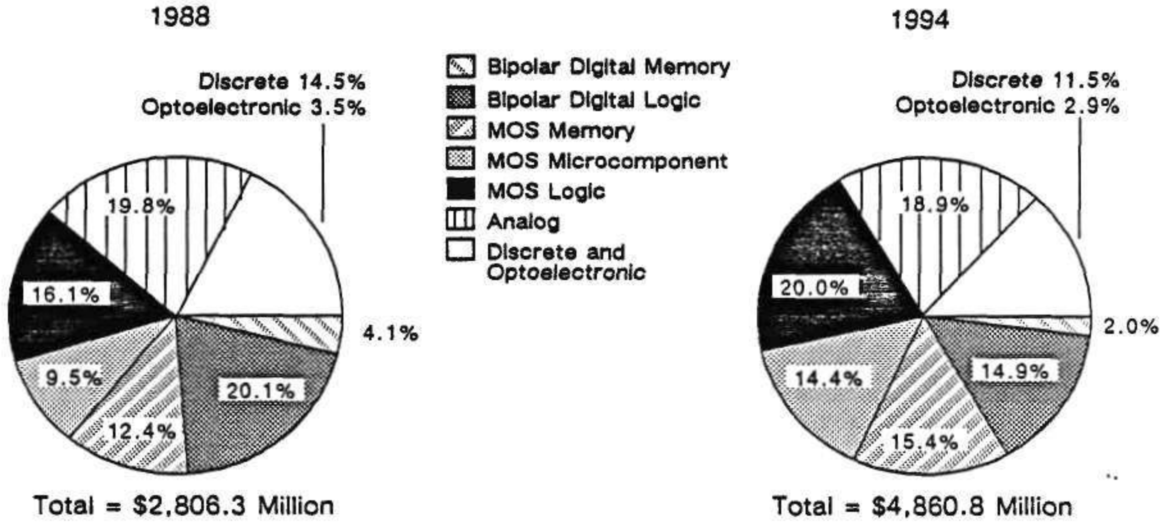
- Fiber-optic data conduits on aircraft and ships will demand transmitters/receivers and other optoelectronics.

Note: In order to avoid double-counting semiconductor usage, commercial computer equipment was factored out of the electronic equipment estimates included in this section.

© 1988 Dataquest Incorporated August

Figure 1

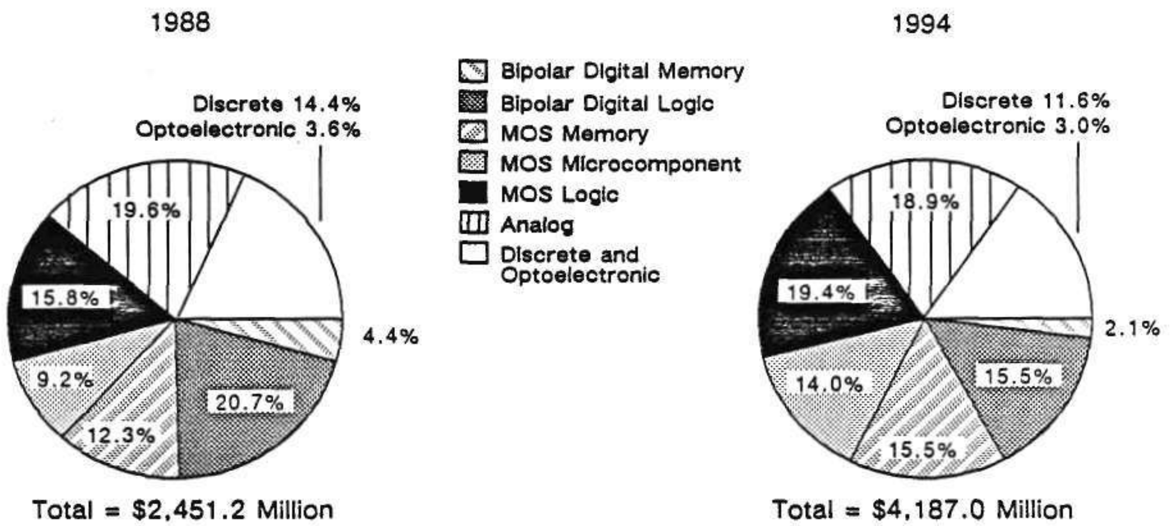
Estimated Worldwide Total Military/Aerospace Semiconductor Consumption



Source: Dataquest
August 1988

Figure 2

Estimated Worldwide Military Semiconductor Consumption



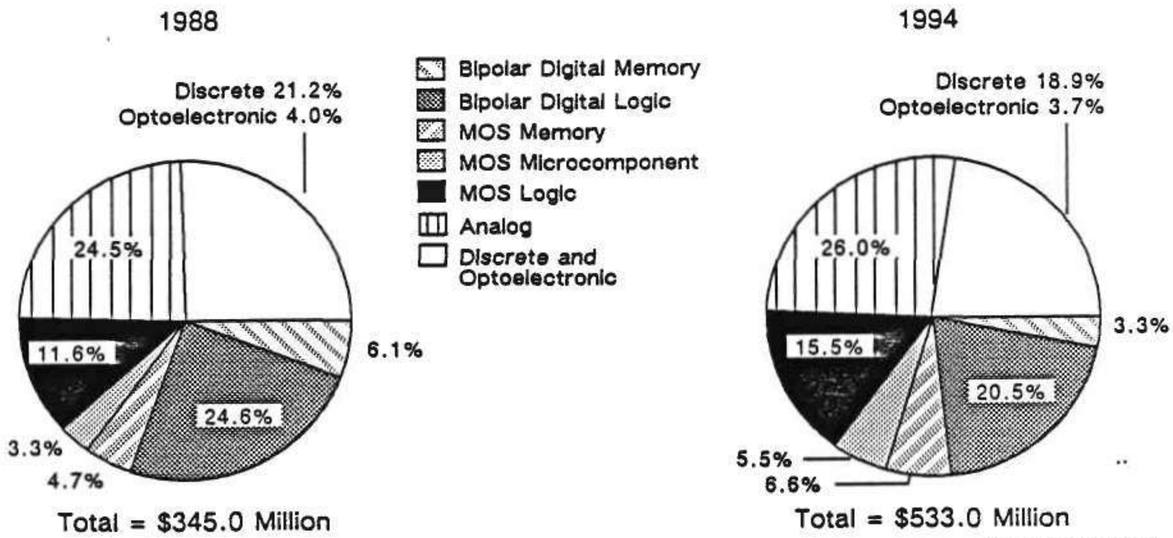
Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

System Semiconductor Utilization

Figure 3

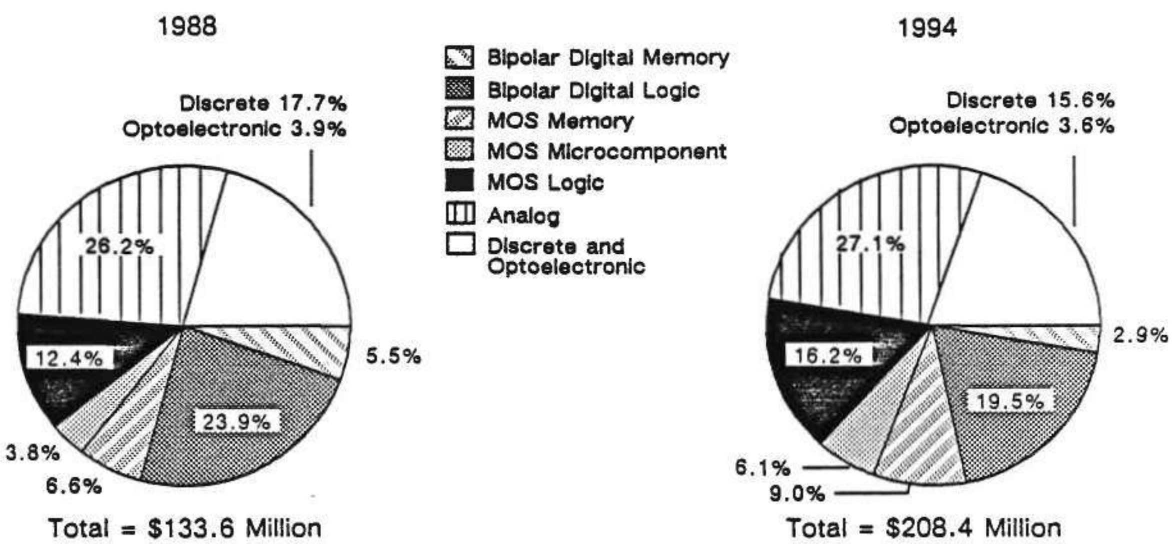
Estimated Worldwide Military Radar Semiconductor Consumption



Source: Dataquest
August 1988

Figure 4

Estimated Worldwide Military Sonar Semiconductor Consumption

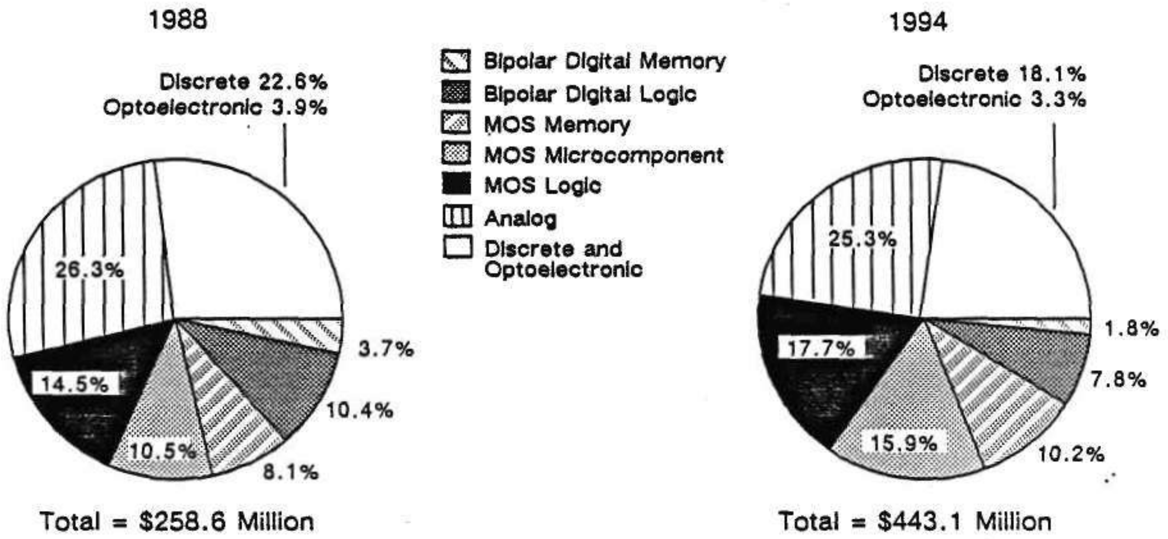


Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Figure 5

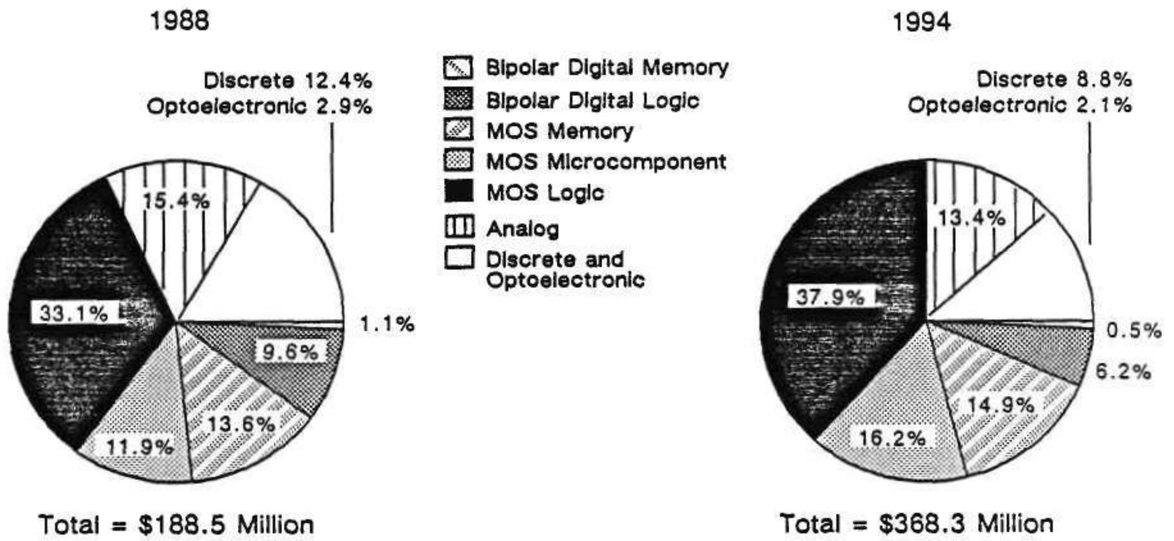
Estimated Worldwide Missile and Weapon Semiconductor Consumption



Source: Dataquest
August 1988

Figure 6

Estimated Worldwide Military Space Semiconductor Consumption



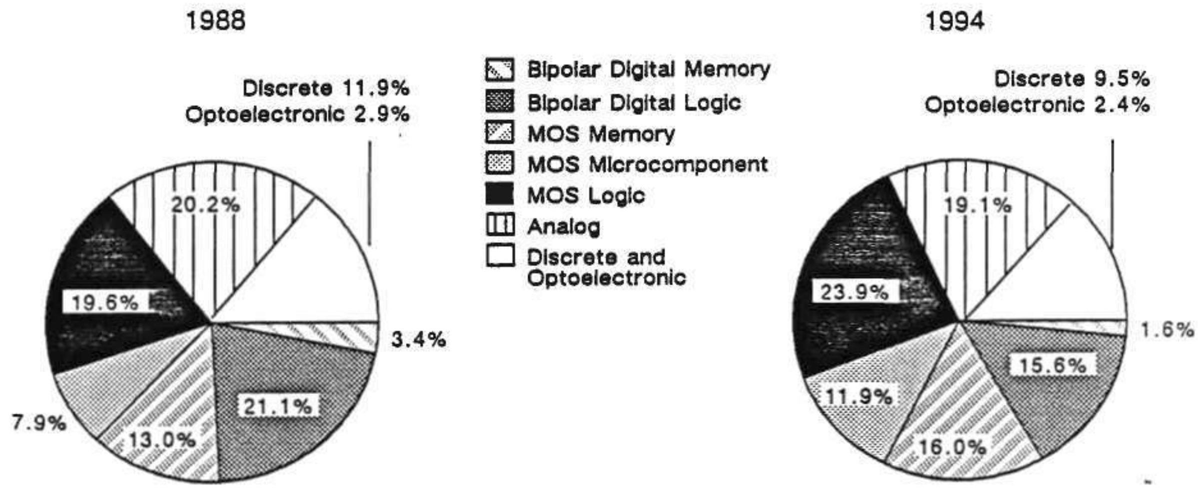
Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

System Semiconductor Utilization

Figure 7

Estimated Worldwide Military Navigation Semiconductor Consumption



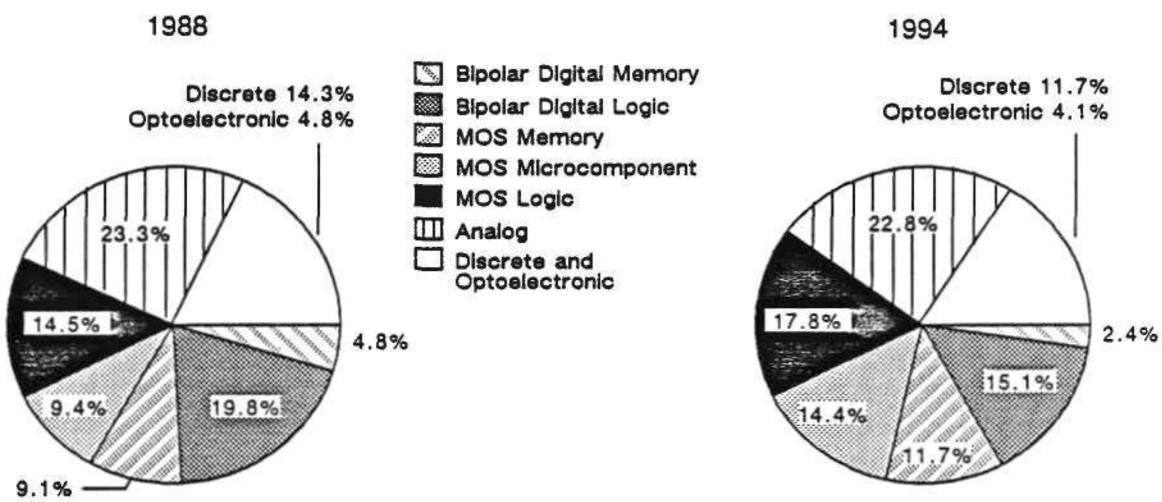
Total = $68.4 Million

Total = $118.7 Million

Source: Dataquest August 1988

Figure 8

Estimated Worldwide Military Communications Semiconductor Consumption



Total = $270.6 Million

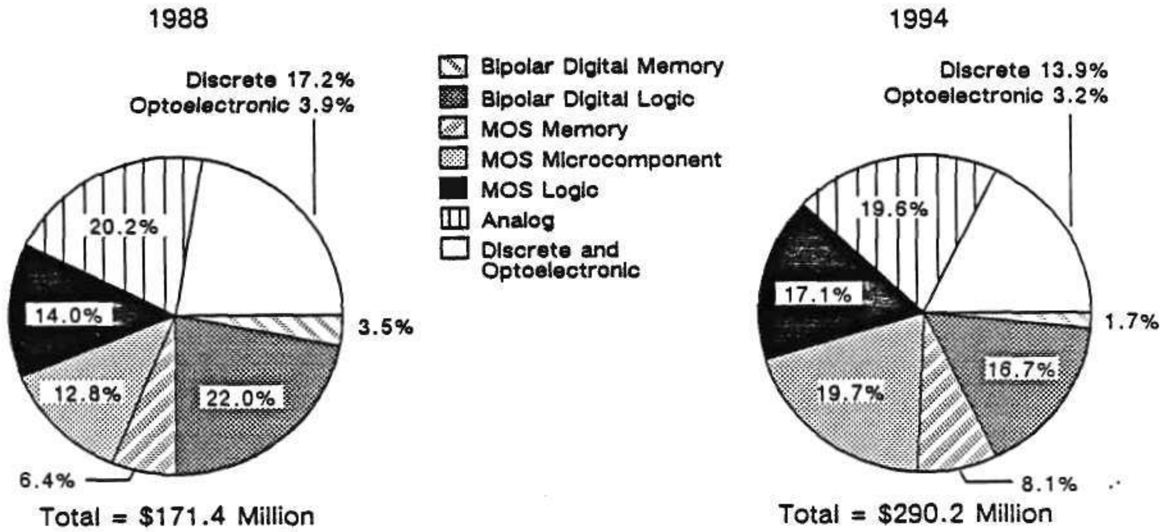
Total = $455.7 Million

Source: Dataquest August 1988

© 1988 Dataquest Incorporated August

Figure 9

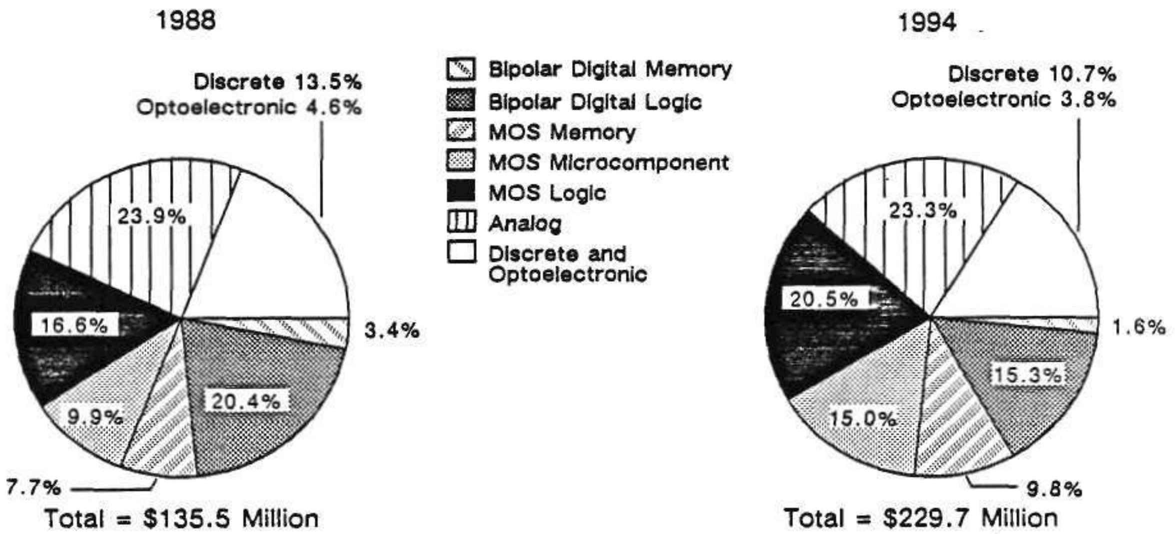
Estimated Worldwide Electronic Warfare Semiconductor Consumption



Source: Dataquest August 1988

Figure 10

Estimated Worldwide Reconnaissance Semiconductor Consumption



Source: Dataquest August 1988

© 1988 Dataquest Incorporated August

Figure 11

Estimated Worldwide Military Aircraft Systems Semiconductor Consumption

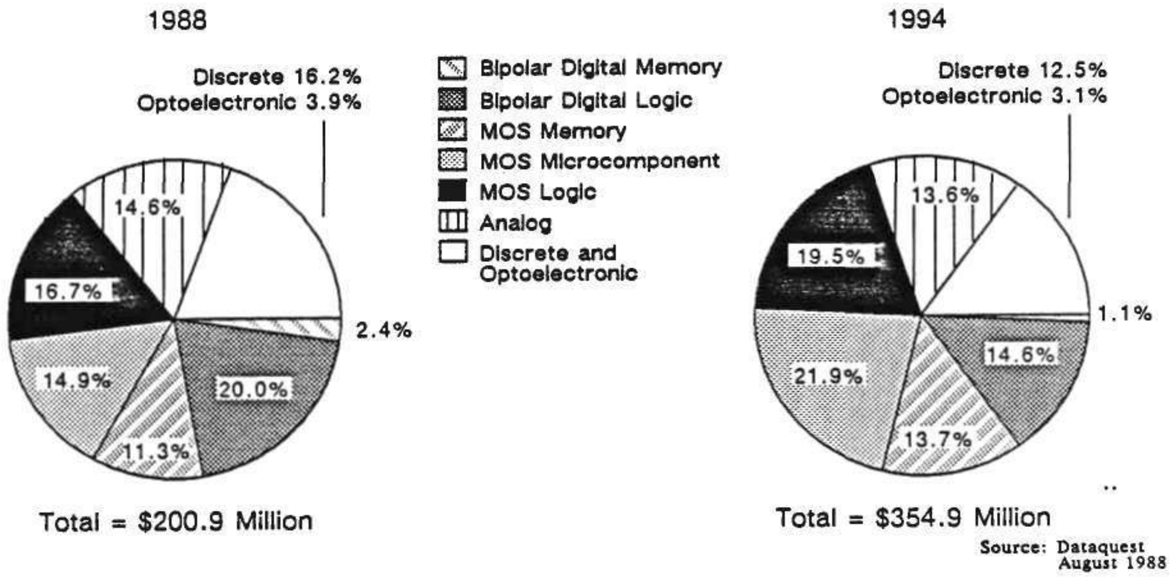
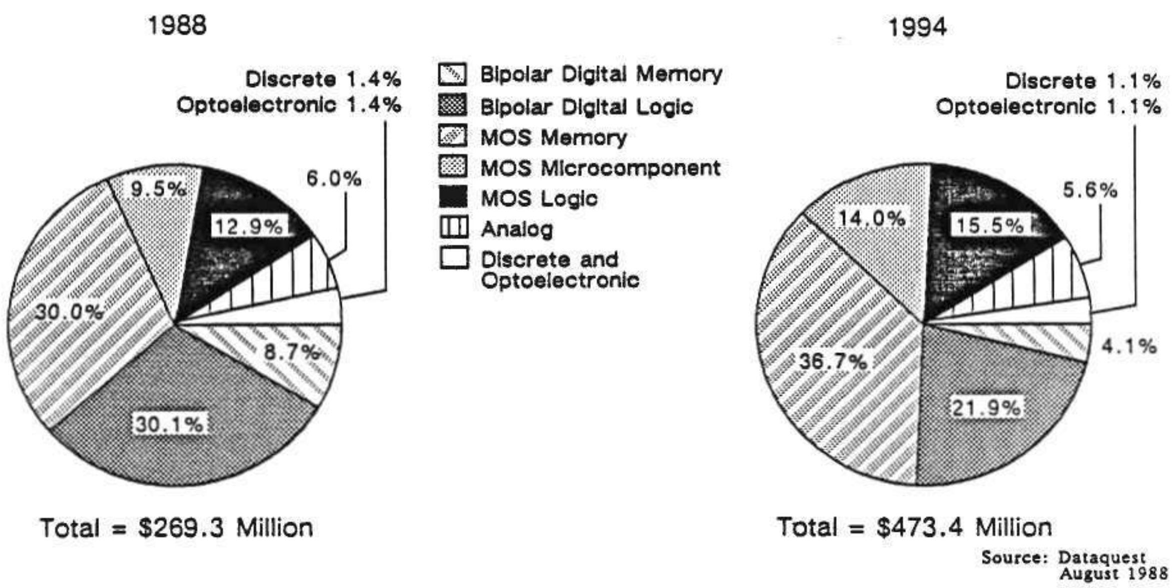


Figure 12

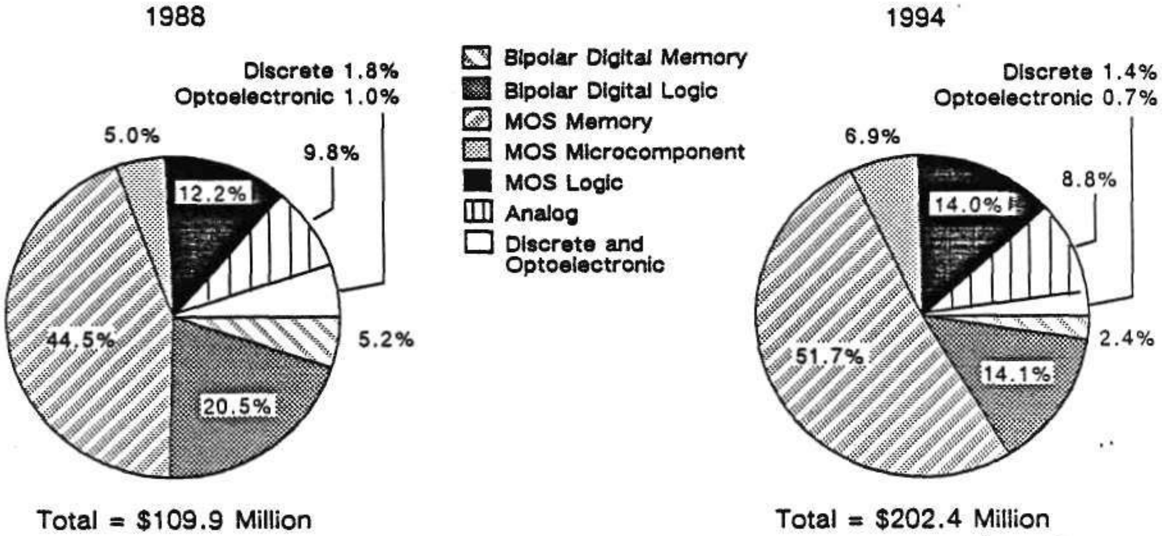
Estimated Worldwide Military Computer Systems Semiconductor Consumption



 © 1988 Dataquest Incorporated August

Figure 13

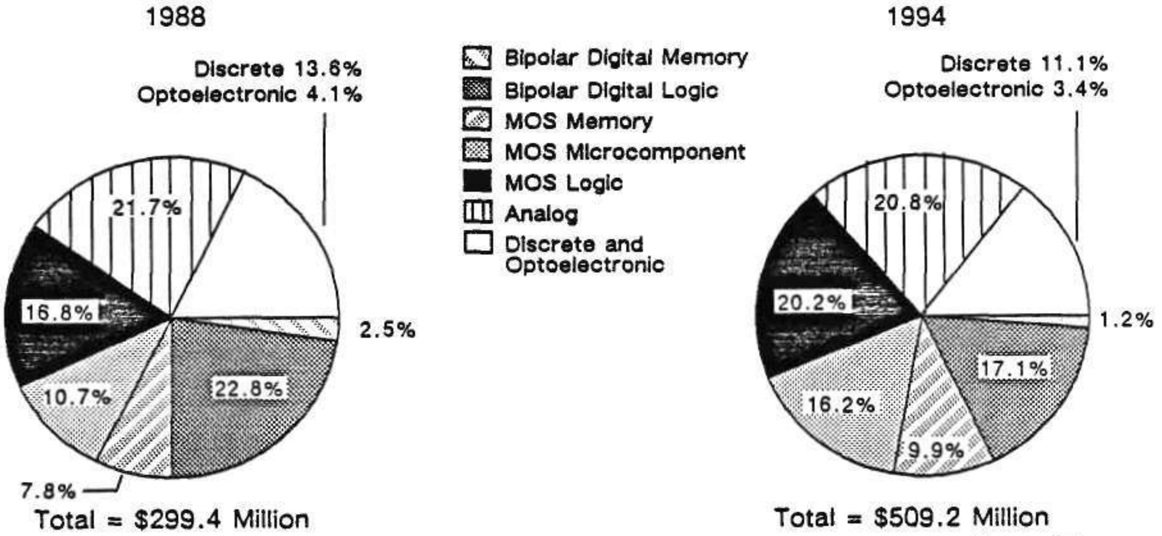
Estimated Worldwide Military Simulation and Training Semiconductor Consumption



Source: Dataquest August 1988

Figure 14

Estimated Worldwide Military Miscellaneous Equipment Semiconductor Consumption



Source: Dataquest August 1988

© 1988 Dataquest Incorporated August

Figure 15

Estimated Worldwide Total Civil Aerospace Semiconductor Consumption

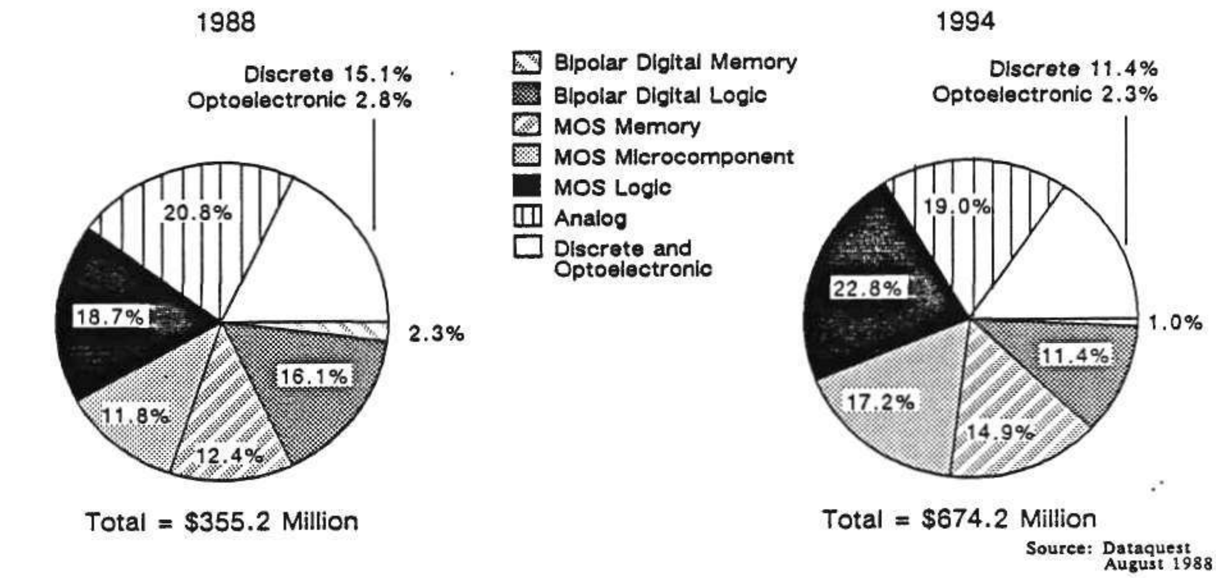
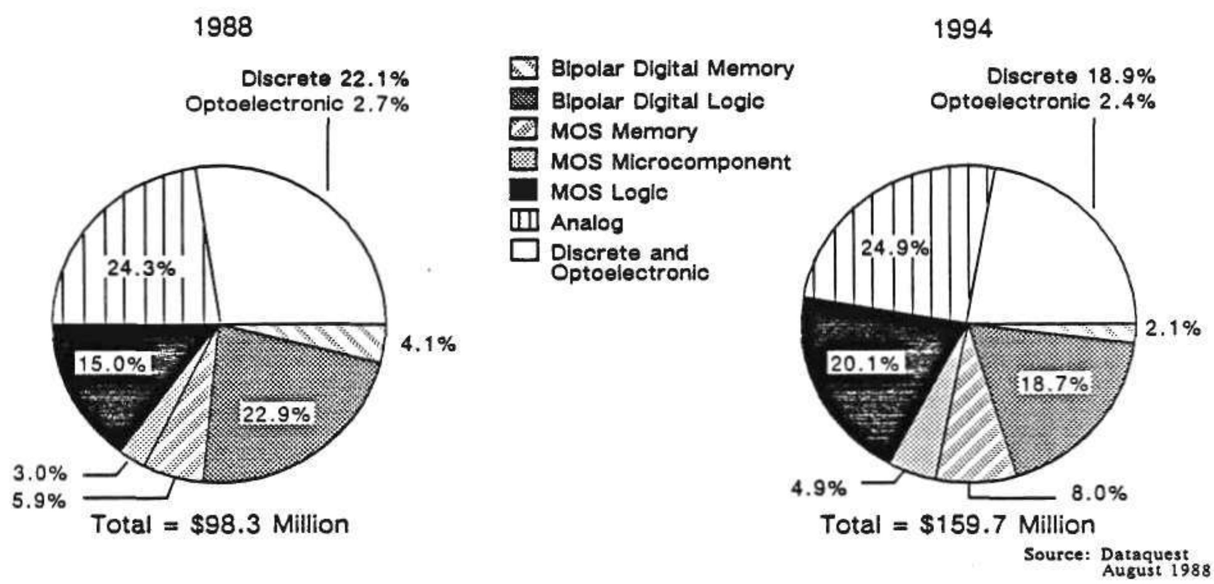


Figure 16

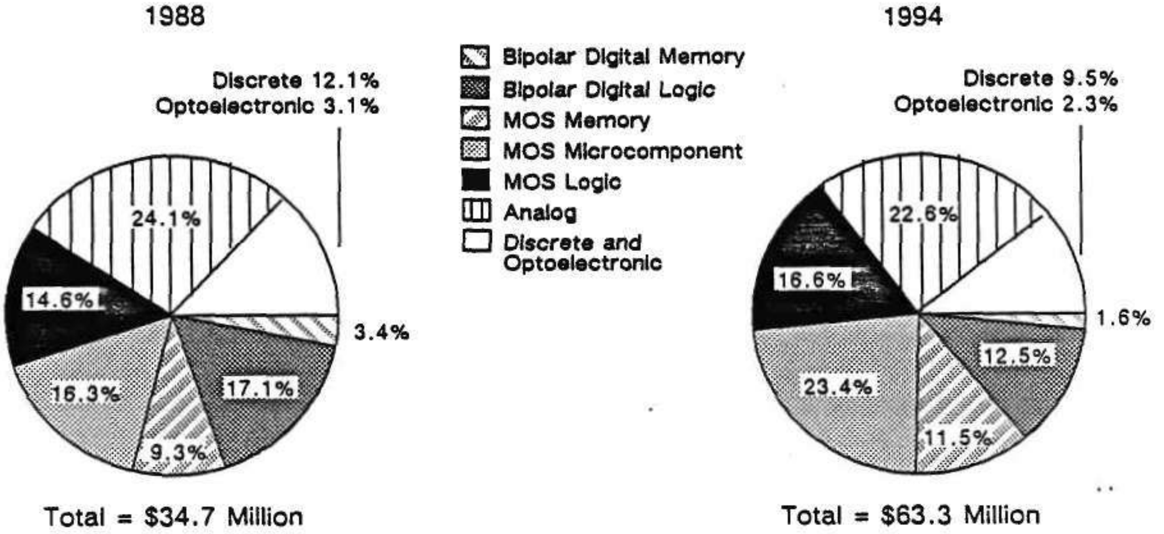
Estimated Worldwide Civil Aerospace Radar Semiconductor Consumption



© 1988 Dataquest Incorporated August

Figure 17

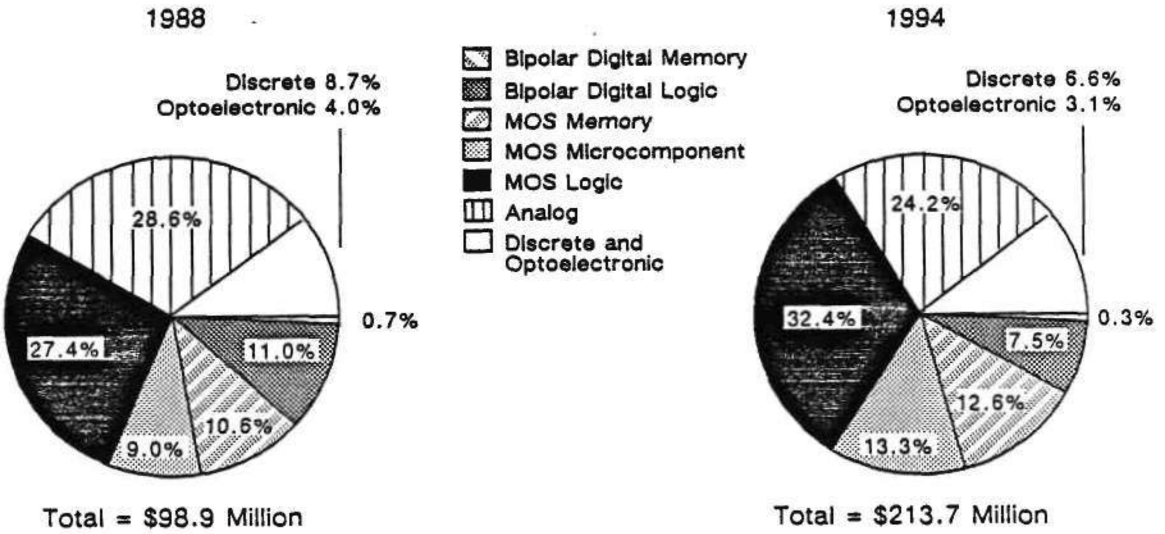
Estimated Worldwide Civil Space Semiconductor Consumption



Source: Dataquest
August 1988

Figure 18

Estimated Worldwide Civil Aerospace Navigation/Communication Semiconductor Consumption

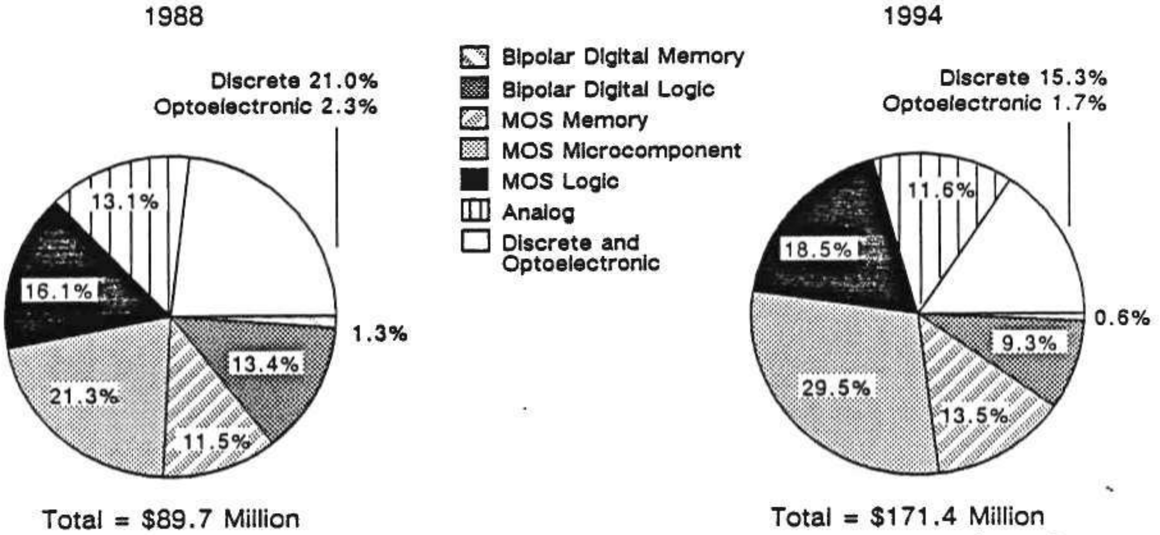


Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Figure 19

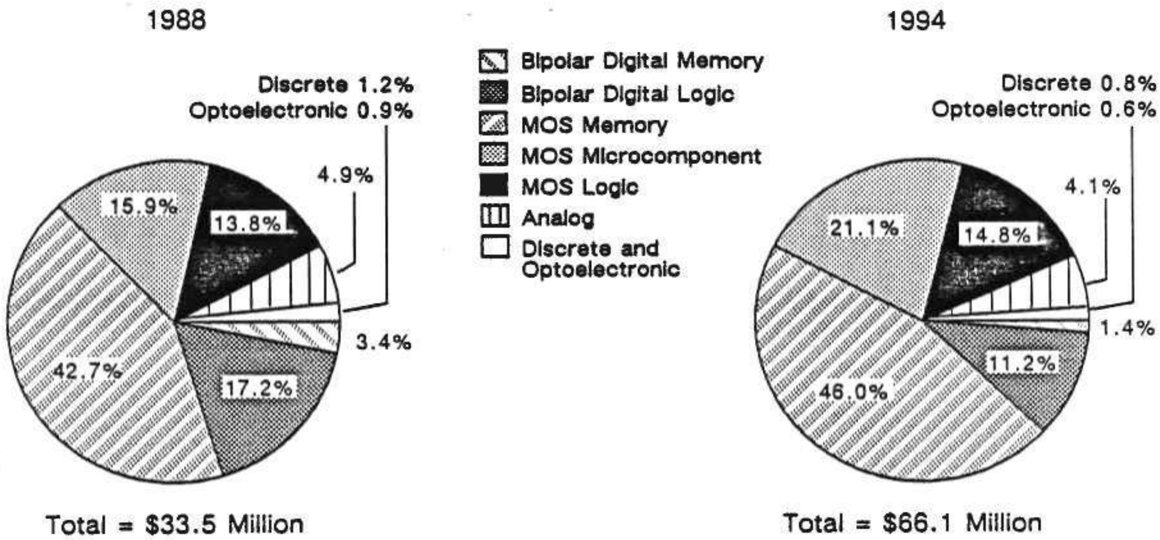
Estimated Worldwide Civil Flight Systems Semiconductor Consumption



Source: Dataquest August 1988

Figure 20

Estimated Worldwide Civil Simulation and Training Semiconductor Consumption



Source: Dataquest August 1988

© 1988 Dataquest Incorporated August

Table 1

Estimated Worldwide Total Military/Aerospace Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$84,654.0	$88,247.0	$90,724.0	$106,410.0	$117,793.0	4.9%
Total Semiconductor	$ 2,565.8	$ 2,806.3	$ 3,070.0	$ 4,019.6	$ 4,860.8	9.6%
IC	$ 2,094.2	$ 2,302.4	$ 2,537.0	$ 3,398.7	$ 4,160.6	10.4%
Bipolar Digital	672.1	680.1	691.9	764.7	822.5	3.2%
Memory	121.8	115.8	112.4	105.2	96.5	(3.0%)
Logic	550.3	564.3	579.5	659.5	726.0	4.3%
MOS Digital	911.4	1,066.4	1,244.8	1,863.1	2,417.7	14.6%
Memory	302.9	346.6	399.2	593.1	750.6	13.7%
Microcomponent	225.0	266.9	315.8	506.7	699.8	17.4%
Logic	383.5	452.9	529.8	763.3	967.3	13.5%
Analog	510.7	555.9	600.3	770.9	920.4	8.8%
Discrete	$ 380.0	$ 406.3	$ 430.1	$ 498.6	$ 560.9	5.5%
Optoelectronic	$ 91.6	$ 97.6	$ 102.9	$ 122.3	$ 139.3	6.1%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

System Semiconductor Utilization

Table 2

Estimated Worldwide Military Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$73,916.0	$76,901.0	$78,277.0	$90,310.0	$98,895.0	4.3%
Total Semiconductor	$ 2,246.3	$ 2,451.2	$ 2,673.6	$ 3,470.7	$ 4,187.0	9.3%
IC	$ 1,833.8	$ 2,011.1	$ 2,210.4	$ 2,931.7	$ 3,579.3	10.1%
Bipolar Digital	607.7	614.8	624.7	687.8	738.6	3.1%
Memory	113.2	107.6	104.4	97.6	89.5	(3.0%)
Logic	494.5	507.2	520.4	590.1	649.0	4.2%
MOS Digital	782.6	914.3	1,065.9	1,580.4	2,048.6	14.4%
Memory	264.6	302.4	347.8	514.3	650.1	13.6%
Microcomponent	190.0	224.9	266.1	423.0	584.3	17.2%
Logic	328.0	387.0	452.0	643.1	814.2	13.2%
Analog	443.5	482.0	519.8	663.5	792.1	8.6%
Discrete	$ 330.3	$ 352.5	$ 372.7	$ 430.2	$ 483.8	5.4%
Optoelectronic	$ 82.3	$ 87.5	$ 90.6	$ 108.8	$ 123.9	6.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 3

Estimated Worldwide Military Radar Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$10,671.0	$11,034.0	$11,124.0	$12,403.0	$13,316.0	3.2%
Total Semiconductor	$ 321.6	$ 345.0	$ 368.6	$ 455.7	$ 533.0	7.5%
IC	$ 240.0	$ 257.8	$ 276.5	$ 348.9	$ 412.7	8.2%
Bipolar Digital	104.9	106.0	107.5	118.2	126.6	3.0%
Memory	22.1	21.2	20.4	19.1	17.5	(3.1%)
Logic	82.7	84.9	87.1	99.1	109.0	4.3%
MOS Digital	57.3	67.2	77.7	114.3	147.2	13.9%
Memory	14.1	16.2	18.6	27.7	35.1	13.8%
Microcomponent	9.6	11.4	13.5	21.1	29.2	17.0%
Logic	33.6	39.7	45.7	65.5	82.9	13.1%
Analog	77.8	84.6	91.2	116.4	138.9	8.6%
Discrete	$ 68.5	$ 73.3	$ 77.4	$ 89.5	$ 100.6	5.4%
Optoelectronic	$ 13.1	$ 13.9	$ 14.7	$ 17.4	$ 19.8	6.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 4

Estimated Worldwide Military Sonar Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$3,682.0	$3,765.0	$3,791.0	$4,283.0	$4,630.0	3.5%
Total Semiconductor	$ 124.8	$ 133.6	$ 141.9	$ 177.0	$ 208.4	7.7%
IC	$ 97.6	$ 104.7	$ 111.6	$ 141.7	$ 168.5	8.3%
Bipolar Digital	39.1	39.3	39.8	43.7	46.7	2.9%
Memory	7.8	7.3	7.1	6.7	6.1	(3.1%)
Logic	31.4	31.9	32.7	37.0	40.6	4.1%
MOS Digital	26.1	30.3	34.5	50.7	65.2	13.6%
Memory	7.7	8.8	10.1	14.8	18.8	13.5%
Microcomponent	4.2	5.0	5.9	9.2	12.7	16.8%
Logic	14.1	16.5	18.6	26.7	33.8	12.6%
Analog	32.4	35.1	37.3	47.4	56.5	8.3%
Discrete	$ 22.3	$ 23.7	$ 24.8	$ 28.8	$ 32.5	5.4%
Optoelectronic	$ 4.9	$ 5.2	$ 5.5	$ 6.5	$ 7.4	6.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 5

Estimated Worldwide Missile and Weapon Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$9,640.0	$10,115.0	$10,360.0	$12,418.0	$13,937.0	5.5%
Total Semiconductor	$ 236.1	$ 258.6	$ 281.5	$ 366.3	$ 443.1	9.4%
IC	$ 172.1	$ 190.2	$ 209.2	$ 282.6	$ 348.8	10.6%
Bipolar Digital	36.3	36.5	36.9	40.0	42.5	2.6%
Memory	10.2	9.6	9.3	8.7	8.0	(3.0%)
Logic	26.1	26.8	27.5	31.3	34.5	4.3%
MOS Digital	73.0	85.5	99.1	148.7	194.2	14.7%
Memory	18.3	20.9	24.1	35.8	45.3	13.8%
Microcomponent	22.9	27.1	32.0	51.1	70.6	17.3%
Logic	31.8	37.5	43.1	61.8	78.3	13.0%
Analog	62.8	68.3	73.2	93.9	112.1	8.6%
Discrete	$ 54.6	$ 58.4	$ 61.7	$ 71.3	$ 80.1	5.4%
Optoelectronic	$ 9.4	$ 10.0	$ 10.6	$ 12.5	$ 14.2	6.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 6

Estimated Worldwide Military Space Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$6,922.0	$7,040.0	$7,066.0	$8,421.0	$9,419.0	5.0%
Total Semiconductor	$ 168.6	$ 188.5	$ 216.3	$ 296.9	$ 368.3	11.8%
IC	$ 141.4	$ 159.7	$ 185.9	$ 261.5	$ 328.3	12.8%
Bipolar Digital	19.9	20.1	20.6	22.9	24.8	3.6%
Memory	2.2	2.0	2.2	2.0	1.8	(1.7%)
Logic	17.7	18.0	18.5	20.9	22.9	4.1%
MOS Digital	94.7	110.5	133.1	197.2	254.3	14.9%
Memory	22.5	25.6	29.3	43.5	54.8	13.6%
Microcomponent	19.0	22.4	26.8	43.1	59.7	17.8%
Logic	53.3	62.6	76.9	110.6	139.8	14.3%
Analog	26.9	29.1	32.2	41.3	49.3	9.2%
Discrete	$ 22.0	$ 23.3	$ 24.7	$ 28.6	$ 32.3	5.6%
Optoelectronic	$ 5.2	$ 5.5	$ 5.7	$ 6.8	$ 7.7	6.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

Table 7

Estimated Worldwide Military Navigation Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$2,183.0	$2,271.0	$2,315.0	$2,671.0	$2,942.0	4.4%
Total Semiconductor	$ 62.5	$ 68.4	$ 74.9	$ 98.1	$ 118.7	9.6%
IC	$ 53.0	$ 58.3	$ 64.2	$ 85.6	$ 104.6	10.2%
Bipolar Digital	16.6	16.8	17.1	18.9	20.4	3.3%
Memory	2.5	2.3	2.3	2.1	1.9	(3.0%)
Logic	14.1	14.4	14.8	16.8	18.5	4.2%
MOS Digital	23.7	27.7	32.2	47.7	61.5	14.2%
Memory	7.8	8.9	10.2	15.0	19.0	13.5%
Microcomponent	4.5	5.4	6.4	10.2	14.1	17.4%
Logic	11.4	13.4	15.7	22.4	28.4	13.3%
Analog	12.7	13.8	14.9	19.0	22.7	8.6%
Discrete	$ 7.6	$ 8.1	$ 8.6	$ 10.0	$ 11.3	5.5%
Optoelectronic	$ 1.8	$ 2.0	$ 2.1	$ 2.5	$ 2.8	6.1%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 8

Estimated Worldwide Military Communications Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$7,169.0	$7,562.0	$7,800.0	$9,161.0	$10,095.0	4.9%
Total Semiconductor	$ 248.2	$ 270.6	$ 294.0	$ 379.0	$ 455.7	9.1%
IC	$ 199.6	$ 218.7	$ 239.2	$ 315.3	$ 383.9	9.8%
Bipolar Digital	65.8	66.5	67.5	74.3	79.7	3.1%
Memory	13.7	13.0	12.7	11.8	10.9	(3.0%)
Logic	52.0	53.5	54.8	62.5	68.8	4.3%
MOS Digital	76.0	89.2	103.8	153.9	200.2	14.4%
Memory	21.6	24.7	28.4	42.2	53.5	13.8%
Microcomponent	21.4	25.4	30.1	47.8	65.8	17.2%
Logic	33.1	39.1	45.3	63.9	80.9	12.9%
Analog	57.8	63.0	67.9	87.1	104.0	8.7%
Discrete	$ 36.2	$ 38.8	$ 40.9	$ 47.3	$ 53.2	5.4%
Optoelectronic	$ 12.3	$ 13.1	$ 13.8	$ 16.4	$ 18.7	6.1%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 9

Estimated Worldwide Electronic Warfare Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$5,173.0	$5,460.0	$5,605.0	$6,608.0	$7,292.0	4.9%
Total Semiconductor	$ 157.0	$ 171.4	$ 184.6	$ 240.3	$ 290.2	9.2%
IC	$ 123.3	$ 135.3	$ 148.1	$ 196.1	$ 240.4	10.1%
Bipolar Digital	43.0	43.7	44.6	49.3	53.3	3.4%
Memory	6.3	6.0	5.8	5.4	5.0	(3.0%)
Logic	36.8	37.7	38.8	43.9	48.3	4.2%
MOS Digital	48.4	56.9	66.1	99.3	130.5	14.8%
Memory	9.5	10.9	12.6	18.6	23.6	13.6%
Microcomponent	18.5	21.9	25.9	41.5	57.2	17.3%
Logic	20.3	24.0	27.7	39.3	49.7	12.9%
Analog	31.9	34.7	37.4	47.4	56.6	8.5%
Discrete	$ 27.6	$ 29.5	$ 31.2	$ 36.0	$ 40.5	5.4%
Optoelectronic	$ 6.2	$ 6.6	$ 5.3	$ 8.2	$ 9.3	5.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 10

Estimated Worldwide Reconnaissance Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$3,514.0	$3,689.0	$3,789.0	$4,412.0	$4,862.0	4.7%
Total Semiconductor	$ 124.1	$ 135.5	$ 147.7	$ 190.3	$ 229.7	9.2%
IC	$ 101.1	$ 111.0	$ 121.7	$ 160.7	$ 196.2	10.0%
Bipolar Digital	31.8	32.2	32.7	36.1	38.9	3.2%
Memory	4.8	4.6	4.4	4.1	3.8	(3.0%)
Logic	27.0	27.6	28.2	32.0	35.1	4.1%
MOS Digital	39.6	46.4	54.1	79.9	104.0	14.4%
Memory	9.2	10.5	12.0	17.8	22.5	13.6%
Microcomponent	11.3	13.4	15.8	24.9	34.4	17.1%
Logic	19.1	22.5	26.3	37.2	47.0	13.0%
Analog	29.8	32.4	35.0	44.7	53.4	8.7%
Discrete	$ 17.1	$ 18.3	$ 19.3	$ 21.9	$ 24.7	5.1%
Optoelectronic	$ 5.9	$ 6.3	$ 6.6	$ 7.7	$ 8.8	5.8%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

 © 1988 Dataquest Incorporated August

Table 11

Estimated Worldwide Military Aircraft Systems Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$6,851.0	$7,139.0	$7,267.0	$8,528.0	$9,489.0	4.9%
Total Semiconductor	$ 182.3	$ 200.9	$ 220.9	$ 290.2	$ 354.9	9.9%
IC	$ 144.5	$ 160.7	$ 178.5	$ 241.2	$ 299.6	10.9%
Bipolar Digital	44.5	45.3	46.2	51.6	56.0	3.6%
Memory	5.1	4.9	4.7	4.4	4.1	(3.0%)
Logic	39.4	40.5	41.5	47.2	51.9	4.2%
MOS Digital	73.2	86.1	100.6	149.1	195.3	14.6%
Memory	19.6	22.7	26.1	38.3	48.5	13.5%
Microcomponent	25.2	29.9	35.3	56.2	77.6	17.2%
Logic	28.4	33.5	39.2	54.6	69.3	12.8%
Analog	26.8	29.3	31.6	40.5	48.3	8.7%
Discrete	$ 30.4	$ 32.5	$ 34.3	$ 39.3	$ 44.2	5.3%
Optoelectronic	$ 7.3	$ 7.8	$ 8.2	$ 9.7	$ 11.1	6.1%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 12

Estimated Worldwide Military Computer Systems Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$2,792.0	$2,900.0	$2,964.0	$3,520.0	$3,923.0	5.2%
Total Semiconductor	$ 247.6	$ 269.3	$ 294.8	$ 390.2	$ 473.4	9.9%
IC	$ 240.4	$ 261.7	$ 286.7	$ 380.8	$ 462.7	10.0%
Bipolar Digital	104.0	104.4	105.7	115.4	122.9	2.8%
Memory	24.8	23.4	22.7	21.2	19.4	(3.0%)
Logic	79.3	81.0	83.0	94.2	103.5	4.2%
MOS Digital	121.6	141.2	163.6	243.2	313.3	14.2%
Memory	70.9	81.1	93.1	137.5	173.7	13.5%
Microcomponent	21.5	25.5	30.0	47.9	66.3	17.3%
Logic	29.2	34.7	40.5	57.8	73.3	13.3%
Analog	14.8	16.1	17.4	22.2	26.5	8.7%
Discrete	$ 3.6	$ 3.9	$ 4.1	$ 4.8	$ 5.4	5.7%
Optoelectronic	$ 3.6	$ 3.8	$ 4.0	$ 4.7	$ 5.3	5.7%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 13

Estimated Worldwide Military Simulation and
Training Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$973.0	$1,029.0	$1,062.0	$1,298.0	$1,474.0	6.2%
Total Semiconductor	$100.4	$ 109.9	$ 121.9	$ 165.7	$ 202.4	10.7%
IC	$ 97.5	$ 106.8	$ 118.7	$ 162.0	$ 198.3	10.9%
Bipolar Digital	28.4	28.2	28.6	31.3	33.3	2.8%
Memory	6.0	5.7	5.6	5.2	4.8	(3.0%)
Logic	22.4	22.5	23.0	26.1	28.6	4.1%
MOS Digital	59.1	67.8	78.4	115.8	147.2	13.8%
Memory	43.1	48.9	56.3	83.2	104.9	13.6%
Microcomponent	4.7	5.5	6.5	10.1	14.0	16.7%
Logic	11.3	13.4	15.6	22.5	28.4	13.4%
Analog	9.9	10.8	11.6	14.9	17.8	8.7%
Discrete	$ 1.9	$ 2.0	$ 2.1	$ 2.5	$ 2.8	5.4%
Optoelectronic	$ 1.0	$ 1.0	$ 1.1	$ 1.2	$ 1.4	4.8%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 14

Estimated Worldwide Military Miscellaneous Equipment
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$14,346.0	$14,897.0	$15,134.0	$16,587.0	$17,516.0	2.7%
Total Semiconductor	$ 273.1	$ 299.4	$ 326.5	$ 420.9	$ 509.2	9.3%
IC	$ 223.2	$ 246.3	$ 270.0	$ 355.4	$ 435.3	10.0%
Bipolar Digital	73.4	75.9	77.6	85.9	93.4	3.5%
Memory	7.7	7.5	7.2	6.8	6.2	(3.2%)
Logic	65.7	68.4	70.4	79.2	87.2	4.1%
MOS Digital	90.0	105.4	122.4	180.7	235.9	14.4%
Memory	20.4	23.4	27.1	39.9	50.6	13.7%
Microcomponent	27.3	32.1	37.8	59.8	82.7	17.1%
Logic	42.3	49.9	57.5	81.0	102.6	12.8%
Analog	59.8	65.0	70.0	88.8	106.0	8.5%
Discrete	$ 38.4	$ 40.9	$ 43.5	$ 50.2	$ 56.5	5.6%
Optoelectronic	$ 11.5	$ 12.3	$ 12.9	$ 15.3	$ 17.4	6.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 15

Estimated Worldwide Total Civil Aerospace Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$10,738.0	$11,346.0	$12,447.0	$16,100.0	$18,898.0	8.9%
Total Semiconductor	$ 319.6	$ 355.2	$ 394.8	$ 549.2	$ 674.2	11.3%
IC	$ 260.5	$ 291.4	$ 326.7	$ 467.2	$ 581.6	12.2%
Bipolar Digital	64.4	65.3	67.2	77.0	84.0	4.3%
Memory	8.6	8.2	8.0	7.6	7.0	(2.7%)
Logic	55.8	57.1	59.2	69.4	77.0	5.1%
MOS Digital	128.8	152.2	179.0	282.9	369.3	15.9%
Memory	38.3	44.2	51.4	78.9	100.5	14.7%
Microcomponent	35.0	42.0	49.7	83.7	115.6	18.4%
Logic	55.5	66.0	77.8	120.3	153.2	15.1%
Analog	67.3	73.9	80.4	107.4	128.4	9.6%
Discrete	$ 49.7	$ 53.7	$ 57.4	$ 68.5	$ 77.1	6.2%
Optoelectronic	$ 9.3	$ 10.1	$ 10.7	$ 13.5	$ 15.4	7.4%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 16

Estimated Worldwide Civil Aerospace Radar Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$2,707.0	$2,961.0	$3,158.0	$3,985.0	$4,623.0	7.7%
Total Semiconductor	$ 91.3	$ 98.3	$ 106.4	$ 134.8	$ 159.7	8.4%
IC	$ 68.5	$ 73.9	$ 80.5	$ 104.6	$ 125.6	9.2%
Bipolar Digital	26.4	26.5	27.2	30.5	33.3	3.9%
Memory	4.2	4.0	3.9	3.6	3.3	(2.9%)
Logic	22.2	22.5	23.3	26.9	29.9	4.9%
MOS Digital	20.3	23.5	27.5	40.8	52.6	14.4%
Memory	5.1	5.8	6.7	10.0	12.7	14.0%
Microcomponent	2.5	3.0	3.5	5.7	7.8	17.5%
Logic	12.7	14.7	17.3	25.1	32.1	13.8%
Analog	21.9	23.9	25.8	33.2	39.7	8.8%
Discrete	$ 20.3	$ 21.7	$ 23.0	$ 26.8	$ 30.2	5.7%
Optoelectronic	$ 2.5	$ 2.7	$ 2.9	$ 3.4	$ 3.9	6.4%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 17

Estimated Worldwide Civil Space Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$3,969.0	$3,932.0	$4,431.0	$6,008.0	$7,113.0	10.4%
Total Semiconductor	$ 86.9	$ 98.9	$ 111.5	$ 171.8	$ 213.7	13.7%
IC	$ 75.3	$ 86.3	$ 98.0	$ 153.6	$ 193.0	14.3%
Bipolar Digital	11.1	11.6	12.0	14.9	16.6	6.2%
Memory	0.7	0.7	0.7	0.7	0.6	(0.9%)
Logic	10.4	10.9	11.3	14.2	15.9	6.6%
MOS Digital	38.7	46.5	55.1	95.5	124.6	17.9%
Memory	8.8	10.5	12.3	20.8	27.0	17.1%
Microcomponent	7.4	8.9	10.7	20.5	28.5	21.3%
Logic	22.5	27.1	32.1	54.1	69.2	16.9%
Analog	25.6	28.3	30.9	43.3	51.8	10.6%
Discrete	$ 7.9	$ 8.6	$ 9.3	$ 12.4	$ 14.0	8.5%
Optoelectronic	$ 3.7	$ 4.0	$ 4.2	$ 5.8	$ 6.6	8.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 18

Estimated Worldwide Civil Aerospace Navigation/Communication Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$992.0	$1,095.0	$1,200.0	$1,522.0	$1,814.0	8.8%
Total Semiconductor	$ 31.2	$ 34.7	$ 38.4	$ 51.7	$ 63.3	10.5%
IC	$ 26.3	$ 29.5	$ 32.8	$ 45.0	$ 55.8	11.2%
Bipolar Digital	6.9	7.1	7.3	8.3	8.9	3.8%
Memory	1.2	1.2	1.2	1.1	1.0	(2.6%)
Logic	5.7	5.9	6.2	7.2	7.9	4.9%
MOS Digital	11.8	14.0	16.3	24.8	32.6	15.1%
Memory	2.8	3.2	3.8	5.7	7.3	14.4%
Microcomponent	4.7	5.7	6.6	10.7	14.8	17.4%
Logic	4.2	5.1	6.0	8.3	10.5	12.9%
Analog	7.6	8.4	9.1	12.0	14.3	9.3%
Discrete	$ 3.9	$ 4.2	$ 4.5	$ 5.3	$ 6.0	6.2%
Optoelectronic	$ 1.0	$ 1.1	$ 1.1	$ 1.3	$ 1.5	5.4%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 19

Estimated Worldwide Civil Flight Systems Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$2,778.0	$3,037.0	$3,310.0	$4,137.0	$4,827.0	8.0%
Total Semiconductor	$ 79.8	$ 89.7	$ 100.7	$ 138.1	$ 171.4	11.4%
IC	$ 60.6	$ 68.9	$ 78.3	$ 112.0	$ 142.1	12.8%
Bipolar Digital	12.8	13.2	13.6	15.5	16.9	4.2%
Memory	1.3	1.2	1.2	1.1	1.0	(2.7%)
Logic	11.5	12.0	12.5	14.4	15.9	4.8%
MOS Digital	37.1	43.9	51.8	79.9	105.3	15.7%
Memory	9.1	10.4	12.1	18.2	23.1	14.3%
Microcomponent	15.9	19.1	22.6	36.7	50.6	17.6%
Logic	12.0	14.4	17.1	24.9	31.6	14.0%
Analog	10.7	11.8	12.9	16.7	19.9	9.2%
Discrete	$ 17.4	$ 18.9	$ 20.2	$ 23.4	$ 26.3	5.7%
Optoelectronic	$ 1.9	$ 2.0	$ 2.2	$ 2.6	$ 3.0	6.5%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 20

Estimated Worldwide Civil Simulation and Training Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$292.0	$321.0	$348.0	$448.0	$521.0	8.4%
Total Semiconductor	$ 30.4	$ 33.5	$ 37.7	$ 52.9	$ 66.1	12.0%
IC	$ 29.7	$ 32.8	$ 37.0	$ 52.0	$ 65.2	12.1%
Bipolar Digital	7.3	6.9	7.0	7.8	8.3	3.2%
Memory	1.2	1.2	1.1	1.0	1.0	(3.0%)
Logic	6.0	5.8	5.9	6.7	7.4	4.2%
MOS Digital	21.0	24.3	28.2	42.0	54.1	14.3%
Memory	12.6	14.3	16.5	24.1	30.4	13.3%
Microcomponent	4.5	5.3	6.3	10.1	13.9	17.4%
Logic	3.9	4.6	5.4	7.8	9.8	13.4%
Analog	1.5	1.7	1.8	2.3	2.7	8.7%
Discrete	$ 0.4	$ 0.4	$ 0.4	$ 0.5	$ 0.6	5.5%
Optoelectronic	$ 0.3	$ 0.3	$ 0.3	$ 0.4	$ 0.4	6.1%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 21

Estimated North American Total Military/Aerospace Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$58,479.0	$59,339.0	$60,654.0	$70,298.0	$77,052.0	4.5%
Total Semiconductor	$ 1,848.3	$ 1,985.7	$ 2,167.7	$ 2,842.7	$ 3,439.1	9.6%
IC	$ 1,532.9	$ 1,654.2	$ 1,815.4	$ 2,428.6	$ 2,967.7	10.2%
Bipolar Digital	501.0	496.7	504.1	552.8	590.2	2.9%
Memory	95.4	89.3	87.0	80.9	73.7	(3.1%)
Logic	405.6	407.4	417.1	471.9	516.5	4.0%
MOS Digital	656.3	754.0	878.3	1,317.9	1,712.2	14.7%
Memory	216.0	244.2	279.5	412.7	518.0	13.4%
Microcomponent	165.1	192.1	225.2	366.5	513.4	17.8%
Logic	275.2	317.7	373.6	538.7	680.8	13.5%
Analog	375.6	403.5	433.0	557.9	665.3	8.7%
Discrete	$ 245.9	$ 258.5	$ 275.8	$ 323.1	$ 368.4	6.1%
Optoelectronic	$ 69.5	$ 73.0	$ 76.5	$ 91.0	$ 103.0	5.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 22

Estimated North American Military Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$51,549.0	$52,345.0	$52,968.0	$60,454.0	$65,604.0	3.8%
Total Semiconductor	$ 1,631.1	$ 1,751.4	$ 1,910.2	$ 2,482.7	$ 2,997.6	9.4%
IC	$ 1,353.1	$ 1,459.3	$ 1,599.8	$ 2,119.4	$ 2,584.0	10.0%
Bipolar Digital	456.3	453.0	459.7	502.7	536.3	2.9%
Memory	89.2	83.5	81.3	75.6	68.9	(3.1%)
Logic	367.1	369.5	378.3	427.1	467.4	4.0%
MOS Digital	568.2	653.3	761.3	1,131.3	1,468.8	14.5%
Memory	190.7	215.9	247.1	363.2	455.8	13.3%
Microcomponent	140.0	162.9	191.4	308.6	432.3	17.7%
Logic	237.5	274.5	322.8	459.5	580.7	13.3%
Analog	328.7	353.1	378.9	485.4	578.8	8.6%
Discrete	$ 215.2	$ 226.2	$ 241.3	$ 281.7	$ 321.2	6.0%
Optoelectronic	$ 62.8	$ 65.9	$ 69.1	$ 81.6	$ 92.4	5.8%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 23

Estimated North American Military Radar Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$7,167.0	$7,203.0	$7,224.0	$8,010.0	$8,580.0	3.0%
Total Semiconductor	$ 227.9	$ 240.2	$ 256.2	$ 317.4	$ 371.2	7.5%
IC	$ 174.3	$ 183.9	$ 196.3	$ 247.1	$ 291.2	8.0%
Bipolar Digital	77.2	76.5	77.4	84.4	89.7	2.7%
Memory	17.2	16.2	15.7	14.6	13.3	(3.2%)
Logic	60.0	60.3	61.7	69.8	76.4	4.0%
MOS Digital	40.4	46.5	53.6	79.0	101.7	13.9%
Memory	9.7	11.0	12.6	18.6	23.3	13.4%
Microcomponent	6.8	7.9	9.2	14.7	20.5	17.3%
Logic	23.9	27.6	31.8	45.8	57.9	13.1%
Analog	56.7	60.9	65.4	83.7	99.8	8.6%
Discrete	$ 43.8	$ 46.0	$ 49.1	$ 57.5	$ 65.6	6.1%
Optoelectronic	$ 9.8	$ 10.3	$ 10.8	$ 12.7	$ 14.4	5.8%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 24

Estimated North American Military Sonar Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$2,886.0	$2,889.0	$2,889.0	$3,240.0	$3,491.0	3.2%
Total Semiconductor	$ 101.9	$ 107.8	$ 114.4	$ 142.8	$ 168.0	7.7%
IC	$ 80.8	$ 85.6	$ 91.0	$ 115.4	$ 136.8	8.1%
Bipolar Digital	32.6	32.3	32.8	35.9	38.2	2.8%
Memory	6.7	6.3	6.1	5.7	5.2	(3.1%)
Logic	26.0	26.1	26.7	30.2	33.1	4.0%
MOS Digital	21.1	24.2	27.5	40.4	52.0	13.6%
Memory	6.0	6.8	7.8	11.6	14.5	13.4%
Microcomponent	3.5	4.0	4.7	7.3	10.3	16.9%
Logic	11.6	13.3	14.9	21.5	27.2	12.6%
Analog	27.0	29.1	30.7	39.1	46.6	8.2%
Discrete	$ 17.0	$ 17.8	$ 18.8	$ 22.0	$ 25.1	5.8%
Optoelectronic	$ 4.2	$ 4.4	$ 4.6	$ 5.5	$ 6.2	5.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 25

Estimated North American Missile and Weapon Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$6,228.0	$6,321.0	$6,404.0	$7,562.0	$8,369.0	4.8%
Total Semiconductor	$ 164.7	$ 177.5	$ 192.9	$ 253.1	$ 307.2	9.6%
IC	$ 123.2	$ 134.0	$ 146.6	$ 198.8	$ 245.3	10.6%
Bipolar Digital	26.0	25.5	25.7	27.7	29.1	2.3%
Memory	7.7	7.1	7.0	6.5	5.9	(3.1%)
Logic	18.3	18.3	18.8	21.2	23.2	4.0%
MOS Digital	51.8	59.7	68.9	104.1	136.4	14.8%
Memory	12.7	14.4	16.5	24.3	30.6	13.4%
Microcomponent	16.5	19.2	22.5	36.7	51.3	17.8%
Logic	22.6	26.1	29.9	43.1	54.5	13.1%
Analog	45.4	48.8	52.0	66.9	79.8	8.5%
Discrete	$ 34.4	$ 36.2	$ 38.6	$ 45.2	$ 51.6	6.1%
Optoelectronic	$ 7.0	$ 7.4	$ 7.7	$ 9.1	$ 10.3	5.7%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 26

Estimated North American Military Space Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$5,281.0	$5,228.0	$5,228.0	$6,192.0	$6,879.0	4.7%
Total Semiconductor	$ 129.7	$ 143.2	$ 165.8	$ 228.5	$ 284.1	12.1%
IC	$ 109.8	$ 122.3	$ 143.6	$ 202.3	$ 254.4	13.0%
Bipolar Digital	15.9	15.9	16.3	18.1	19.6	3.5%
Memory	1.7	1.6	1.7	1.6	1.5	(1.4%)
Logic	14.2	14.3	14.6	16.5	18.1	4.0%
MOS Digital	72.9	83.8	102.1	151.8	196.2	15.2%
Memory	17.3	19.5	22.4	33.0	41.4	13.4%
Microcomponent	14.9	17.3	20.7	33.7	47.2	18.2%
Logic	40.7	47.0	59.0	85.1	107.6	14.8%
Analog	21.0	22.6	25.1	32.4	38.6	9.3%
Discrete	$ 15.7	$ 16.5	$ 17.7	$ 20.7	$ 23.6	6.1%
Optoelectronic	$ 4.2	$ 4.4	$ 4.6	$ 5.5	$ 6.2	5.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 27

Estimated North American Military Navigation Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$1,537.0	$1,566.0	$1,589.0	$1,798.0	$1,953.0	3.8%
Total Semiconductor	$ 45.4	$ 48.8	$ 53.4	$ 70.3	$ 85.1	9.7%
IC	$ 39.1	$ 42.2	$ 46.4	$ 62.1	$ 75.7	10.2%
Bipolar Digital	12.5	12.4	12.6	13.9	14.9	3.1%
Memory	2.0	1.8	1.7	1.6	1.5	(3.1%)
Logic	10.5	10.6	10.8	12.3	13.4	4.0%
MOS Digital	17.2	19.7	23.0	34.2	44.2	14.4%
Memory	5.6	6.3	7.3	10.7	13.5	13.4%
Microcomponent	3.3	3.8	4.5	7.3	10.3	17.8%
Logic	8.3	9.5	11.2	16.2	20.4	13.5%
Analog	9.4	10.1	10.8	13.9	16.6	8.7%
Discrete	$ 4.9	$ 5.2	$ 5.5	$ 6.5	$ 7.4	6.1%
Optoelectronic	$ 1.4	$ 1.5	$ 1.5	$ 1.8	$ 2.1	5.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 28

Estimated North American Military Communications Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$4,616.0	$4,750.0	$4,878.0	$5,680.0	$6,202.0	4.5%
Total Semiconductor	$ 172.0	$ 184.1	$ 199.6	$ 257.8	$ 310.2	9.1%
IC	$ 140.9	$ 151.3	$ 164.9	$ 216.9	$ 263.7	9.7%
Bipolar Digital	47.0	46.5	47.1	51.4	54.6	2.7%
Memory	10.5	9.8	9.6	8.9	8.1	(3.1%)
Logic	36.5	36.7	37.5	42.5	46.5	4.0%
MOS Digital	52.6	60.5	70.1	104.1	135.9	14.5%
Memory	14.7	16.6	19.0	28.1	35.2	13.4%
Microcomponent	15.0	17.5	20.5	33.0	46.2	17.6%
Logic	22.8	26.4	30.6	43.1	54.5	12.9%
Analog	41.3	44.4	47.6	61.4	73.2	8.7%
Discrete	$ 22.1	$ 23.3	$ 24.8	$ 29.1	$ 33.2	6.1%
Optoelectronic	$ 9.0	$ 9.5	$ 9.9	$ 11.8	$ 13.4	5.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

 © 1988 Dataquest Incorporated August

Table 29

Estimated North American Electronic Warfare Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$3,413.0	$3,518.0	$3,596.0	$4,222.0	$4,637.0	4.7%
Total Semiconductor	$ 109.8	$ 117.7	$ 127.7	$ 165.4	$ 200.3	9.3%
IC	$ 88.0	$ 94.8	$ 103.3	$ 136.8	$ 167.8	10.0%
Bipolar Digital	31.1	30.9	31.5	34.7	37.3	3.1%
Memory	4.8	4.5	4.4	4.0	3.7	(3.1%)
Logic	26.4	26.5	27.1	30.7	33.6	4.0%
MOS Digital	34.0	39.2	45.5	68.6	90.7	15.0%
Memory	6.5	7.3	8.4	12.4	15.5	13.4%
Microcomponent	13.2	15.4	18.0	29.3	41.1	17.8%
Logic	14.3	16.5	19.1	26.9	34.0	12.8%
Analog	22.9	24.6	26.4	33.5	39.9	8.4%
Discrete	$ 17.2	$ 18.1	$ 19.3	$ 22.6	$ 25.8	6.1%
Optoelectronic	$ 4.6	$ 4.8	$ 5.0	$ 5.9	$ 6.7	5.6%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 30

Estimated North American Reconnaissance Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$2,422.0	$2,488.0	$2,550.0	$2,935.0	$3,205.0	4.3%
Total Semiconductor	$ 91.5	$ 98.2	$ 107.0	$ 138.4	$ 167.2	9.3%
IC	$ 75.6	$ 81.5	$ 89.2	$ 117.9	$ 143.9	10.0%
Bipolar Digital	24.1	23.9	24.3	26.8	28.8	3.1%
Memory	3.8	3.6	3.5	3.2	2.9	(3.1%)
Logic	20.3	20.4	20.9	23.6	25.8	4.0%
MOS Digital	28.9	33.3	38.9	57.6	75.3	14.5%
Memory	6.5	7.3	8.4	12.4	15.5	13.4%
Microcomponent	8.4	9.8	11.5	18.3	25.7	17.4%
Logic	14.0	16.2	19.1	26.9	34.0	13.2%
Analog	22.5	24.2	26.0	33.5	39.9	8.7%
Discrete	$ 11.3	$ 11.9	$ 12.7	$ 14.5	$ 16.6	5.7%
Optoelectronic	$ 4.6	$ 4.8	$ 5.0	$ 5.9	$ 6.7	5.6%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

 © 1988 Dataquest Incorporated August

Table 31

Estimated North American Military Aircraft Systems Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$4,555.0	$4,637.0	$4,697.0	$5,422.0	$5,967.0	4.3%
Total Semiconductor	$ 128.3	$ 138.9	$ 152.7	$ 200.9	$ 246.3	10.0%
IC	$ 102.8	$ 112.2	$ 124.2	$ 167.8	$ 208.6	10.9%
Bipolar Digital	32.2	32.1	32.7	36.3	39.1	3.3%
Memory	3.8	3.6	3.5	3.2	2.9	(3.1%)
Logic	28.4	28.5	29.2	33.0	36.2	4.0%
MOS Digital	51.8	59.9	69.9	103.6	136.2	14.7%
Memory	13.4	15.4	17.6	25.6	32.1	13.1%
Microcomponent	18.3	21.3	25.0	40.3	56.5	17.6%
Logic	20.1	23.2	27.3	37.7	47.7	12.8%
Analog	18.8	20.2	21.7	27.9	33.3	8.7%
Discrete	$ 19.9	$ 20.9	$ 22.3	$ 25.8	$ 29.5	5.9%
Optoelectronic	$ 5.6	$ 5.8	$ 6.1	$ 7.3	$ 8.2	5.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 32

Estimated North American Military Computer Systems
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$2,112.0	$2,154.0	$2,193.0	$2,575.0	$2,839.0	4.7%
Total Semiconductor	$ 191.5	$ 205.2	$ 224.2	$ 295.7	$ 357.4	9.7%
IC	$ 186.2	$ 199.7	$ 218.3	$ 288.8	$ 349.6	9.8%
Bipolar Digital	82.3	81.1	82.1	89.1	94.4	2.6%
Memory	20.6	19.2	18.7	17.4	15.8	(3.1%)
Logic	61.7	61.9	63.4	71.7	78.5	4.0%
MOS Digital	92.7	106.4	123.2	182.9	235.3	14.1%
Memory	54.0	61.3	70.2	103.2	129.5	13.3%
Microcomponent	16.7	19.4	22.7	36.7	51.3	17.6%
Logic	22.0	25.7	30.3	43.1	54.5	13.3%
Analog	11.3	12.1	13.0	16.7	20.0	8.7%
Discrete	$ 2.5	$ 2.6	$ 2.8	$ 3.2	$ 3.7	6.1%
Optoelectronic	$ 2.8	$ 3.0	$ 3.1	$ 3.6	$ 4.1	5.5%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 33

Estimated North American Military Simulation and Training Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$671.0	$695.0	$715.0	$863.0	$970.0	5.7%
Total Semiconductor	$ 73.7	$ 79.4	$ 87.8	$118.7	$144.8	10.5%
IC	$ 71.7	$ 77.3	$ 85.6	$116.2	$141.9	10.7%
Bipolar Digital	21.4	20.8	21.0	22.9	24.3	2.7%
Memory	4.8	4.5	4.4	4.0	3.7	(3.1%)
Logic	16.6	16.3	16.7	18.9	20.7	4.0%
MOS Digital	42.8	48.5	55.9	82.1	104.2	13.6%
Memory	31.1	34.9	40.0	58.6	73.6	13.2%
Microcomponent	3.5	4.0	4.7	7.3	10.3	16.9%
Logic	8.3	9.5	11.2	16.2	20.4	13.5%
Analog	7.5	8.1	8.7	11.2	13.3	8.7%
Discrete	$ 1.2	$ 1.3	$ 1.4	$ 1.6	$ 1.8	6.1%
Optoelectronic	$ 0.8	$ 0.8	$ 0.8	$ 0.9	$ 1.0	4.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 34

Estimated North American Military Miscellaneous Equipment Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$10,661.0	$10,896.0	$11,005.0	$11,955.0	$12,512.0	2.3%
Total Semiconductor	$ 194.5	$ 210.3	$ 228.5	$ 293.9	$ 355.7	9.2%
IC	$ 160.6	$ 174.7	$ 190.4	$ 249.4	$ 305.0	9.7%
Bipolar Digital	53.9	55.2	56.1	61.5	66.4	3.1%
Memory	5.6	5.4	5.2	4.9	4.4	(3.4%)
Logic	48.3	49.7	50.9	56.6	62.0	3.7%
MOS Digital	62.0	71.5	82.8	122.6	160.8	14.5%
Memory	13.2	14.9	17.0	24.8	31.1	13.0%
Microcomponent	20.0	23.2	27.2	44.0	61.6	17.6%
Logic	28.9	33.4	38.5	53.9	68.1	12.6%
Analog	44.7	48.0	51.5	65.3	77.8	8.4%
Discrete	$ 25.1	$ 26.4	$ 28.4	$ 33.0	$ 37.6	6.1%
Optoelectronic	$ 8.8	$ 9.3	$ 9.7	$ 11.6	$ 13.1	5.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 35

Estimated North American Total Civil Aerospace Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$6,930.0	$6,994.0	$7,686.0	$9,844.0	$11,448.0	8.6%
Total Semiconductor	$ 217.2	$ 234.2	$ 257.4	$ 360.0	$ 441.5	11.1%
IC	$ 179.7	$ 194.8	$ 215.5	$ 309.2	$ 383.7	12.0%
Bipolar Digital	44.7	43.6	44.4	50.1	53.9	3.6%
Memory	6.2	5.8	5.6	5.3	4.8	(3.0%)
Logic	38.5	37.9	38.8	44.8	49.1	4.4%
MOS Digital	88.1	100.7	117.0	186.6	243.4	15.8%
Memory	25.3	28.3	32.4	49.5	62.2	14.0%
Microcomponent	25.1	29.2	33.8	57.9	81.1	18.6%
Logic	37.7	43.2	50.8	79.2	100.1	15.0%
Analog	47.0	50.4	54.1	72.5	86.5	9.4%
Discrete	$ 30.7	$ 32.3	$ 34.5	$ 41.4	$ 47.2	6.5%
Optoelectronic	$ 6.7	$ 7.1	$ 7.4	$ 9.4	$ 10.6	7.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

System Semiconductor Utilization

Table 36

Estimated North American Civil Aerospace Radar Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$1,590.0	$1,709.0	$1,826.0	$2,332.0	$2,710.0	8.0%
Total Semiconductor	$ 59.9	$ 62.9	$ 67.9	$ 85.7	$ 101.2	8.2%
IC	$ 45.9	$ 48.2	$ 52.2	$ 67.3	$ 80.2	8.9%
Bipolar Digital	17.5	16.9	17.2	18.9	20.3	3.1%
Memory	2.9	2.7	2.6	2.4	2.2	(3.1%)
Logic	14.6	14.3	14.6	16.5	18.1	4.0%
MOS Digital	13.4	15.1	17.7	26.0	33.3	14.1%
Memory	3.2	3.7	4.2	6.2	7.8	13.4%
Microcomponent	1.7	1.9	2.3	3.7	5.1	17.8%
Logic	8.5	9.5	11.2	16.2	20.4	13.5%
Analog	15.0	16.1	17.3	22.3	26.6	8.7%
Discrete	$ 12.3	$ 12.9	$ 13.8	$ 16.2	$ 18.4	6.1%
Optoelectronic	$ 1.7	$ 1.8	$ 1.9	$ 2.3	$ 2.6	5.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 37

Estimated North American Civil Space Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$2,693.0	$2,464.0	$2,794.0	$3,770.0	$4,356.0	10.0%
Total Semiconductor	$ 57.7	$ 63.2	$ 70.1	$ 112.0	$ 138.2	13.9%
IC	$ 50.7	$ 55.8	$ 62.3	$ 100.8	$ 125.4	14.5%
Bipolar Digital	7.7	7.7	7.9	9.8	10.7	5.6%
Memory	0.4	0.4	0.4	0.4	0.4	(1.4%)
Logic	7.3	7.3	7.5	9.4	10.3	5.9%
MOS Digital	25.3	29.1	34.0	62.0	80.1	18.4%
Memory	5.2	5.9	6.7	12.0	15.0	17.0%
Microcomponent	5.0	5.8	6.8	13.9	19.5	22.5%
Logic	15.1	17.5	20.5	36.1	45.6	17.3%
Analog	17.7	19.0	20.4	29.0	34.6	10.5%
Discrete	$ 4.4	$ 4.7	$ 5.0	$ 7.1	$ 8.1	9.7%
Optoelectronic	$ 2.6	$ 2.8	$ 2.9	$ 4.1	$ 4.6	8.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 38

Estimated North American Civil Aerospace Navigation/Communication
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$663.0	$713.0	$781.0	$970.0	$1,156.0	8.4%
Total Semiconductor	$ 22.3	$ 24.1	$ 26.3	$ 34.5	$ 42.3	9.8%
IC	$ 19.1	$ 20.7	$ 22.7	$ 30.3	$ 37.6	10.4%
Bipolar Digital	5.0	5.0	5.0	5.5	5.9	2.9%
Memory	1.0	0.9	0.9	0.8	0.7	(3.1%)
Logic	4.1	4.1	4 2	4.7	5.2	4.0%
MOS Digital	8.4	9.7	11.1	16.4	21.7	14.3%
Memory	1.9	2.2	2.5	3.7	4.7	13.4%
Microcomponent	3.5	4.0	4.5	7.3	10.3	16.9%
Logic	3.0	3.5	4.1	5.4	6.8	11.8%
Analog	5.6	6.1	6.5	8.4	10.0	8.7%
Discrete	$ 2.5	$ 2.6	$ 2.8	$ 3.2	$ 3.7	6.1%
Optoelectronic	$ 0.8	$ 0.8	$ 0.8	$ 0.9	$ 1.0	4.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 39

Estimated North American Civil Flight Systems Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$1,783.0	$1,892.0	$2,053.0	$2,480.0	$2,893.0	7.3%
Total Semiconductor	$ 55.3	$ 60.2	$ 66.6	$ 90.7	$ 113.4	11.1%
IC	$ 42.6	$ 46.9	$ 52.4	$ 74.4	$ 94.7	12.4%
Bipolar Digital	9.1	9.0	9.2	10.2	11.1	3.4%
Memory	1.0	0.9	0.9	0.8	0.7	(3.1%)
Logic	8.1	8.1	8.3	9.4	10.3	4.0%
MOS Digital	26.0	29.8	34.5	53.0	70.3	15.4%
Memory	6.0	6.6	7.5	11.1	14.0	13.4%
Microcomponent	11.7	13.6	15.8	25.7	35.9	17.5%
Logic	8.3	9.5	11.2	16.2	20.4	13.5%
Analog	7.5	8.1	8.7	11.2	13.3	8.7%
Discrete	$ 11.3	$ 11.9	$ 12.7	$ 14.5	$ 16.6	5.7%
Optoelectronic	$ 1.4	$ 1.5	$ 1.5	$ 1.8	$ 2.1	5.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 40

Estimated North American Civil Simulation
and Training Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$201.0	$216.0	$232.0	$292.0	$333.0	7.5%
Total Semiconductor	$ 21.9	$ 23.7	$ 26.5	$ 37.0	$ 46.4	11.8%
IC	$ 21.5	$ 23.2	$ 26.0	$ 36.4	$ 45.7	12.0%
Bipolar Digital	5.4	5.0	5.0	5.5	5.9	2.9%
Memory	1.0	0.9	0.9	0.8	0.7	(3.1%)
Logic	4.5	4.1	4.2	4.7	5.2	4.0%
MOS Digital	14.9	17.0	19.7	29.2	37.8	14.2%
Memory	8.9	10.0	11.5	16.5	20.7	12.9%
Microcomponent	3.3	3.8	4.5	7.3	10.3	17.8%
Logic	2.8	3.2	3.7	5.4	6.8	13.5%
Analog	1.1	1.2	1.3	1.7	2.0	8.7%
Discrete	$ 0.2	$ 0.3	$ 0.3	$ 0.3	$ 0.4	6.1%
Optoelectronic	$ 0.2	$ 0.2	$ 0.2	$ 0.3	$ 0.3	5.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 41

Estimated Western European Total Military/Aerospace
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$22,126.0	$24,468.0	$25,195.0	$29,688.0	$33,036.0	5.1%
Total Semiconductor	$ 579.9	$ 664.6	$ 724.9	$ 930.5	$ 1,112.9	9.0%
IC	$ 447.7	$ 518.4	$ 572.8	$ 759.5	$ 925.9	10.2%
Bipolar Digital	135.3	144.7	146.0	160.5	172.2	2.9%
Memory	19.5	19.8	18.8	18.1	16.9	(2.6%)
Logic	115.8	124.9	127.2	142.4	155.3	3.7%
MOS Digital	208.5	256.4	298.5	437.8	560.5	13.9%
Memory	66.5	78.2	89.8	135.3	173.6	14.2%
Microcomponent	52.1	65.1	78.8	121.3	160.4	16.2%
Logic	89.9	113.1	129.9	181.2	226.5	12.3%
Analog	103.9	117.3	128.3	161.2	193.2	8.7%
Discrete	$ 113.4	$ 125.3	$ 129.9	$ 145.0	$ 157.0	3.8%
Optoelectronic	$ 18.8	$ 20.9	$ 22.2	$ 26.0	$ 30.0	6.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 42

Estimated Western European Military Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$19,350.0	$21,271.0	$21,729.0	$25,231.0	$27,826.0	4.6%
Total Semiconductor	$ 508.6	$ 579.6	$ 626.9	$ 798.9	$ 953.8	8.7%
IC	$ 392.4	$ 451.7	$ 496.0	$ 650.6	$ 791.6	9.8%
Bipolar Digital	122.5	130.7	131.5	143.8	154.2	2.8%
Memory	18.2	18.4	17.5	16.8	15.7	(2.7%)
Logic	104.3	112.2	114.0	127.0	138.5	3.6%
MOS Digital	178.8	218.7	253.1	367.9	470.9	13.6%
Memory	58.0	67.9	77.7	116.4	149.3	14.0%
Microcomponent	43.9	54.6	65.6	99.8	132.0	15.9%
Logic	76.9	96.2	109.8	151.7	189.6	12.0%
Analog	91.1	102.4	111.4	139.0	166.5	8.4%
Discrete	$ 99.3	$ 109.1	$ 112.7	$ 125.1	$ 135.5	3.7%
Optoelectronic	$ 17.0	$ 18.8	$ 18.2	$ 23.1	$ 26.7	6.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 43

Estimated Western European Military Radar Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$3,041.0	$3,336.0	$3,370.0	$3,747.0	$3,998.0	3.1%
Total Semiconductor	$ 77.2	$ 86.5	$ 91.9	$ 111.1	$ 128.5	6.8%
IC	$ 53.0	$ 59.8	$ 64.2	$ 80.2	$ 94.8	8.0%
Bipolar Digital	22.3	23.8	24.0	26.3	28.1	2.8%
Memory	3.8	3.8	3.6	3.5	3.3	(2.6%)
Logic	18.6	20.0	20.4	22.8	24.8	3.7%
MOS Digital	14.0	17.2	19.9	28.5	36.2	13.2%
Memory	3.4	3.9	4.5	6.8	8.7	14.2%
Microcomponent	2.3	2.9	3.4	5.2	6.9	15.8%
Logic	8.3	10.4	12.0	16.5	20.6	12.1%
Analog	16.7	18.8	20.4	25.5	30.5	8.4%
Discrete	$ 21.4	$ 23.6	$ 24.3	$ 27.0	$ 29.2	3.6%
Optoelectronic	$ 2.8	$ 3.1	$ 3.3	$ 3.9	$ 4.5	6.1%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

System Semiconductor Utilization

Table 44

Estimated Western European Military Sonar Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$692.0	$763.0	$779.0	$886.0	$955.0	3.8%
Total Semiconductor	$ 19.0	$ 21.3	$ 22.5	$ 27.4	$ 32.0	7.0%
IC	$ 13.7	$ 15.5	$ 16.5	$ 20.7	$ 24.6	8.0%
Bipolar Digital	5.4	5.7	5.7	6.2	6.6	2.5%
Memory	0.8	0.9	0.8	0.8	0.7	(2.6%)
Logic	4.5	4.9	4.9	5.4	5.9	3.3%
MOS Digital	4.0	4.9	5.6	7.9	10.1	12.8%
Memory	1.2	1.4	1.6	2.3	3.0	13.1%
Microcomponent	0.6	0.8	0.9	1.5	1.9	16.2%
Logic	2.2	2.7	3.1	4.2	5.2	11.5%
Analog	4.4	4.9	5.3	6.6	7.9	8.5%
Discrete	$ 4.6	$ 5.1	$ 5.2	$ 5.8	$ 6.3	3.6%
Optoelectronic	$ 0.7	$ 0.7	$ 0.8	$ 0.9	$ 1.1	6.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 45

Estimated Western European Missile and Weapon Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$2,935.0	$3,273.0	$3,387.0	$4,115.0	$4,684.0	6.2%
Total Semiconductor	$ 59.0	$ 67.1	$ 72.8	$ 91.7	$ 109.1	8.4%
IC	$ 39.5	$ 45.6	$ 50.5	$ 66.8	$ 82.0	10.3%
Bipolar Digital	8.0	8.5	8.5	9.1	9.7	2.2%
Memory	1.9	1.9	1.8	1.7	1.6	(2.8%)
Logic	6.1	6.6	6.7	7.4	8.1	3.4%
MOS Digital	17.8	21.8	25.4	36.9	47.4	13.8%
Memory	4.3	5.0	5.7	8.7	11.1	14.2%
Microcomponent	5.7	7.0	8.4	12.9	17.0	15.9%
Logic	7.9	9.8	11.2	15.4	19.3	11.9%
Analog	13.7	15.3	16.7	20.8	24.9	8.5%
Discrete	$ 17.5	$ 19.2	$ 19.9	$ 22.0	$ 23.9	3.7%
Optoelectronic	$ 2.0	$ 2.3	$ 2.4	$ 2.8	$ 3.2	6.1%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 46

Estimated Western European Military Space Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$1,375.0	$1,523.0	$1,523.0	$1,825.0	$2,062.0	5.2%
Total Semiconductor	$ 32.3	$ 38.0	$ 42.2	$ 56.2	$ 68.8	10.4%
IC	$ 26.1	$ 31.3	$ 35.2	$ 48.3	$ 60.2	11.6%
Bipolar Digital	3.3	3.6	3.6	4.0	4.3	3.1%
Memory	0.3	0.3	0.3	0.3	0.3	(2.6%)
Logic	3.0	3.3	3.3	3.7	4.0	3.5%
MOS Digital	18.2	22.6	26.0	37.4	47.7	13.3%
Memory	4.0	4.7	5.3	8.0	10.2	13.9%
Microcomponent	3.6	4.5	5.4	8.2	10.9	15.9%
Logic	10.7	13.4	15.3	21.2	26.5	12.0%
Analog	4.5	5.1	5.6	6.9	8.3	8.5%
Discrete	$ 5.3	$ 5.8	$ 6.0	$ 6.7	$ 7.2	3.6%
Optoelectronic	$ 0.8	$ 0.9	$ 1.0	$ 1.1	$ 1.3	6.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 47

Estimated Western European Military Navigation Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$558.0	$607.0	$617.0	$724.0	$806.0	4.8%
Total Semiconductor	$ 14.1	$ 16.3	$ 17.7	$ 22.5	$ 26.9	8.7%
IC	$ 11.5	$ 13.3	$ 14.7	$ 19.0	$ 23.2	9.6%
Bipolar Digital	3.4	3.7	3.7	4.1	4.4	3.0%
Memory	0.4	0.4	0.4	0.4	0.4	(2.6%)
Logic	3.0	3.2	3.3	3.7	4.0	3.7%
MOS Digital	5.5	6.7	7.8	11.1	14.1	13.1%
Memory	1.7	2.0	2.3	3.4	4.3	13.5%
Microcomponent	1.0	1.3	1.6	2.4	3.2	16.2%
Logic	2.7	3.4	3.9	5.3	6.6	11.6%
Analog	2.6	2.9	3.2	3.9	4.6	7.9%
Discrete	$ 2.3	$ 2.5	$ 2.6	$ 2.9	$ 3.1	3.8%
Optoelectronic	$ 0.4	$ 0.4	$ 0.4	$ 0.5	$ 0.6	6.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 48

Estimated Western European Military Communications Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$2,209.0	$2,430.0	$2,498.0	$2,901.0	$3,198.0	4.7%
Total Semiconductor	$ 63.8	$ 72.5	$ 78.5	$ 99.4	$ 118.3	8.5%
IC	$ 48.6	$ 55.8	$ 61.1	$ 79.9	$ 96.9	9.6%
Bipolar Digital	15.1	16.0	16.1	17.6	18.8	2.7%
Memory	2.6	2.6	2.5	2.4	2.2	(2.7%)
Logic	12.5	13.4	13.6	15.2	16.6	3.6%
MOS Digital	19.9	24.4	28.4	41.3	53.0	13.8%
Memory	5.4	6.3	7.3	11.0	14.1	14.2%
Microcomponent	5.6	7.0	8.5	13.0	17.2	16.0%
Logic	8.8	11.0	12.6	17.4	21.7	12.0%
Analog	13.7	15.4	16.7	21.0	25.1	8.5%
Discrete	$ 12.2	$ 13.5	$ 13.9	$ 15.5	$ 16.8	3.8%
Optoelectronic	$ 2.9	$ 3.2	$ 3.4	$ 4.0	$ 4.6	6.1%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 49

Estimated Western European Electronic Warfare Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$1,523.0	$1,680.0	$1,719.0	$1,995.0	$2,179.0	4.4%
Total Semiconductor	$ 39.8	$ 45.4	$ 47.5	$ 62.0	$ 73.8	8.4%
IC	$ 29.3	$ 33.8	$ 37.1	$ 48.5	$ 59.0	9.8%
Bipolar Digital	9.8	10.5	10.6	11.6	12.5	2.9%
Memory	1.1	1.1	1.1	1.0	1.0	(2.6%)
Logic	8.7	9.3	9.5	10.5	11.5	3.5%
MOS Digital	12.3	15.2	17.7	26.0	33.4	14.0%
Memory	2.4	2.8	3.2	4.7	6.1	13.7%
Microcomponent	4.8	5.9	7.1	10.9	14.4	16.0%
Logic	5.2	6.5	7.4	10.3	12.9	12.1%
Analog	7.2	8.0	8.7	11.0	13.1	8.5%
Discrete	$ 9.1	$ 10.1	$ 10.5	$ 11.6	$ 12.6	3.7%
Optoelectronic	$ 1.4	$ 1.6	$ 0	$ 1.9	$ 2.2	6.1%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 50

Estimated Western European Reconnaissance Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$978.0	$1,075.0	$1,101.0	$1,293.0	$1,439.0	5.0%
Total Semiconductor	$ 28.4	$ 32.5	$ 35.2	$ 44.2	$ 52.8	8.4%
IC	$ 22.0	$ 25.5	$ 27.9	$ 36.2	$ 44.0	9.5%
Bipolar Digital	6.6	7.0	7.0	7.7	8.3	2.8%
Memory	0.8	0.8	0.8	0.7	0.7	(2.6%)
Logic	5.8	6.2	6.3	7.0	7.6	3.3%
MOS Digital	9.2	11.4	13.2	19.0	24.3	13.5%
Memory	2.1	2.5	2.8	4.2	5.4	13.6%
Microcomponent	2.6	3.3	3.9	5.9	7.9	15.8%
Logic	4.5	5.7	6.4	8.9	11.1	11.9%
Analog	6.2	7.0	7.7	9.5	11.4	8.4%
Discrete	$ 5.1	$ 5.6	$ 5.8	$ 6.4	$ 6.9	3.4%
Optoelectronic	$ 1.2	$ 1.3	$ 1.4	$ 1.6	$ 1.9	5.8%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 51

Estimated Western European Military Aircraft Systems
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$1,986.0	$2,163.0	$2,198.0	$2,618.0	$2,941.0	5.3%
Total Semiconductor	$ 44.1	$ 50.7	$ 55.4	$ 71.3	$ 86.0	9.2%
IC	$ 33.5	$ 39.1	$ 43.4	$ 58.0	$ 71.4	10.6%
Bipolar Digital	9.8	10.5	10.6	11.6	12.5	3.0%
Memory	0.9	0.9	0.8	0.8	0.7	(2.6%)
Logic	8.9	9.6	9.7	10.8	11.8	3.5%
MOS Digital	18.0	22.1	25.8	37.7	48.4	14.0%
Memory	4.9	5.8	6.6	9.9	12.7	14.0%
Microcomponent	6.1	7.7	9.3	14.2	18.8	16.1%
Logic	6.9	8.7	9.9	13.6	17.0	11.9%
Analog	5.7	6.5	7.1	8.7	10.4	8.3%
Discrete	$ 9.1	$ 10.0	$ 10.3	$ 11.3	$ 12.2	3.5%
Optoelectronic	$ 1.5	$ 1.7	$ 1.8	$ 2.1	$ 2.4	6.1%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 52

Estimated Western European Military Computer Systems
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$590.0	$645.0	$658.0	$786.0	$884.0	5.4%
Total Semiconductor	$ 45.9	$ 52.4	$ 57.2	$ 75.4	$ 91.5	9.7%
IC	$ 44.3	$ 50.7	$ 55.4	$ 73.4	$ 89.3	9.9%
Bipolar Digital	18.1	19.3	19.4	21.1	22.5	2.6%
Memory	3.4	3.4	3.3	3.1	2.9	(2.7%)
Logic	14.7	15.9	16.1	17.9	19.6	3.6%
MOS Digital	23.8	28.6	33.0	48.6	62.4	13.9%
Memory	13.8	16.2	18.5	27.6	35.4	14.0%
Microcomponent	4.2	5.2	6.2	9.6	12.7	16.0%
Logic	5.8	7.2	8.2	11.4	14.3	12.0%
Analog	2.5	2.8	3.1	3.7	4.4	7.9%
Discrete	$ 0.9	$ 1.0	$ 1.0	$ 1.2	$ 1.3	3.8%
Optoelectronic	$ 0.6	$ 0.7	$ 0.7	$ 0.8	$ 1.0	6.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 53

Estimated Western European Military Simulation and Training Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$263.0	$291.0	$300.0	$373.0	$429.0	6.7%
Total Semiconductor	$ 22.0	$ 25.4	$ 28.2	$ 38.5	$ 47.4	10.9%
IC	$ 21.3	$ 24.6	$ 27.3	$ 37.5	$ 46.3	11.1%
Bipolar Digital	5.8	6.2	6.1	6.6	7.1	2.4%
Memory	1.0	1.0	1.0	0.9	0.9	(2.6%)
Logic	4.7	5.1	5.2	5.7	6.2	3.3%
MOS Digital	13.4	16.1	18.6	27.6	35.3	14.0%
Memory	9.7	11.4	13.1	19.8	25.3	14.2%
Microcomponent	1.0	1.3	1.6	2.4	3.2	16.2%
Logic	2.7	3.4	3.9	5.4	6.8	12.3%
Analog	2.1	2.3	2.6	3.2	3.9	8.7%
Discrete	$ 0.6	$ 0.6	$ 0.6	$ 0.7	$ 0.8	3.8%
Optoelectronic	$ 0.2	$ 0.2	$ 0.2	$ 0.3	$ 0.3	6.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 54

Estimated Western European Military Miscellaneous Equipment
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$3,200.0	$3,485.0	$3,579.0	$3,968.0	$4,251.0	3.4%
Total Semiconductor	$ 63.1	$ 71.6	$ 78.0	$ 99.2	$ 118.7	8.8%
IC	$ 49.5	$ 56.8	$ 62.6	$ 82.0	$ 99.8	9.9%
Bipolar Digital	15.0	15.9	16.2	17.9	19.4	3.4%
Memory	1.2	1.3	1.2	1.1	1.1	(2.7%)
Logic	13.7	14.6	15.0	16.8	18.3	3.8%
MOS Digital	22.7	27.5	31.9	45.8	58.6	13.4%
Memory	5.0	5.8	6.7	10.1	13.0	14.3%
Microcomponent	6.4	7.7	9.1	13.6	18.0	15.2%
Logic	11.3	14.0	16.0	22.1	27.6	12.0%
Analog	11.9	13.4	14.5	18.2	21.8	8.5%
Discrete	$ 11.2	$ 12.2	$ 12.6	$ 14.1	$ 15.2	3.8%
Optoelectronic	$ 2.4	$ 2.6	$ 2.8	$ 3.2	$ 3.7	5.7%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 55

Estimated Western European Total Civil Aerospace
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$2,776.0	$3,197.0	$3,466.0	$4,457.0	$5,210.0	8.5%
Total Semiconductor	$ 71.4	$ 85.1	$ 96.4	$ 131.8	$ 159.4	11.0%
IC	$ 55.4	$ 66.8	$ 76.9	$ 109.1	$ 134.5	12.4%
Bipolar Digital	12.8	14.1	14.6	16.7	18.0	4.2%
Memory	1.3	1.4	1.3	1.3	1.2	(1.9%)
Logic	11.5	12.7	13.3	15.4	16.8	4.7%
MOS Digital	29.7	37.8	45.5	70.1	89.8	15.5%
Memory	8.5	10.3	12.1	19.0	24.4	15.4%
Microcomponent	8.1	10.6	13.3	21.5	28.4	17.9%
Logic	13.0	16.9	20.1	29.6	37.0	13.9%
Analog	12.8	14.9	16.8	22.3	26.7	10.2%
Discrete	$ 14.2	$ 16.1	$ 17.2	$ 19.9	$ 21.6	5.0%
Optoelectronic	$ 1.8	$ 2.1	$ 2.3	$ 2.9	$ 3.3	7.8%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 56

Estimated Western European Civil Aerospace Radar
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$786.0	$884.0	$924.0	$1,094.0	$1,225.0	5.6%
Total Semiconductor	$ 19.6	$ 22.2	$ 23.8	$ 29.2	$ 34.0	7.4%
IC	$ 13.5	$ 15.4	$ 16.7	$ 21.3	$ 25.4	8.7%
Bipolar Digital	5.0	5.4	5.5	6.0	6.5	3.0%
Memory	0.6	0.7	0.6	0.6	0.6	(2.6%)
Logic	4.4	4.7	4.8	5.4	5.9	3.7%
MOS Digital	4.3	5.3	6.2	8.9	11.2	13.2%
Memory	1.0	1.2	1.3	2.0	2.6	14.2%
Microcomponent	0.5	0.7	0.8	1.2	1.6	16.2%
Logic	2.8	3.5	4.0	5.6	7.0	12.3%
Analog	4.2	4.7	5.1	6.4	7.7	8.7%
Discrete	$ 5.7	$ 6.3	$ 6.5	$ 7.3	$ 7.9	3.8%
Optoelectronic	$ 0.5	$ 0.5	$ 0.6	$ 0.7	$ 0.8	6.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 57

Estimated Western European Civil Space Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$811.0	$940.0	$1,038.0	$1,382.0	$1,672.0	10.1%
Total Semiconductor	$ 17.8	$ 21.9	$ 25.5	$ 37.0	$ 45.1	12.8%
IC	$ 15.0	$ 18.7	$ 21.9	$ 32.6	$ 40.3	13.7%
Bipolar Digital	2.0	2.3	2.4	3.0	3.2	5.9%
Memory	0.1	0.1	0.1	0.1	0.1	(0.4%)
Logic	1.9	2.2	2.3	2.9	3.1	6.1%
MOS Digital	8.5	11.0	13.4	21.2	26.9	16.1%
Memory	1.6	2.0	2.4	4.0	5.1	16.8%
Microcomponent	1.7	2.2	2.8	4.6	6.1	18.9%
Logic	5.2	6.8	8.2	12.6	15.7	14.8%
Analog	4.5	5.4	6.1	8.4	10.1	11.2%
Discrete	$ 2.1	$ 2.4	$ 2.6	$ 3.2	$ 3.5	6.2%
Optoelectronic	$ 0.7	$ 0.8	$ 0.9	$ 1.2	$ 1.4	8.6%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 58

Estimated Western European Civil Aerospace Navigation/Communication Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$283.0	$332.0	$363.0	$479.0	$571.0	9.5%
Total Semiconductor	$ 7.3	$ 8.8	$ 10.2	$ 14.4	$ 17.4	11.9%
IC	$ 5.9	$ 7.2	$ 8.4	$ 12.3	$ 15.0	13.0%
Bipolar Digital	1.5	1.7	1.8	2.2	2.3	5.2%
Memory	0.2	0.2	0.2	0.2	0.2	(0.5%)
Logic	1.3	1.5	1.6	2.0	2.1	5.9%
MOS Digital	2.8	3.6	4.4	7.0	9.1	16.8%
Memory	0.6	0.8	0.9	1.5	2.0	16.7%
Microcomponent	1.1	1.4	1.8	3.0	4.0	18.7%
Logic	1.0	1.4	1.6	2.5	3.1	14.7%
Analog	1.6	1.9	2.2	3.0	3.6	11.0%
Discrete	$ 1.2	$ 1.4	$ 1.5	$ 1.8	$ 2.0	6.1%
Optoelectronic	$ 0.2	$ 0.2	$ 0.3	$ 0.3	$ 0.4	8.5%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 59

Estimated Western European Civil Flight Systems
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$819.0	$951.0	$1,042.0	$1,368.0	$1,581.0	8.8%
Total Semiconductor	$ 19.7	$ 24.0	$ 27.8	$ 38.4	$ 46.8	11.8%
IC	$ 14.2	$ 17.6	$ 20.9	$ 30.3	$ 38.0	13.7%
Bipolar Digital	2.8	3.1	3.3	3.8	4.1	4.8%
Memory	0.2	0.2	0.2	0.2	0.2	(1.2%)
Logic	2.6	2.9	3.1	3.6	3.9	5.2%
MOS Digital	9.2	11.9	14.6	22.7	29.3	16.1%
Memory	2.4	2.9	3.5	5.5	7.1	15.9%
Microcomponent	3.8	5.0	6.3	10.2	13.5	17.9%
Logic	3.0	4.0	4.8	7.0	8.7	13.9%
Analog	2.2	2.6	3.0	3.9	4.6	10.3%
Discrete	$ 5.1	$ 5.9	$ 6.4	$ 7.5	$ 8.1	5.3%
Optoelectronic	$ 0.4	$ 0.5	$ 0.5	$ 0.6	$ 0.7	7.8%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 60

Estimated Western European Civil Simulation and Training
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$77.0	$90.0	$99.0	$134.0	$161.0	10.2%
Total Semiconductor	$ 6.9	$ 8.1	$ 9.1	$ 12.8	$ 16.0	12.1%
IC	$ 6.7	$ 7.9	$ 8.9	$ 12.6	$ 15.8	12.2%
Bipolar Digital	1.5	1.6	1.6	1.7	1.9	3.0%
Memory	0.2	0.2	0.2	0.2	0.2	(2.6%)
Logic	1.3	1.4	1.4	1.6	1.7	3.7%
MOS Digital	5.0	6.0	7.0	10.4	13.3	14.3%
Memory	2.9	3.4	4.0	6.0	7.6	14.2%
Microcomponent	1.0	1.3	1.6	2.4	3.2	16.2%
Logic	1.0	1.2	1.4	2.0	2.5	12.3%
Analog	0.3	0.4	0.4	0.5	0.6	8.7%
Discrete	$ 0.1	$ 0.1	$ 0.1	$ 0.1	$ 0.2	3.8%
Optoelectronic	$ 0.1	$ 0.1	$ 0.1	$ 0.1	$ 0.1	6.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 61

Estimated Rest of World Total Military/Aerospace
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$4,050.0	$4,440.0	$4,876.0	$6,425.0	$7,705.0	9.6%
Total Semiconductor	$ 137.6	$ 156.0	$ 177.4	$ 246.4	$ 308.8	12.1%
IC	$ 113.6	$ 129.8	$ 148.8	$ 210.6	$ 267.0	12.8%
Bipolar Digital	35.8	38.7	41.8	51.4	60.1	7.6%
Memory	6.9	6.7	6.6	6.2	5.9	(2.1%)
Logic	28.9	32.0	35.2	45.2	54.2	9.2%
MOS Digital	46.6	56.0	68.0	107.4	145.0	17.2%
Memory	20.4	24.2	29.9	45.1	59.0	16.0%
Microcomponent	7.8	9.7	11.8	18.9	26.0	17.9%
Logic	18.4	22.1	26.3	43.4	60.0	18.1%
Analog	31.2	35.1	39.0	51.8	61.9	9.9%
Discrete	$ 20.7	$ 22.5	$ 24.4	$ 30.5	$ 35.5	7.9%
Optoelectronic	$ 3.3	$ 3.7	$ 4.2	$ 5.3	$ 6.3	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 62

Estimated Rest of World Military Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$3,018.0	$3,285.0	$3,581.0	$4,626.0	$5,465.0	8.9%
Total Semiconductor	$ 106.7	$ 120.1	$ 136.5	$ 189.1	$ 235.5	11.9%
IC	$ 88.2	$ 100.1	$ 114.6	$ 161.7	$ 203.6	12.6%
Bipolar Digital	28.9	31.1	33.6	41.2	48.0	7.5%
Memory	5.8	5.6	5.5	5.2	4.9	(2.1%)
Logic	23.1	25.5	28.1	36.0	43.1	9.1%
MOS Digital	35.6	42.4	51.5	81.3	108.9	17.0%
Memory	15.9	18.6	23.0	34.7	45.0	15.8%
Microcomponent	6.1	7.5	9.1	14.6	20.0	17.8%
Logic	13.7	16.3	19.4	32.0	43.9	18.0%
Analog	23.7	26.6	29.5	39.2	46.7	9.9%
Discrete	$ 15.9	$ 17.2	$ 18.7	$ 23.3	$ 27.1	7.9%
Optoelectronic	$ 2.5	$ 2.8	$ 3.2	$ 4.0	$ 4.8	9.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 63

Estimated Rest of World Military Radar Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$463.0	$495.0	$530.0	$646.0	$738.0	6.9%
Total Semiconductor	$ 16.5	$ 18.4	$ 20.5	$ 27.3	$ 33.3	10.4%
IC	$ 12.6	$ 14.2	$ 15.9	$ 21.6	$ 26.6	11.1%
Bipolar Digital	5.3	5.7	6.2	7.5	8.8	7.3%
Memory	1.2	1.2	1.1	1.1	1.0	(2.1%)
Logic	4.1	4.6	5.0	6.5	7.8	9.2%
MOS Digital	2.9	3.5	4.3	6.8	9.3	17.3%
Memory	1.1	1.3	1.6	2.3	3.1	16.0%
Microcomponent	0.5	0.6	0.8	1.3	1.7	17.9%
Logic	1.4	1.6	1.9	3.2	4.4	18.1%
Analog	4.3	4.9	5.4	7.2	8.6	9.9%
Discrete	$ 3.4	$ 3.7	$ 4.0	$ 5.0	$ 5.8	7.9%
Optoelectronic	$ 0.5	$ 0.5	$ 0.6	$ 0.7	$ 0.9	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 64

Estimated Rest of World Military Sonar
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$104.0	$113.0	$123.0	$157.0	$184.0	8.5%
Total Semiconductor	$ 4.0	$ 4.4	$ 5.0	$ 6.8	$ 8.4	11.2%
IC	$ 3.2	$ 3.6	$ 4.1	$ 5.6	$ 7.1	11.9%
Bipolar Digital	1.1	1.2	1.3	1.6	1.9	7.5%
Memory	0.2	0.2	0.2	0.2	0.2	(2.1%)
Logic	0.9	1.0	1.1	1.4	1.7	9.2%
MOS Digital	1.0	1.2	1.5	2.3	3.1	17.2%
Memory	0.4	0.5	0.7	1.0	1.3	16.0%
Microcomponent	0.2	0.2	0.2	0.4	0.5	17.9%
Logic	0.4	0.5	0.6	1.0	1.3	18.1%
Analog	1.0	1.2	1.3	1.7	2.0	9.9%
Discrete	$ 0.7	$ 0.7	$ 0.8	$ 1.0	$ 1.2	7.9%
Optoelectronic	$ 0.1	$ 0.1	$ 0.1	$ 0.2	$ 0.2	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 65

Estimated Rest of World Missile and Weapon Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$477.0	$521.0	$569.0	$741.0	$884.0	9.2%
Total Semiconductor	$ 12.4	$ 14.0	$ 15.8	$ 21.6	$ 26.8	11.4%
IC	$ 9.3	$ 10.6	$ 12.1	$ 17.0	$ 21.5	12.4%
Bipolar Digital	2.3	2.5	2.7	3.2	3.7	6.9%
Memory	0.6	0.6	0.6	0.6	0.5	(2.1%)
Logic	1.7	1.9	2.1	2.7	3.2	9.2%
MOS Digital	3.3	4.0	4.9	7.7	10.4	17.3%
Memory	1.3	1.5	1.9	2.8	3.7	16.0%
Microcomponent	0.7	0.8	1.0	1.6	2.2	17.9%
Logic	1.4	1.7	2.0	3.3	4.6	18.1%
Analog	3.7	4.1	4.6	6.1	7.3	9.9%
Discrete	$ 2.7	$ 2.9	$ 3.2	$ 4.0	$ 4.7	7.9%
Optoelectronic	$ 0.3	$ 0.4	$ 0.4	$ 0.6	$ 0.7	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 66

Estimated Rest of World Military Space Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$266.0	$289.0	$315.0	$404.0	$478.0	8.7%
Total Semiconductor	$ 6.6	$ 7.2	$ 8.4	$ 12.3	$ 15.4	13.4%
IC	$ 5.5	$ 6.1	$ 7.2	$ 10.8	$ 13.7	14.3%
Bipolar Digital	0.6	0.6	0.7	0.8	0.9	6.6%
Memory	0.2	0.1	0.1	0.1	0.1	(2.6%)
Logic	0.5	0.5	0.5	0.7	0.8	8.6%
MOS Digital	3.6	4.1	5.0	7.9	10.4	16.8%
Memory	1.2	1.3	1.6	2.5	3.1	15.4%
Microcomponent	0.5	0.6	0.7	1.2	1.6	17.2%
Logic	1.9	2.2	2.6	4.3	5.7	17.5%
Analog	1.3	1.4	1.5	2.1	2.4	9.3%
Discrete	$ 0.9	$ 1.0	$ 1.0	$ 1.3	$ 1.5	7.3%
Optoelectronic	$ 0.1	$ 0.1	$ 0.2	$ 0.2	$ 0.2	8.7%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 67

Estimated Rest of World Military Navigation Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$88.0	$98.0	$109.0	$149.0	$183.0	11.0%
Total Semiconductor	$ 2.9	$ 3.3	$ 3.8	$ 5.3	$ 6.6	12.3%
IC	$ 2.4	$ 2.8	$ 3.2	$ 4.5	$ 5.8	13.1%
Bipolar Digital	0.7	0.7	0.8	1.0	1.1	7.8%
Memory	0.1	0.1	0.1	0.1	0.1	(2.1%)
Logic	0.5	0.6	0.7	0.9	1.0	9.2%
MOS Digital	1.0	1.2	1.5	2.4	3.2	17.3%
Memory	0.4	0.5	0.6	0.9	1.2	16.0%
Microcomponent	0.2	0.2	0.3	0.5	0.7	17.9%
Logic	0.4	0.5	0.6	1.0	1.4	18.1%
Analog	0.7	0.8	0.9	1.2	1.4	9.9%
Discrete	$ 0.4	$ 0.5	$ 0.5	$ 0.6	$ 0.7	7.9%
Optoelectronic	$ 0.1	$ 0.1	$ 0.1	$ 0.1	$ 0.1	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 68

Estimated Rest of World Military Communications Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$344.0	$382.0	$424.0	$580.0	$695.0	10.5%
Total Semiconductor	$ 12.4	$ 14.0	$ 15.8	$ 21.8	$ 27.1	11.7%
IC	$ 10.2	$ 11.6	$ 13.2	$ 18.5	$ 23.3	12.3%
Bipolar Digital	3.7	4.0	4.3	5.3	6.2	7.8%
Memory	0.6	0.6	0.6	0.6	0.5	(2.1%)
Logic	3.0	3.4	3.7	4.7	5.7	9.2%
MOS Digital	3.6	4.4	5.3	8.4	11.3	17.3%
Memory	1.4	1.7	2.1	3.2	4.2	16.0%
Microcomponent	0.7	0.9	1.1	1.8	2.5	17.9%
Logic	1.4	1.7	2.1	3.4	4.7	18.1%
Analog	2.9	3.2	3.6	4.8	5.7	9.9%
Discrete	$ 1.9	$ 2.0	$ 2.2	$ 2.7	$ 3.2	7.9%
Optoelectronic	$ 0.3	$ 0.4	$ 0.4	$ 0.6	$ 0.7	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 69

Estimated Rest of World Electronic Warfare Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$237.0	$262.0	$290.0	$391.0	$476.0	10.5%
Total Semiconductor	$ 7.4	$ 8.3	$ 9.4	$ 12.9	$ 16.1	11.6%
IC	$ 5.9	$ 6.8	$ 7.7	$ 10.8	$ 13.6	12.3%
Bipolar Digital	2.1	2.3	2.5	3.0	3.6	7.7%
Memory	0.4	0.4	0.4	0.3	0.3	(2.1%)
Logic	1.7	1.9	2.1	2.7	3.3	9.2%
MOS Digital	2.0	2.4	3.0	4.7	6.4	17.4%
Memory	0.7	0.8	1.0	1.5	1.9	16.0%
Microcomponent	0.5	0.6	0.8	1.2	1.7	17.9%
Logic	0.8	1.0	1.2	2.0	2.8	18.1%
Analog	1.8	2.0	2.3	3.0	3.6	9.9%
Discrete	$ 1.2	$ 1.4	$ 1.5	$ 1.8	$ 2.1	7.9%
Optoelectronic	$ 0.2	$ 0.2	$ 0.3	$ 0.3	$ 0.4	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 70

Estimated Rest of World Reconnaissance Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$114.0	$126.0	$138.0	$184.0	$218.0	9.6%
Total Semiconductor	$ 4.3	$ 4.9	$ 5.6	$ 7.7	$ 9.6	12.0%
IC	$ 3.5	$ 4.0	$ 4.6	$ 6.5	$ 8.3	12.8%
Bipolar Digital	1.1	1.2	1.3	1.6	1.8	7.7%
Memory	0.2	0.2	0.2	0.2	0.2	(2.1%)
Logic	0.9	1.0	1.1	1.4	1.7	9.2%
MOS Digital	1.4	1.7	2.0	3.2	4.4	17.3%
Memory	0.6	0.7	0.8	1.2	1.6	16.0%
Microcomponent	0.3	0.3	0.4	0.7	0.9	17.9%
Logic	0.6	0.7	0.8	1.3	1.9	18.1%
Analog	1.0	1.2	1.3	1.7	2.0	9.9%
Discrete	$ 0.7	$ 0.7	$ 0.8	$ 1.0	$ 1.2	7.9%
Optoelectronic	$ 0.1	$ 0.1	$ 0.1	$ 0.2	$ 0.2	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 71

Estimated Rest of World Military Aircraft Systems Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$310.0	$339.0	$372.0	$488.0	$581.0	9.4%
Total Semiconductor	$ 10.0	$ 11.3	$ 12.9	$ 18.0	$ 22.6	12.2%
IC	$ 8.3	$ 9.5	$ 10.9	$ 15.4	$ 19.6	12.9%
Bipolar Digital	2.5	2.8	3.0	3.7	4.3	7.8%
Memory	0.4	0.4	0.4	0.4	0.4	(2.1%)
Logic	2.1	2.3	2.6	3.3	4.0	9.2%
MOS Digital	3.4	4.1	5.0	7.9	10.7	17.3%
Memory	1.3	1.5	1.9	2.8	3.7	16.0%
Microcomponent	0.7	0.9	1.1	1.7	2.3	17.9%
Logic	1.4	1.7	2.0	3.3	4.6	18.1%
Analog	2.3	2.6	2.9	3.9	4.6	9.9%
Discrete	$ 1.4	$ 1.6	$ 1.7	$ 2.1	$ 2.5	7.9%
Optoelectronic	$ 0.2	$ 0.3	$ 0.3	$ 0.4	$ 0.5	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 72

Estimated Rest of World Military Computer Systems Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$91.0	$101.0	$114.0	$160.0	$200.0	11.9%
Total Semiconductor	$10.2	$ 11.7	$ 13.5	$ 19.2	$ 24.5	13.1%
IC	$ 9.8	$ 11.3	$ 13.1	$ 18.7	$ 23.8	13.3%
Bipolar Digital	3.7	4.0	4.3	5.2	6.1	7.5%
Memory	0.8	0.7	0.7	0.7	0.6	(2.1%)
Logic	2.9	3.2	3.5	4.5	5.4	9.2%
MOS Digital	5.1	6.1	7.5	11.7	15.7	16.9%
Memory	3.0	3.6	4.4	6.7	8.8	16.0%
Microcomponent	0.7	0.9	1.1	1.8	2.3	17.9%
Logic	1.4	1.7	2.0	3.3	4.6	18.1%
Analog	1.0	1.2	1.3	1.7	2.1	9.9%
Discrete	$ 0.2	$ 0.3	$ 0.3	$ 0.4	$ 0.4	7.9%
Optoelectronic	$ 0.1	$ 0.1	$ 0.1	$ 0.2	$ 0.2	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 73

Estimated Rest of World Military Simulation and Training
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$39.0	$43.0	$47.0	$62.0	$75.0	9.7%
Total Semiconductor	$ 4.6	$ 5.0	$ 5.9	$ 8.5	$10.3	12.7%
IC	$ 4.5	$ 4.9	$ 5.8	$ 8.3	$10.1	12.8%
Bipolar Digital	1.3	1.3	1.4	1.7	1.9	6.5%
Memory	0.3	0.2	0.2	0.2	0.2	(3.0%)
Logic	1.0	1.1	1.2	1.5	1.7	8.1%
MOS Digital	2.9	3.2	4.0	6.1	7.6	15.3%
Memory	2.3	2.6	3.2	4.8	6.0	14.9%
Microcomponent	0.2	0.2	0.2	0.4	0.5	16.7%
Logic	0.4	0.4	0.5	0.9	1.1	17.0%
Analog	0.3	0.4	0.4	0.5	0.6	8.9%
Discrete	$ 0.1	$ 0.1	$ 0.1	$ 0.1	$ 0.1	6.9%
Optoelectronic	$ 0.0	$ 0.0	$ 0.0	$ 0.0	$ 0.1	8.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 74

Estimated Rest of World Military Miscellaneous Equipment
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$485.0	$516.0	$550.0	$664.0	$753.0	6.5%
Total Semiconductor	$ 15.5	$ 17.6	$ 20.0	$ 27.7	$ 34.8	12.1%
IC	$ 13.0	$ 14.8	$ 17.0	$ 24.0	$ 30.4	12.7%
Bipolar Digital	4.5	4.9	5.3	6.5	7.6	7.7%
Memory	0.8	0.8	0.8	0.8	0.7	(2.1%)
Logic	3.7	4.1	4.5	5.7	6.9	9.2%
MOS Digital	5.3	6.4	7.7	12.2	16.5	17.2%
Memory	2.2	2.7	3.3	5.0	6.5	16.0%
Microcomponent	0.9	1.2	1.4	2.3	3.1	17.9%
Logic	2.1	2.5	3.0	5.0	6.9	18.1%
Analog	3.2	3.6	4.0	5.3	6.3	9.9%
Discrete	$ 2.2	$ 2.3	$ 2.5	$ 3.2	$ 3.7	7.9%
Optoelectronic	$ 0.4	$ 0.4	$ 0.5	$ 0.6	$ 0.7	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 75

Estimated Rest of World Total Civil Aerospace Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$1,032.0	$1,155.0	$1,295.0	$1,799.0	$2,240.0	11.7%
Total Semiconductor	$ 31.0	$ 35.9	$ 41.0	$ 57.4	$ 73.3	12.6%
IC	$ 25.4	$ 29.7	$ 34.2	$ 48.9	$ 63.4	13.5%
Bipolar Digital	6.9	7.6	8.2	10.2	12.1	8.2%
Memory	1.1	1.1	1.1	1.0	1.0	(1.8%)
Logic	5.8	6.5	7.1	9.2	11.2	9.4%
MOS Digital	11.0	13.6	16.5	26.1	36.1	17.7%
Memory	4.5	5.6	6.9	10.4	14.0	16.6%
Microcomponent	1.7	2.2	2.7	4.3	6.0	18.1%
Logic	4.7	5.8	6.9	11.5	16.1	18.4%
Analog	7.5	8.6	9.5	12.6	15.2	10.1%
Discrete	$ 4.8	$ 5.3	$ 5.8	$ 7.2	$ 8.4	8.0%
Optoelectronic	$ 0.8	$ 0.9	$ 1.0	$ 1.3	$ 1.5	9.4%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 76

Estimated Rest of World Civil Aerospace Radar Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$331.0	$368.0	$408.0	$559.0	$688.0	11.0%
Total Semiconductor	$ 11.7	$ 13.1	$ 14.7	$ 19.8	$ 24.4	11.0%
IC	$ 9.1	$ 10.3	$ 11.6	$ 16.0	$ 19.9	11.7%
Bipolar Digital	3.8	4.2	4.5	5.6	6.5	7.8%
Memory	0.7	0.6	0.6	0.6	0.6	(2.1%)
Logic	3.2	3.5	3.9	5.0	6.0	9.2%
MOS Digital	2.6	3.1	3.7	5.9	8.1	17.4%
Memory	0.8	1.0	1.2	1.8	2.4	16.0%
Microcomponent	0.3	0.4	0.5	0.8	1.1	17.9%
Logic	1.4	1.7	2.0	3.3	4.6	18.1%
Analog	2.7	3.0	3.4	4.5	5.3	9.9%
Discrete	$ 2.3	$ 2.5	$ 2.7	$ 3.4	$ 3.9	7.9%
Optoelectronic	$ 0.3	$ 0.3	$ 0.4	$ 0.5	$ 0.6	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 77

Estimated Rest of World Civil Space Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$465.0	$528.0	$599.0	$856.0	$1,085.0	12.8%
Total Semiconductor	$ 11.3	$ 13.8	$ 15.9	$ 22.8	$ 30.4	14.1%
IC	$ 9.6	$ 11.9	$ 13.8	$ 20.2	$ 27.3	14.9%
Bipolar Digital	1.3	1.5	1.7	2.1	2.7	9.5%
Memory	0.2	0.2	0.2	0.2	0.2	(0.2%)
Logic	1.1	1.3	1.5	1.9	2.5	10.6%
MOS Digital	4.9	6.4	7.8	12.3	17.6	18.3%
Memory	2.0	2.6	3.2	4.9	6.9	17.6%
Microcomponent	0.8	1.0	1.2	2.0	2.8	18.6%
Logic	2.2	2.8	3.3	5.5	7.9	18.9%
Analog	3.4	3.9	4.4	5.8	7.1	10.2%
Discrete	$ 1.3	$ 1.5	$ 1.7	$ 2.1	$ 2.4	8.2%
Optoelectronic	$ 0.3	$ 0.4	$ 0.4	$ 0.5	$ 0.6	9.6%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 78

Estimated Rest of World Civil Aerospace Navigation/Communication
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$46.0	$50.0	$56.0	$73.0	$87.0	9.7%
Total Semiconductor	$ 1.5	$ 1.8	$ 2.0	$ 2.8	$ 3.5	12.3%
IC	$ 1.3	$ 1.5	$ 1.7	$ 2.4	$ 3.1	13.0%
Bipolar Digital	0.4	0.4	0.5	0.6	0.7	7.6%
Memory	0.1	0.1	0.1	0.1	0.1	(2.1%)
Logic	0.3	0.4	0.4	0.5	0.6	9.2%
MOS Digital	0.6	0.7	0.8	1.3	1.8	17.2%
Memory	0.2	0.3	0.3	0.5	0.6	16.0%
Microcomponent	0.2	0.2	0.2	0.4	0.5	17.9%
Logic	0.2	0.2	0.3	0.4	0.6	18.1%
Analog	0.3	0.4	0.4	0.6	0.7	9.9%
Discrete	$ 0.2	$ 0.2	$ 0.2	$ 0.3	$ 0.4	7.9%
Optoelectronic	$ 0.0	$ 0.0	$ 0.0	$ 0.1	$ 0.1	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 79

Estimated Rest of World Civil Flight Systems
Semiconductor Consumption
(Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$176.0	$194.0	$215.0	$289.0	$353.0	10.5%
Total Semiconductor	$ 4.8	$ 5.5	$ 6.3	$ 8.9	$ 11.3	12.6%
IC	$ 3.8	$ 4.4	$ 5.1	$ 7.3	$ 9.4	13.6%
Bipolar Digital	1.0	1.1	1.1	1.4	1.7	8.4%
Memory	0.1	0.1	0.1	0.1	0.1	(2.1%)
Logic	0.9	1.0	1.1	1.4	1.6	9.2%
MOS Digital	1.8	2.2	2.7	4.2	5.7	17.3%
Memory	0.7	0.8	1.0	1.6	2.1	16.0%
Microcomponent	0.3	0.4	0.5	0.8	1.1	17.9%
Logic	0.8	0.9	1.1	1.8	2.5	18.1%
Analog	1.0	1.1	1.2	1.7	2.0	9.9%
Discrete	$ 1.0	$ 1.0	$ 1.1	$ 1.4	$ 1.6	7.9%
Optoelectronic	$ 0.1	$ 0.1	$ 0.1	$ 0.2	$ 0.2	9.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 80

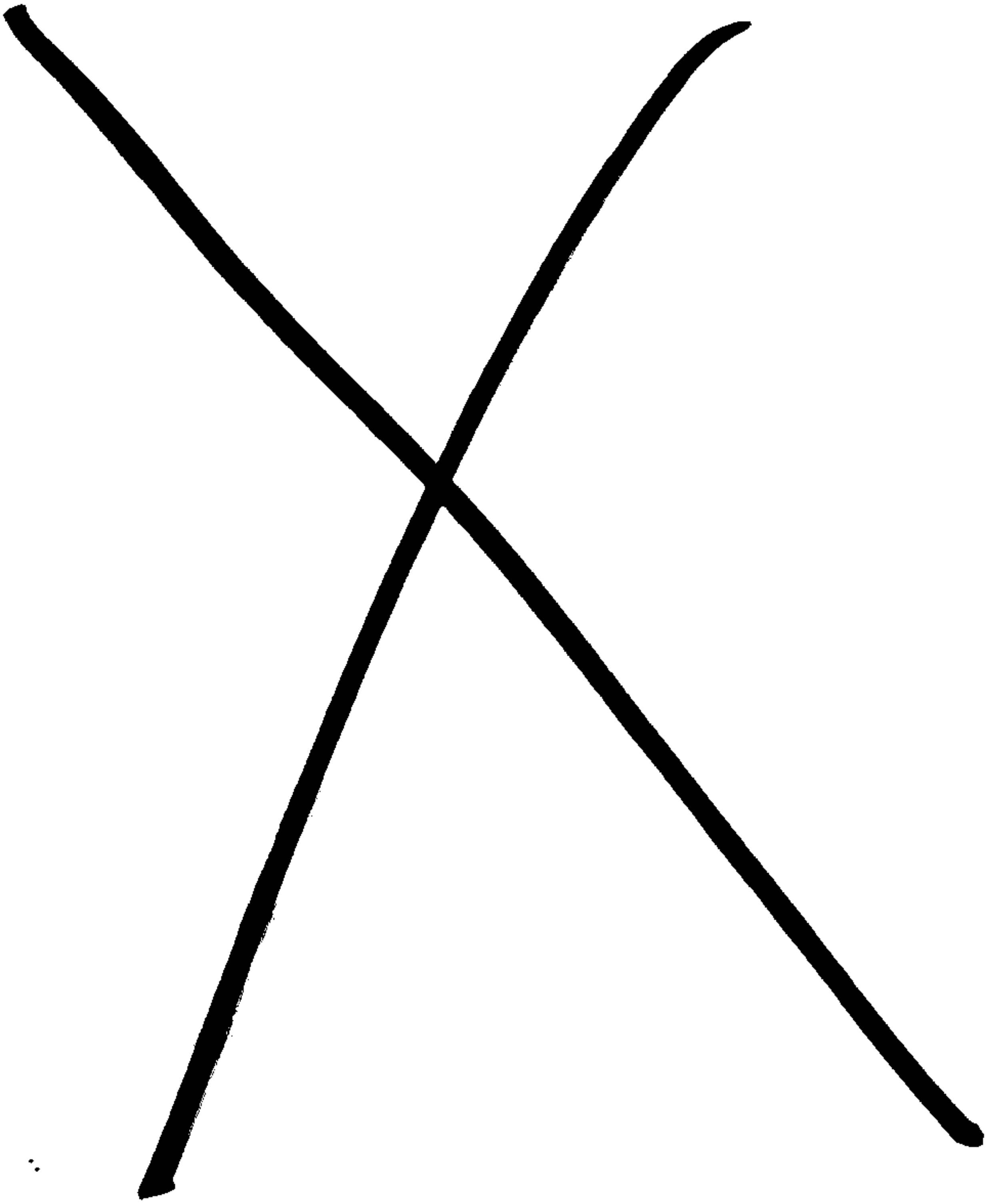
Estimated Rest of World Civil Simulation and Training Semiconductor Consumption (Millions of Dollars)

	1987	1988	1989	1992	1994	CAGR 1988-1994
Equipment Production	$14.0	$15.0	$17.0	$22.0	$27.0	10.3%
Total Semiconductor	$ 1.6	$ 1.7	$ 2.1	$ 3.0	$ 3.7	13.4%
IC	$ 1.6	$ 1.7	$ 2.0	$ 3.0	$ 3.7	13.5%
Bipolar Digital	0.4	0.4	0.4	0.5	0.6	6.7%
Memory	0.1	0.1	0.1	0.1	0.1	(3.0%)
Logic	0.3	0.3	0.3	0.4	0.5	8.1%
MOS Digital	1.1	1.2	1.5	2.4	3.0	15.5%
Memory	0.8	0.9	1.1	1.6	2.0	14.9%
Microcomponent	0.1	0.2	0.2	0.3	0.4	16.7%
Logic	0.2	0.2	0.2	0.4	0.5	17.0%
Analog	0.1	0.1	0.1	0.1	0.2	8.9%
Discrete	0	0	0	0	0	6.9%
Optoelectronic	0	0	0	0	0	8.2%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August



Semiconductor Procurement

The following is a list of material in this section

- Life Cycle and Obsolescence Analysis
- Quality and Reliability
- Military Semiconductor Pricing

NOTE: The arrow symbol indicates the latest document(s) correct location behind this subject tab.

Life Cycle and Obsolescence Analysis

OVERVIEW

In general, the life cycles of military/aerospace hi-rel semiconductor products are derived from their overall commercial life cycles. We define life cycle here as meaning the period over which the product (die) is fabricated. Most often, hi-rel versions (ceramic package, MIL-STD-883 class B compliant) are released three months to two years after commercial introduction. The exact time depends upon the supplier's ability and the market demand for hi-rel versions of the subject product. JAN or CECC approvals can take 18 to 24 months more.

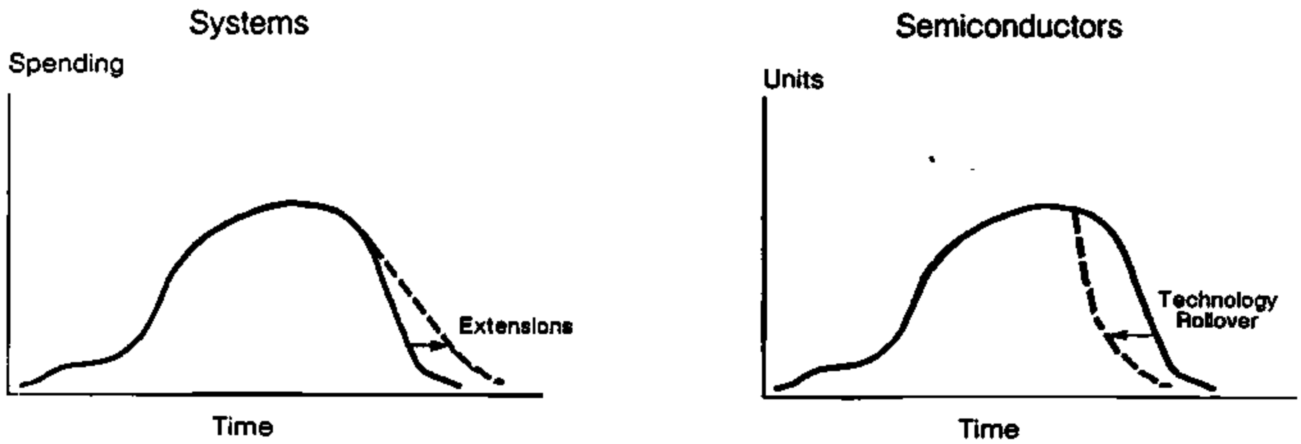
LIFE CYCLE MISMATCH

Perhaps the most chronic issue facing the buyers of semiconductors for military and aerospace electronic equipment is the problem of obsolescent parts or diminishing manufacturing sources (DMS). As depicted in Figure 1, military/aerospace system life cycles can last 20 to 25 years (e.g., airframe). The trend for system life cycles is getting longer as shrinking defense budgets are forcing extended use of existing systems. This trend impacts the need for additional and replacement components (for spares and maintenance).

Conversely, rapid semiconductor technology turnover as demanded by world markets and competition is forcing semiconductor life cycles to shorten to as little as seven years. The result is that there can be a 10- to 15-year gap between the life cycle of the semiconductor and the life cycle of the system into which the semiconductor is built.

Figure 1

Life Cycle Dilemma



0006768-1

Source: Dataquest
May 1990

©1990 Dataquest Incorporated May

DMS SOLUTIONS

In response to this problem, a myriad of solutions are being developed and employed in the United States. A major aspect of the problem is the difficulty of assessing when obsolescence is an issue. To date, there has not been a systematic gathering of bill-of-material-type information to determine future problem areas.

This issue is a priority, however, and there are several databases emerging to address it. The Defense Electronics Supply Center (DESC), DMS unit; the Material Parts Available Control program (MPAC-Army); the Naval Avionics Microcircuit Obsolescence Program; and the Institute for Technology Development (Starkville, Mississippi) are some of the organizations chartered to maintain databases to support obsolescence planning.

Some of the proposed solutions to this DMS problem are listed below. One or a combination of these may be required for any particular program and/or semiconductor product. Dataquest believes that if government logistics planners, program managers, and OEMs assess each program for its life cycle component requirements and then use semiconductor life cycle information to project mismatches with the system life cycle, they can develop a component sourcing plan that recognizes the nature of the shortfall of semiconductor availability. The plan would address which semiconductors are at risk and how the risk can be minimized using various solutions. Some of the proposed solutions include the following:

- Life-of-type buys
- Aftermarket suppliers
- Emulation
- Equipment redesign

Life-of-Type (LOT) Buys

This is the most predominant past practice employed to ensure semiconductor supply. When a supplier announces an upcoming obsolescence, DESC will take the initiative to poll the services for their requirements, purchase the required amount, and stock for future needs. Packaged semiconductors, wafers, or die can be involved. In addition, DESC proactively stocks class S space-grade components to take advantage of infrequent production runs by merchant suppliers. The principle disadvantage to LOT buying is the risk of either stocking too much or not enough of a part type as a result of variability in the accuracy of program requirement estimates.

Aftermarket Suppliers

This category includes the class of suppliers that acquire inventories, production equipment, mask sets, and database know-how from the original suppliers. This alternative is becoming increasingly more popular because it comes the closest to ensuring the continued production of the exact same parts at variable future quantities. For example, aftermarket manufacturers include Lansdale, Micrel, and Teledyne Mil (a new concern). Standard logic families represent the most common product type that these companies support. Rochester Electronics maintains an inventory of discontinued parts and recently acquired mask sets from Fairchild for many of its older standard logic families. The principle risk to this DMS alternative is the financial stability of the vendors.

©1990 Dataquest Incorporated May

Emulation

Emulation is the use of alternative semiconductor technology to create products that are like the obsolete products in form, fit, and function. Emulation can be accomplished through the direct replacement of obsolete parts with ASICs and PROMs or through reverse engineering techniques that often employ ASICs. In either case, CAD tools such as simulators (either digital or linear) must be employed to ensure fidelity with the original parts. The other ingredient needed for successful emulation is compatible process technology, which, when used with the new designs, creates a part that has the same electrical characteristics as the original.

Several studies are investigating the use of emulation techniques. One important program is being conducted by the Air Force Sacramento Air Logistics Center called the Microelectronic Technology Support Program (MTSP), which is employing the use of VHSIC technology on gate arrays to emulate TTL logic parts. Another effort, called the Generalized Emulation Microcircuit (GEM) program, is directed by DESC and employs BiCMOS gate array technology.

To date, emulation is meeting with mixed success as an overall DMS solution. Some of the studies indicate that there are ongoing electrical parameter fidelity problems with the older parts. For this aspect, aftermarket supply could prove to be the more economical alternative. However, to prevent future problems with the semiconductors being designed into systems today, modular process-transparent technology is needed, and the various emulation techniques under development could help avoid future problems. One of the more significant developments associated with emulation will be the continued emergence of the VHSIC Hardware Description Language (VHDL) to document semiconductor designs. VHDL will allow designs to be captured in a consistent, communicable manner and to be reproduced on future versions of process technology.

Equipment Redesign

Equipment redesign is the most costly alternative. When interoperability is not an issue, the various system elements affected by obsolete parts can be redesigned with current semiconductor technology.

LIFE CYCLE ACCELERATORS

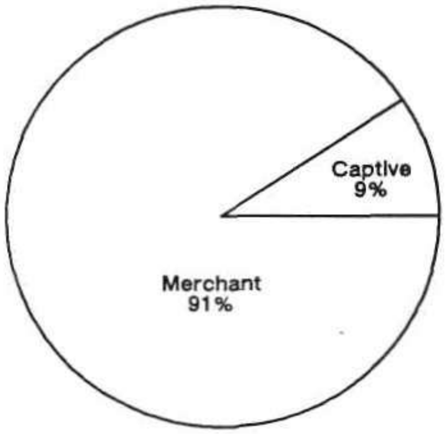
Several variables affect the life cycle of any given semiconductor product or family. Any one of these variables can be catastrophic in the sense of shortening a product's continued production and postsale support (e.g., accountability for quality). Availability of semiconductor products sold to military/aerospace OEMs is most dramatically affected by the commercial marketplace. On the average (as of 1990), military/aerospace demand accounts for 11 percent of the U.S. merchant semiconductor market (see Figure 2). Considering this, along with the fact that 91 percent (as of 1990) of semiconductors consumed by the military/aerospace market are supplied by merchant suppliers, the exposure of availability to world market vagaries is dramatic.

Figure 3 further illustrates the dynamics of a typical product life cycle and its impact on profitability. Note that in the crucial later stages, when most of the suppliers have dropped out, product gross profits may or may not return to the positive. This is because the surviving suppliers may or may not continue investing in late life cycle cost-saving (or cost-maintaining) programs, and typically capacity is underused at that point.

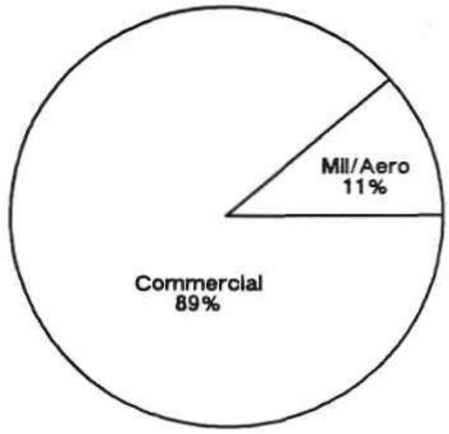
©1990 Dataquest Incorporated May

Figure 2

Supply Base Dilemma



Military Semiconductor Sources
1990



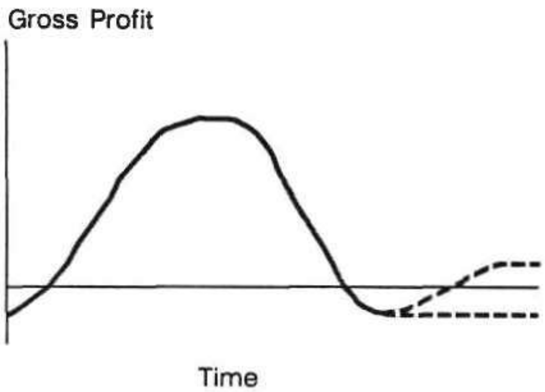
Merchant Supplier Business Mix
1990

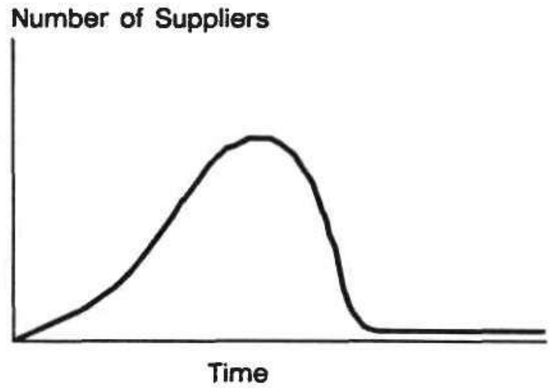
0006768-2

Source: Dataquest
May 1990

Figure 3

Semiconductor Life Cycle Profile (Standard Products)





0006768-3

Source: Dataquest
May 1990

©1990 Dataquest Incorporated May

The following lists the more important life cycle acceleration factors to take into consideration when assessing the status or predicting the future availability of a semiconductor product:

- Market acceptance—How broadly accepted is a new product or standard?
- Product displacements—Are the subject products competing with alternative solutions or emulators?
- Commercial market health—What is the state of world markets, pricing, inventory cycles?
- Multisourcing status—If there is multisourcing, how viable is it?
- Profit margin—Are pricing and run rates sufficient to cover variable costs?
- Investment recovery—Has the vendor recovered product development costs?
- Financial stability—Is this a crucial issue for sole-source situations?
- Military-specific product—Was the product designed especially for military/aerospace applications?
- Dedicated military resources—Are the suppliers of subject products long-term players in the market? JAN certified?
- Opportunity loss—Is the vendor missing more lucrative and easier-to-serve opportunities?
- Aftermarket manufacturers—Are technology and equipment transferred to another manufacturer?

SEMICONDUCTOR PRODUCT LIFE CYCLES

The following paragraphs describe the current life cycle status of various categories of semiconductor products. During the R&D and introduction phase, most products are sole-sourced. These early phases are characterized by sampling, customer evaluation, and design-in activities. The growth-through-saturation phases are characterized by rapid growth as military/aerospace programs utilizing those components enter production. These intermediate phases also often witness the entrance of several duplicate or emulating competing products if the product is visibly successful. The decline and phaseout period is characterized by the gradual withdrawal of suppliers and a thinning of the line offerings. The phaseout period can be lengthened by the presence of aftermarket suppliers that take over production from the original manufacturer.

Bipolar Memory

TTL RAMs, in general, are being displaced by CMOS alternatives and EE technology. Emerging products include 64K and 128K TTL PROMs as well as faster and registered versions of lower-density PROMs. The 256K ECL RAMs are emerging also. Lower-density PROMs are finding applications as logic replacements (see Figure 4).

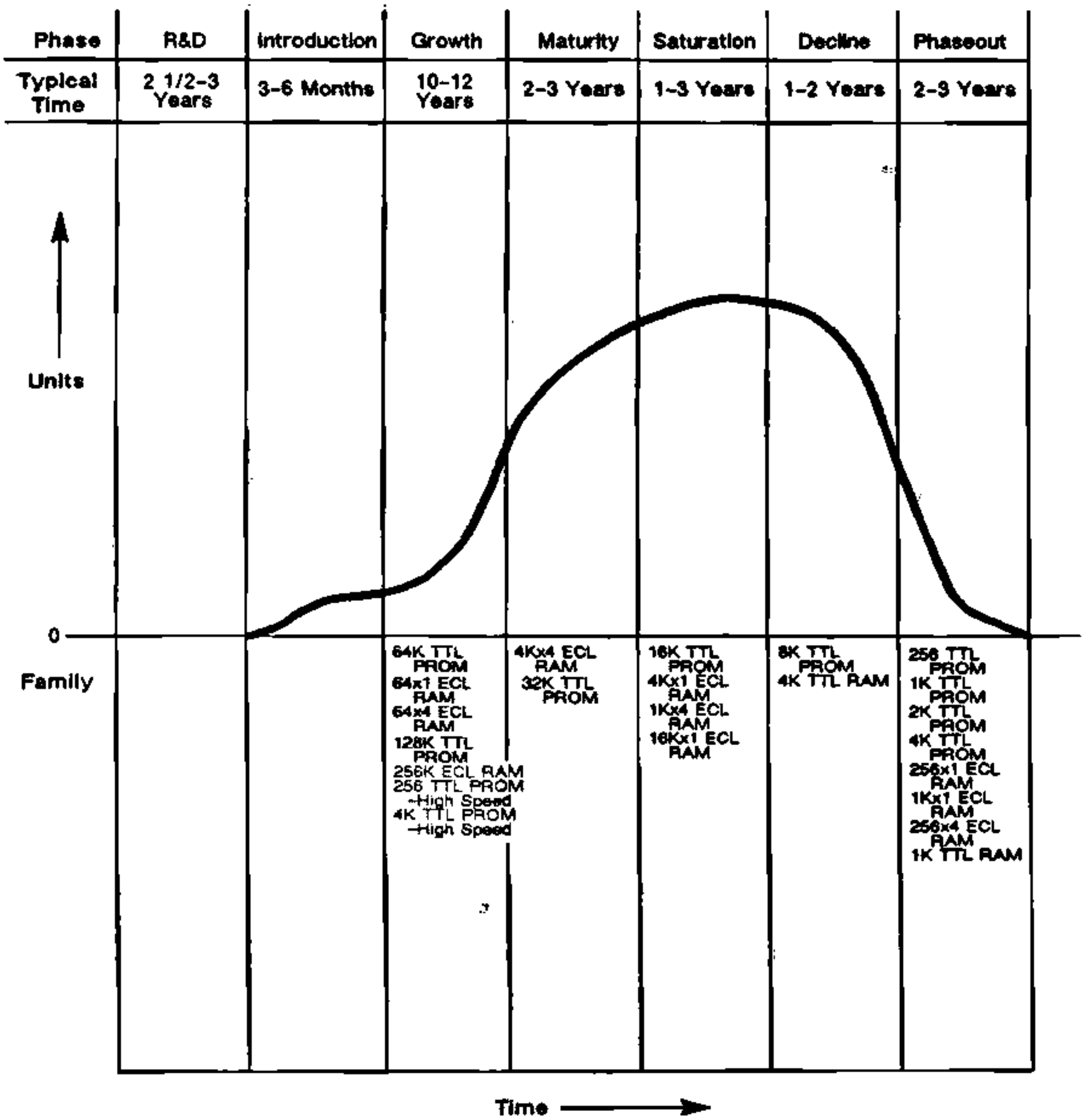
DRAMs

To date, DRAMs have not found as much use in military/aerospace equipment as in commercial equipment; however, their hi-rel use is growing rapidly. Both 256K and 1Mb versions are being designed in today. The 64K devices principally are being designed out (see Figure 5).

©1990 Dataquest Incorporated May

Figure 4

Bipolar Memory Life Cycle



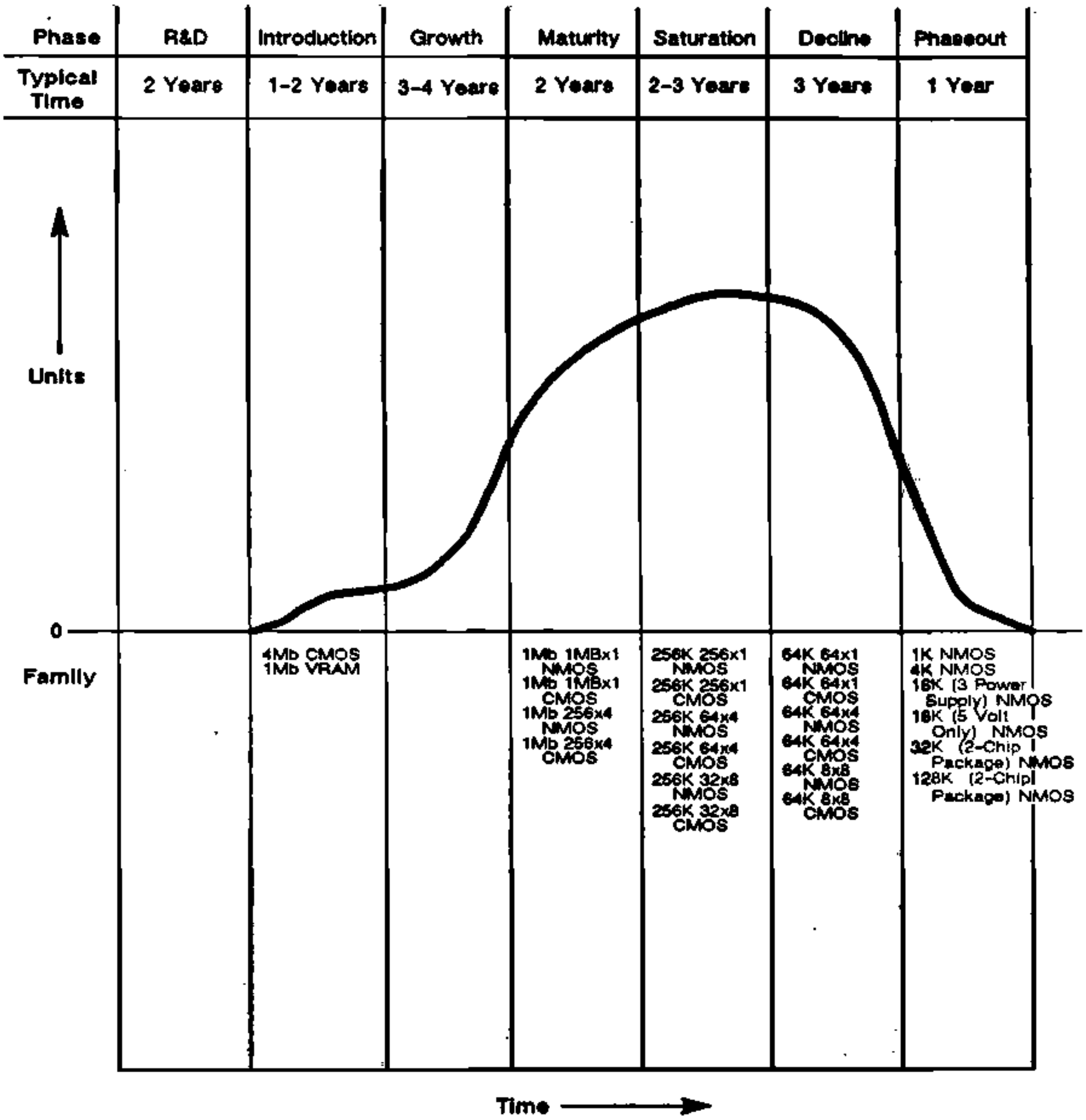
0006768-4

Source: Dataquest
May 1990

©1990 Dataquest Incorporated May

Figure 5

DRAM Life Cycle



0006768-5

Source: Dataquest
May 1990

©1990 Dataquest Incorporated May

SRAMs

Slow SRAMs are mostly x8 configurations, and 256Ks are quickly supplanting 64Ks. Military 1Mbs are being sampled in the first half of 1990 by some companies and will be broadly available next year (see Figure 6).

Fast 64K and 256K SRAM densities are ramping up use, having been designed in for several years now. Although still popular, 16Ks are leveling out from a market perspective. BiCMOS and GaAs versions are also emerging as very high speed (sub-25ns) alternatives (see Figure 7).

EPROMs

The 256K EPROM density level is displacing 128K and 64K. The 1Mb density and, to a lesser extent, the 512K density are ramping up as the predominant products. High-speed sub-70ns versions are being released two to three years behind the slower-speed versions (see Figure 8).

ROMs

The 256K and 512K density ROMs are being rapidly displaced by the ramping-up of 1Mb and 2Mb versions. Life cycle displacements are extremely quick in ROM technology (see Figure 9).

EEPROMs and Flash Memory

The 64K and 16K densities make up the mainstream of military/aerospace use and shipment. The 256K density level is emerging and will become the mainstream product quickly. The 512K density flash memory product now is being designed in. The predominance of hi-rel use in this product category will help ensure lower-density availability longer than most memory technologies (see Figure 10).

Standard Logic

Mainstream growth families include FAST and ALS. The new advanced CMOS logic families are ramping up quickly as they enter their growth phase. HC/HCT is in saturation as alternatives hasten its market life. The S and LS families are finding declining usage. Products at the phaseout stage are prolonged by aftermarket manufacturers (see Figure 11).

CMOS Gate Arrays

The overall average life cycle for a particular CMOS gate array technology is seven years. The 1.4- to 2.0-micron technology is the current mainstream production technology. However, new design activity is being targeted at the 0.8- to 1.4-micron range (see Figure 12).

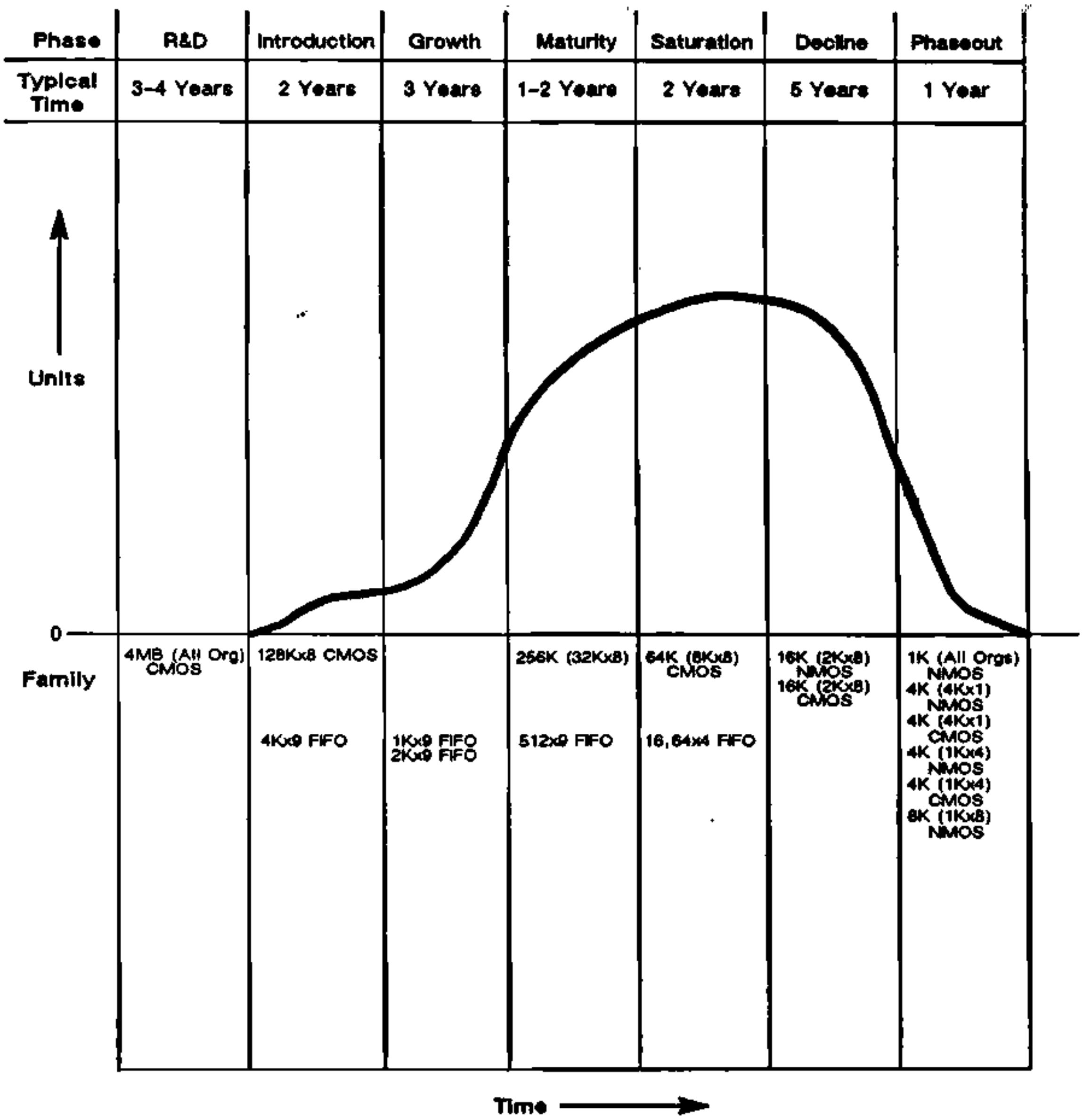
High-Performance Gate Arrays

The overall average life cycle for a particular high-performance gate array technology is 10 years. Mainstream ECL use is at 5,000-gate technology in the 0.25ns gate delay range (see Figure 13). BiCMOS and GaAs are securing higher-density and higher-speed design-ins, respectively.

©1990 Dataquest Incorporated May

Figure 6

Slow SRAM Life Cycle and FIFO



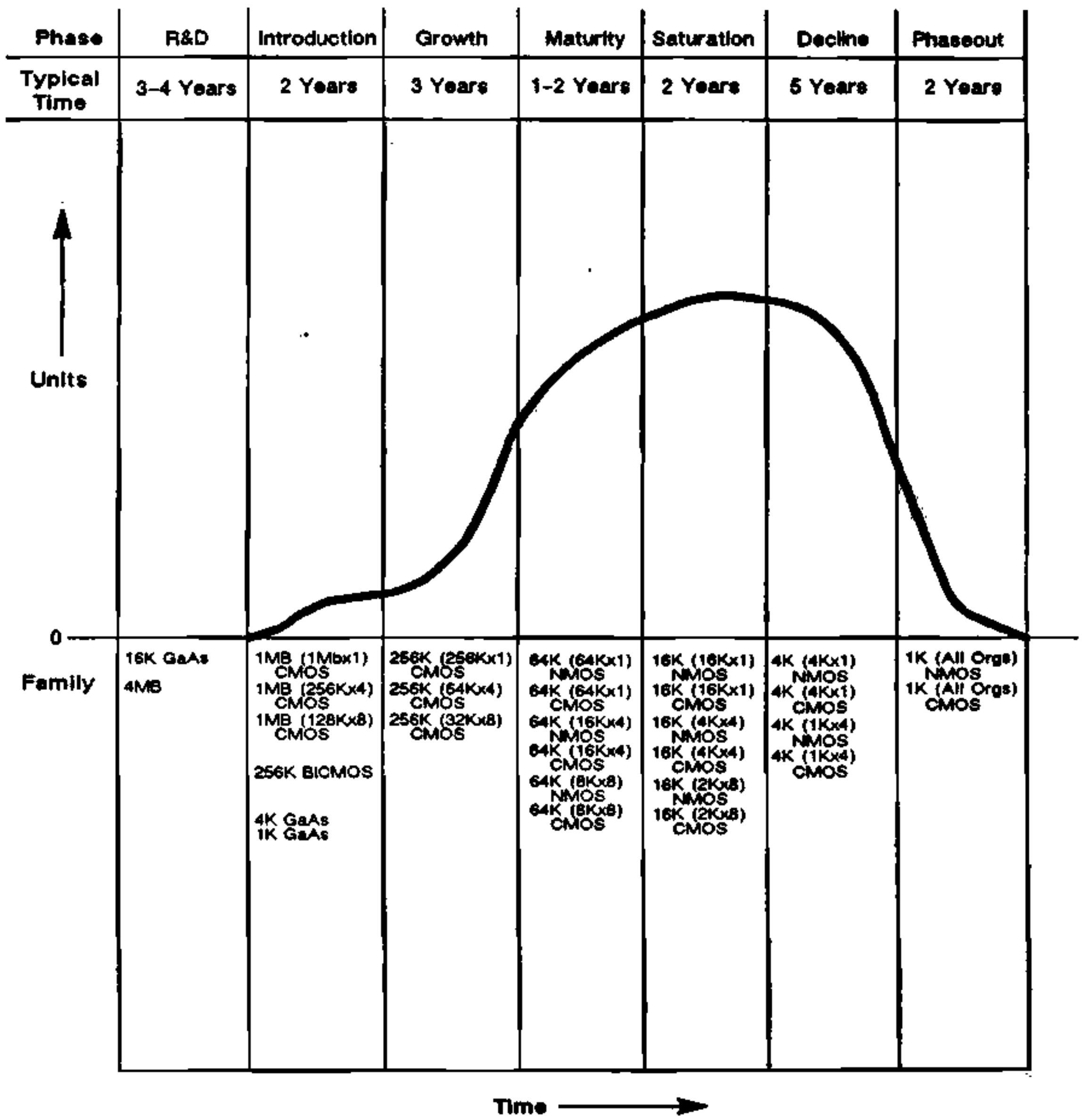
0006768-6

Source: Dataquest
May 1990

©1990 Dataquest Incorporated May

Figure 7

Fast SRAM Life Cycle



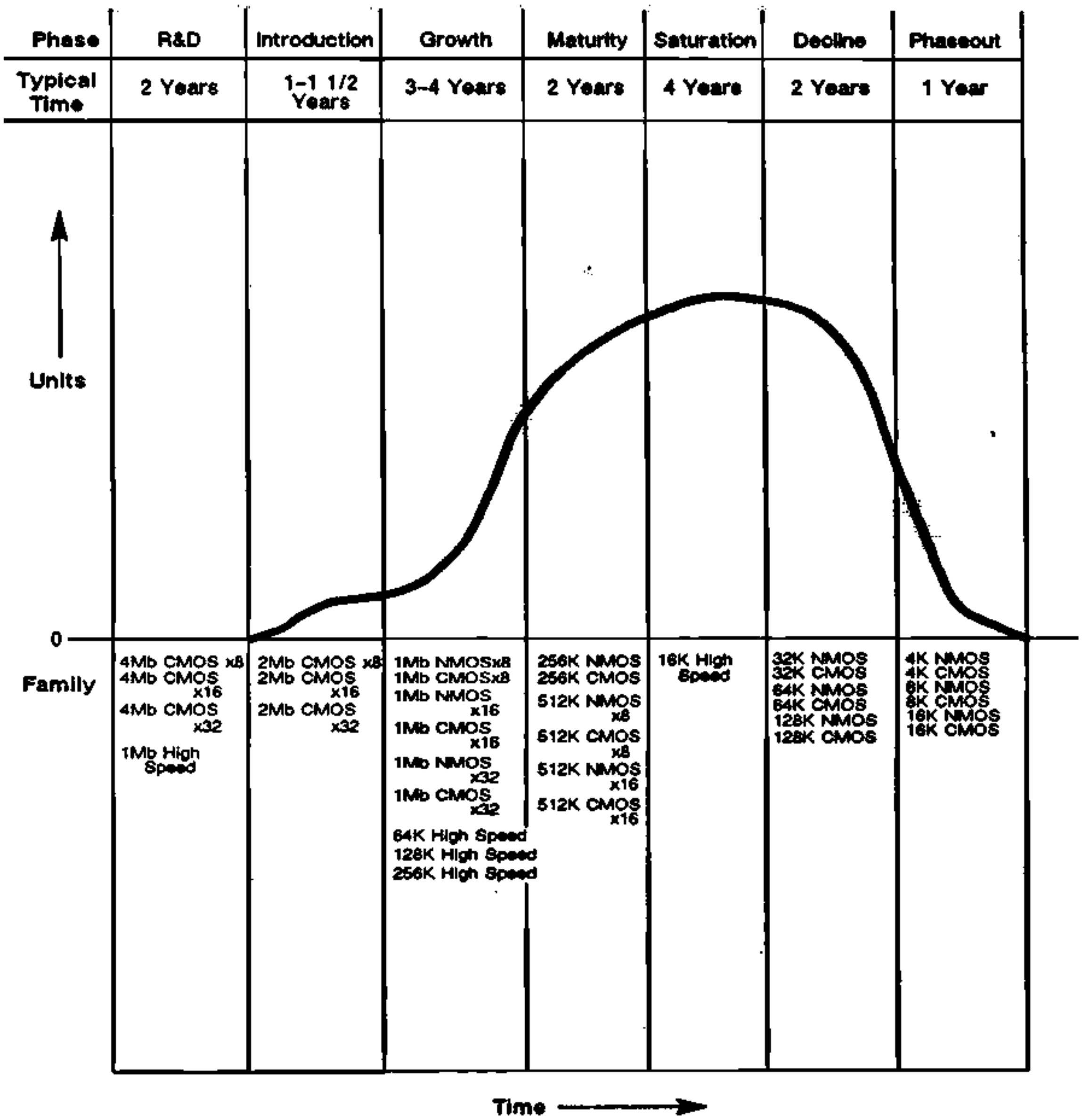
0006768-7

Source: Dataquest
May 1990

©1990 Dataquest Incorporated May

Figure 8

EPROM Life Cycle

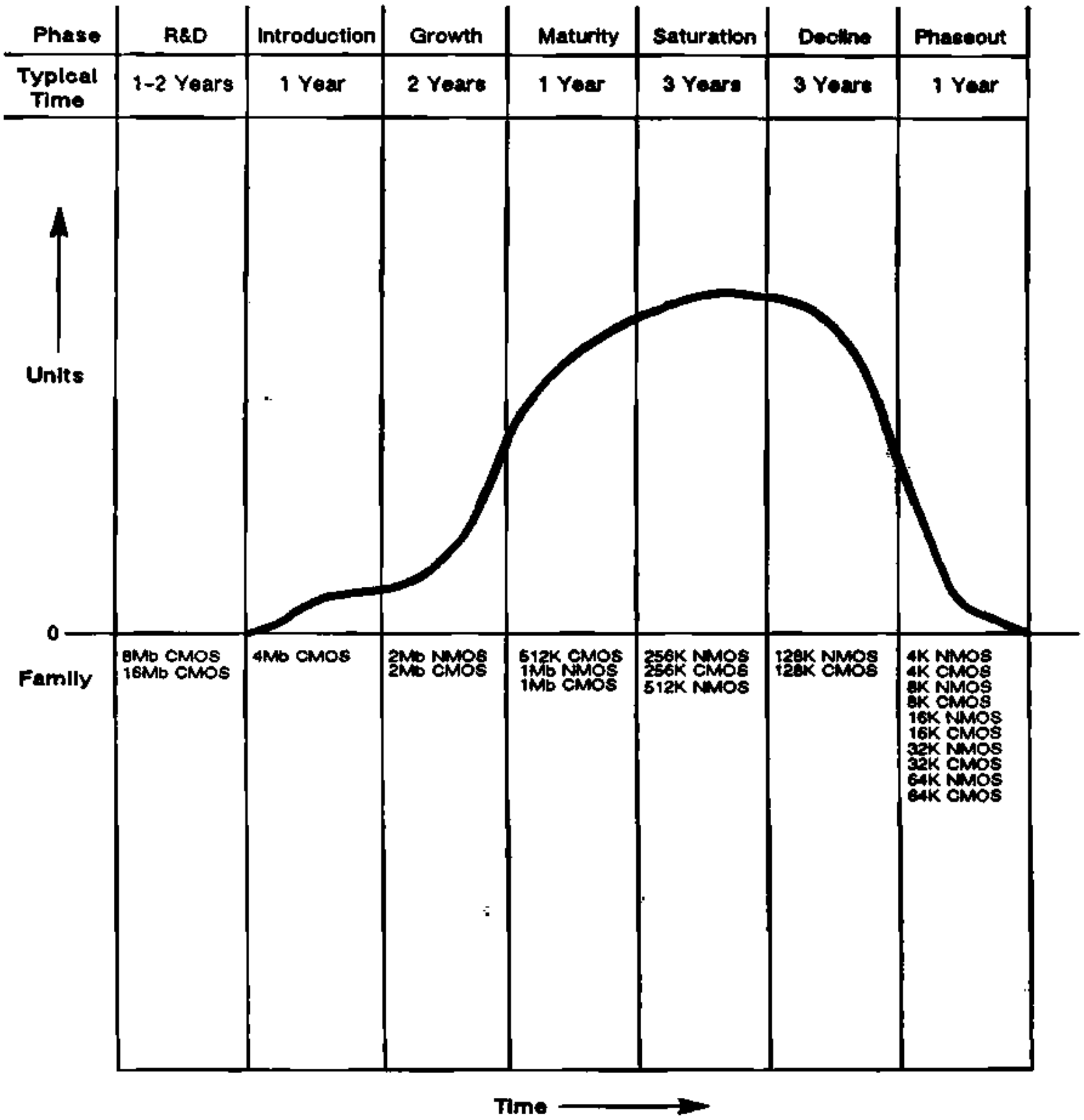


0006768-8

Source: Dataquest
May 1990

Figure 9

ROM Life Cycle



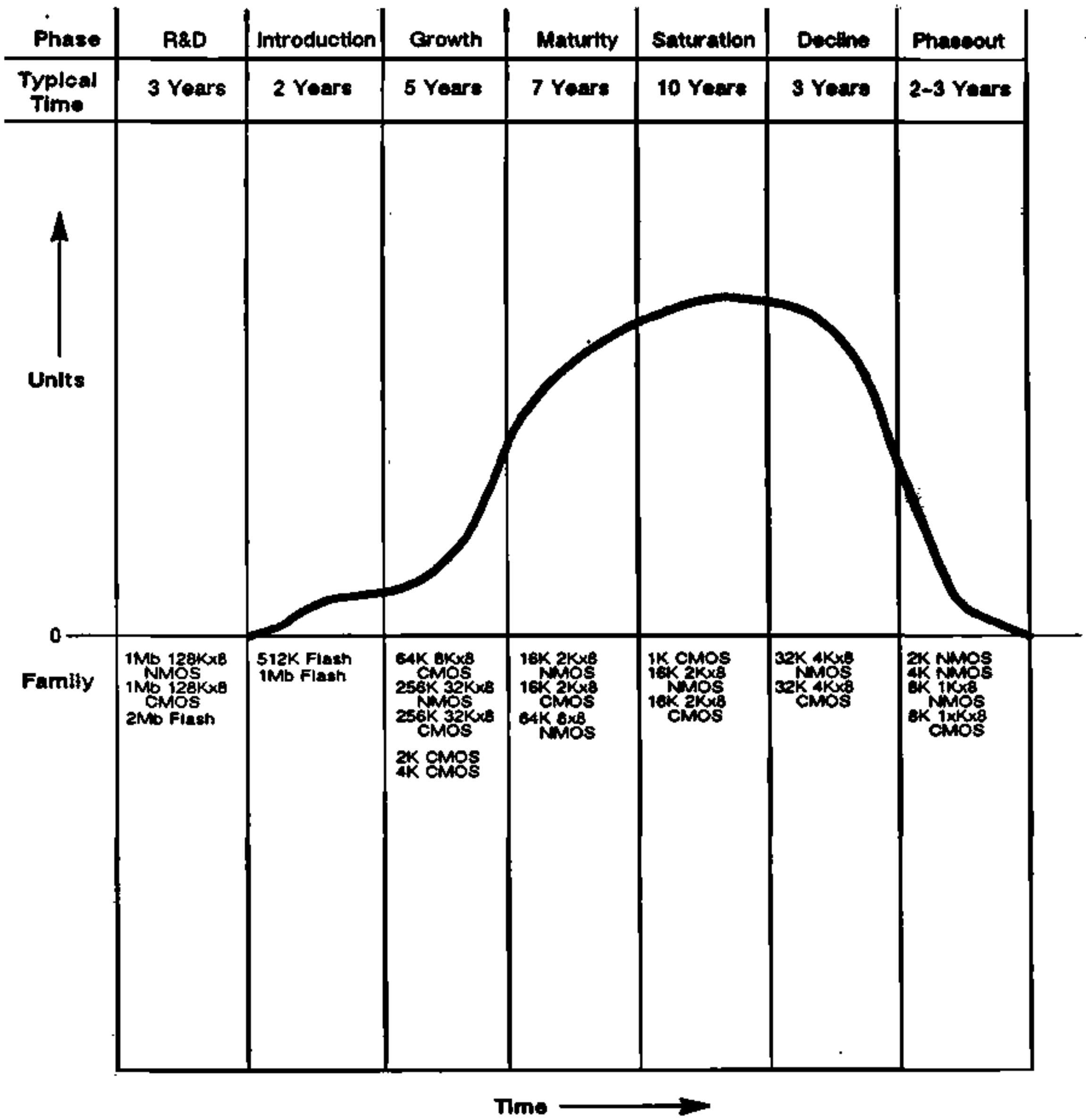
0006768-9

Source: Dataquest
May 1990

©1990 Dataquest Incorporated May

Figure 10

EEPROM and Flash Memory Life Cycle

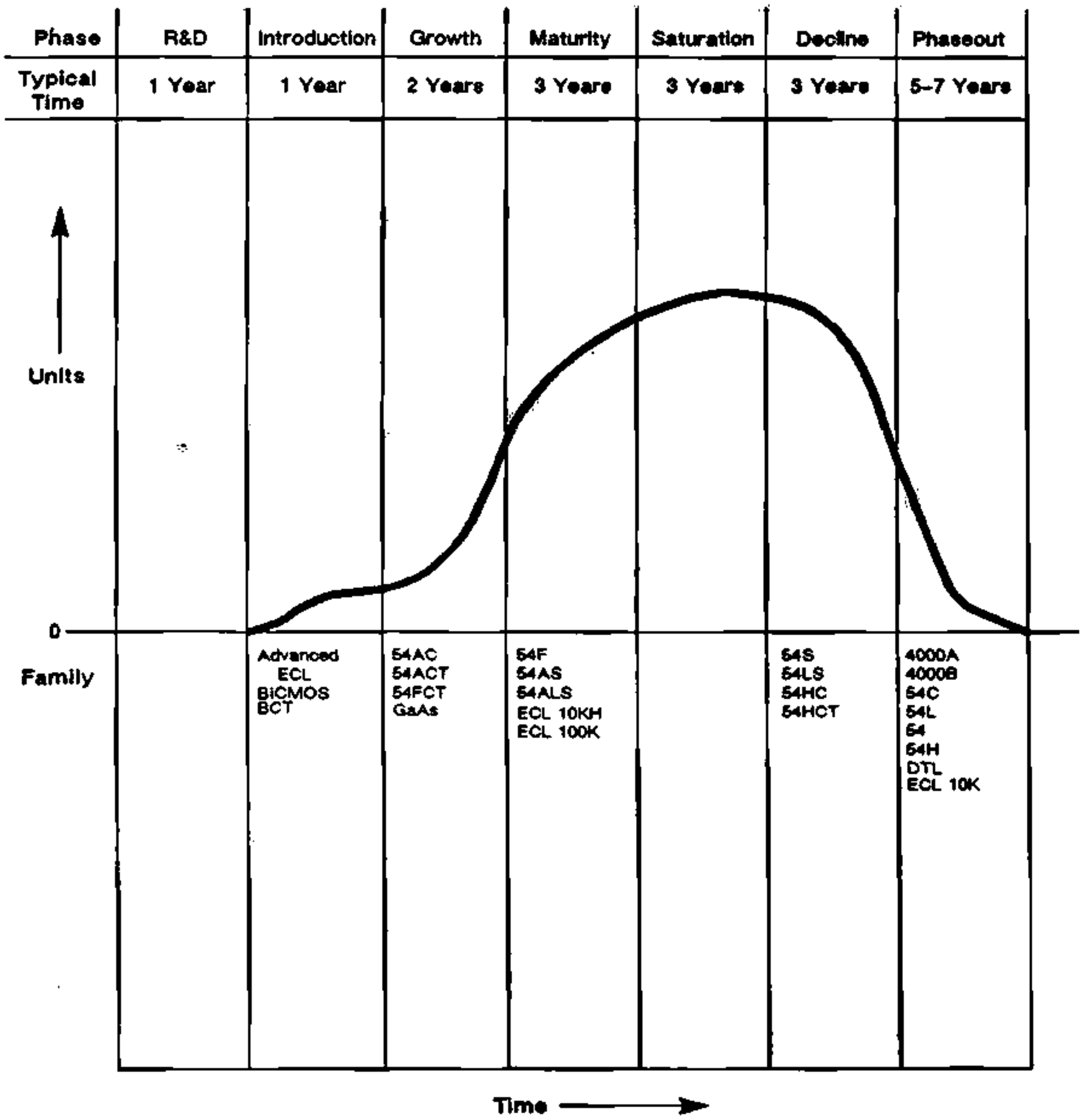


0006768-10

Source: Dataquest
May 1990

Figure 11

Standard Logic Product Life Cycle



0006768-11

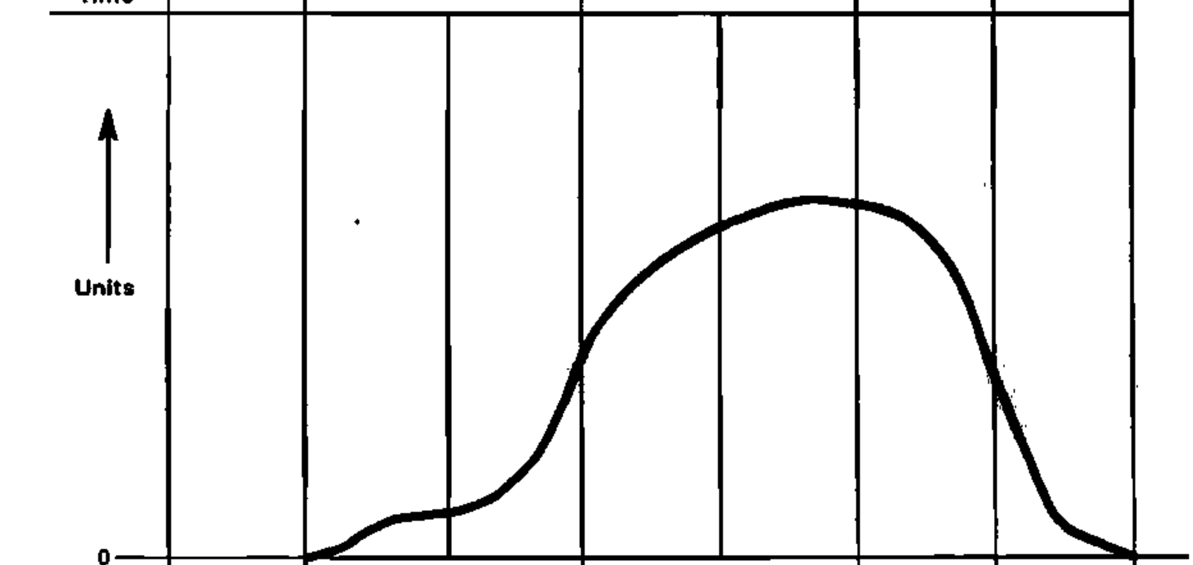
Source: Dataquest
May 1990

©1990 Dataquest Incorporated May

Figure 12

CMOS Gate Array Life Cycle

Phase	R&D	Introduction	Growth	Maturity	Saturation	Decline	Phaseout
Typical Time	1-2 Years	1 1/2 Years		1 1/2 Years		2 Years	2 Years



Family	R&D	Introduction / Growth	Maturity / Saturation	Decline	Phaseout
Linewidth	< 0.8µ	0.8-1.4µ	1.5-2.0µ	2.0-2.9µ	≧3µ
Maximum Complexity (Gates)	> 100,000	100,000	10,000 - 20,000	6,000	1,500
Gate Delays (2 Input Nand, FO=2)	< 0.5ns	0.5ns-1.0ns	1.4ns - 2.0ns	21.ns- 3.0ns	>3.1ns

Time →

0006768-12

Source: Dataquest
May 1990

Figure 13

High-Performance Gate Array Life Cycle

Phase	R&D	Introduction	Growth	Maturity	Saturation	Decline	Phaseout
Typical Time	2-3 Years	3 Years		1 1/2 Years	1 1/2 Years	2 Years	2 Years

Family							
Linewidth	< 0.8μ	0.8-1.4 μ		1.5-2.0 μ	2.0-3.9 μ	4.0-4.9 μ	≧ 5 μ
Maximum Complexity Gates							
(ECL)	30,000	15,000		5,000	3,000	1,000	600
(BICMOS)	120,000	25,000-50,000					
(GaAs)	15,000	6,000-12,000		3,000-4,000			
Gate Delays (ECL) (2 Input Nand, FO=2)	< 0.1ns	0.1ns		0.25ns	0.6ns	0.9ns	1.5ns

0006768-13

Source: Dataquest May 1990

 ©1990 Dataquest Incorporated May

Programmable Logic Devices

Bipolar TTL devices with speeds greater than 30ns are being displaced by faster bipolar devices and the CMOS versions. The 25ns CMOS versions are entering their high-growth phase. ECL versions are entering their growth phase (see Figure 14). CMOS field-programmable gate arrays (FPGAs) are beginning to find broad acceptance.

CMOS Cell-Based ICs

Currently, 1.4- to 2.0-micron technology for CMOS CBICs is in the mainstream of usage. The 0.8- to 1.4-micron technology is entering its growth phase for military/ aerospace usage. Military cell libraries now are becoming more prevalent (see Figure 15).

Bipolar and GaAs Cell-Based ICs

In bipolar and GaAs CBICs, 2.0- to 3.0-micron bipolar technology has matured and is being displaced by 1.4- to 2.0-micron technology. This category includes mixed-signal capability. High-density ECL and medium-density GaAs offerings are currently in the introduction phase (see Figure 16).

Microcomponents

Products in maturity include most 8-bit MCUs and 16-bit MPUs. The 32-bit MPUs, 16-bit single-chip DSP ICs, and 16-bit MPUs are ramping up to growth-phase volumes. Both MIL-STD-1750A and 1553B ICs are in their late growth phases. Most of the new peripheral chip sets are in the introduction-to-growth phase of their life cycles (see Figure 17).

Analog

General-purpose, single-supply op amps and three-terminal regulators are reaching the peak of their life cycles, but they are still growing at a low level. They are being displaced by application-specific amplifiers and switchmode regulators, respectively. Intelligent power ICs, which combine logic and analog switch functions, are in the introductory phase. First-generation GaAs analog ICs such as oscillators and amplifiers are in the later growth stage, whereas the MMIC class circuits are still in R&D (see Figure 18).

Analog switches and most types of line driver/receivers are in the saturation stage. High-speed/high-resolution data conversion (general-purpose and video) is displacing the slower/ lower-resolution versions. Most display drivers are in their maturity phase (see Figure 19).

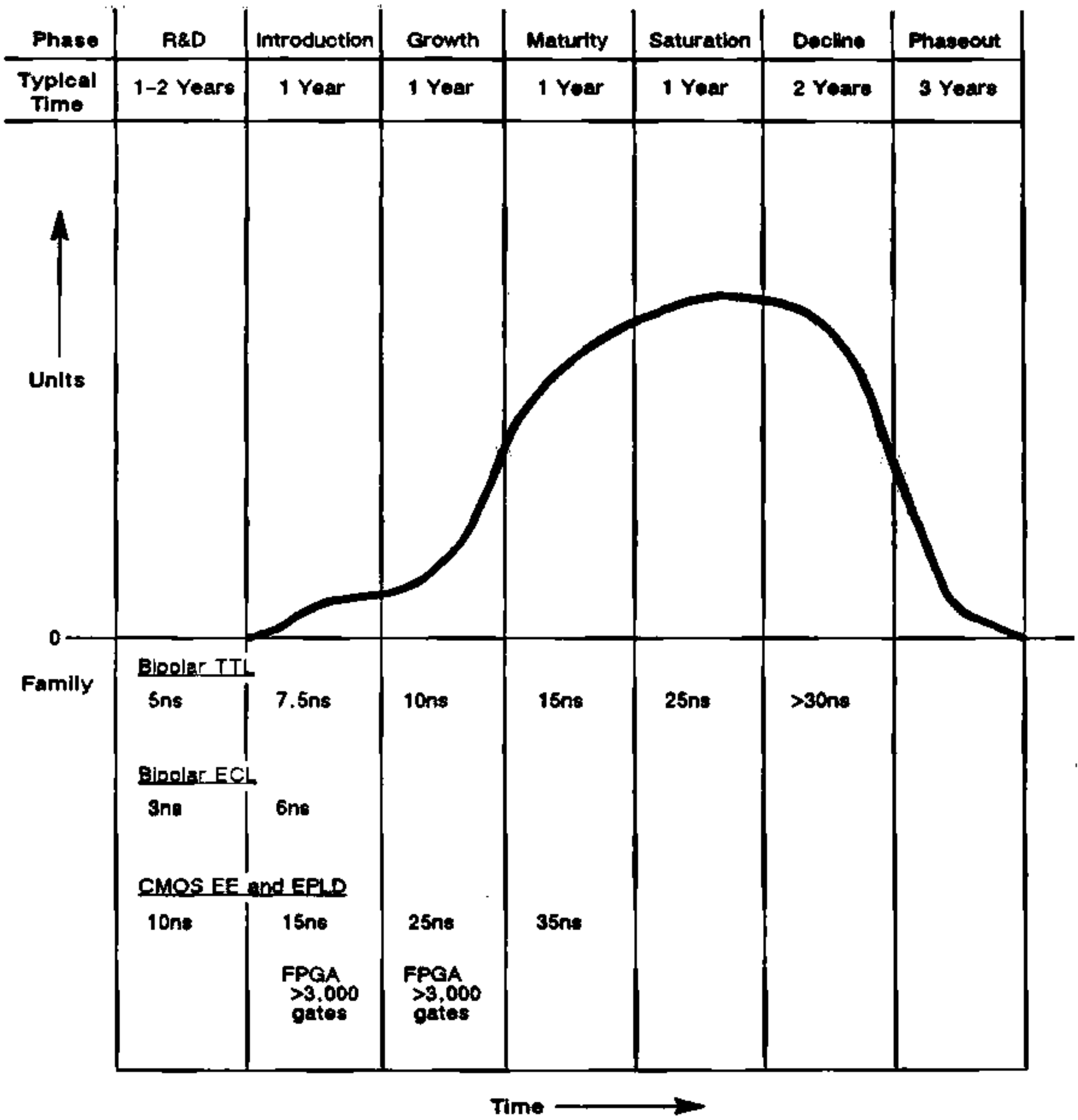
Discretes and Optoelectronics

As surface-mount small-signal packages enter the mainstream, they are displacing through-hole versions in most applications. Power MOSFETs are rapidly winning design acceptance, thus displacing bipolar versions in many lower-current applications. The emergence of radiation hardness characterization data has helped accelerate power MOSFET use. Fast recovery rectifiers and microwave discretes are in their maturity phase (see Figure 20).

©1990 Dataquest Incorporated May

Figure 14

Programmable Logic Device Life Cycle



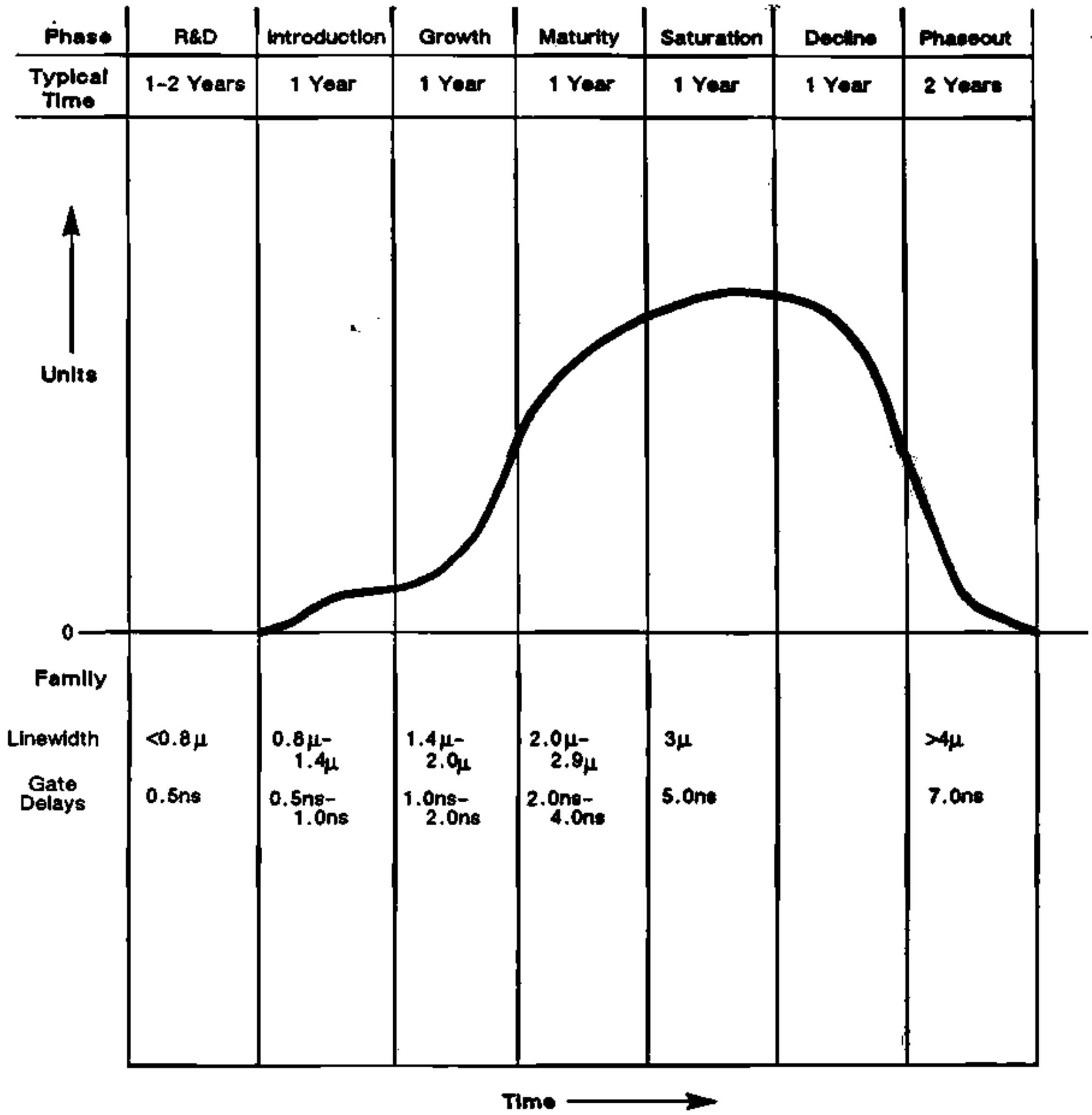
0006768-14

Source: Dataquest
May 1990

Source: Dataquest
May 1990

Figure 15

CMOS Cell-Based IC Life Cycle



0006768-15

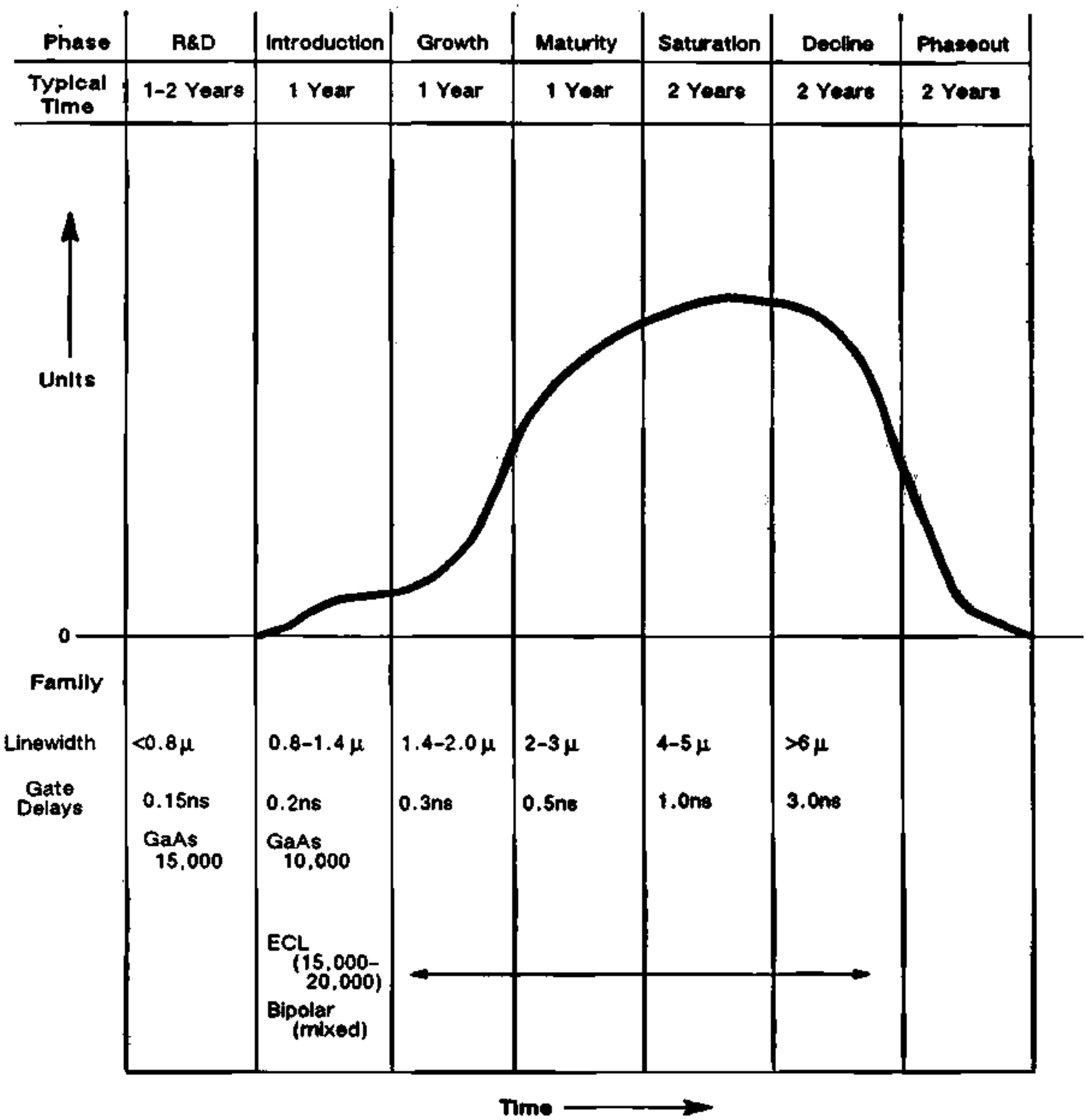
Source: Dataquest
May 1990

Source: Dataquest
May 1990

©1990 Dataquest Incorporated May

Figure 16

Bipolar and GaAs Cell-Based IC Life Cycle



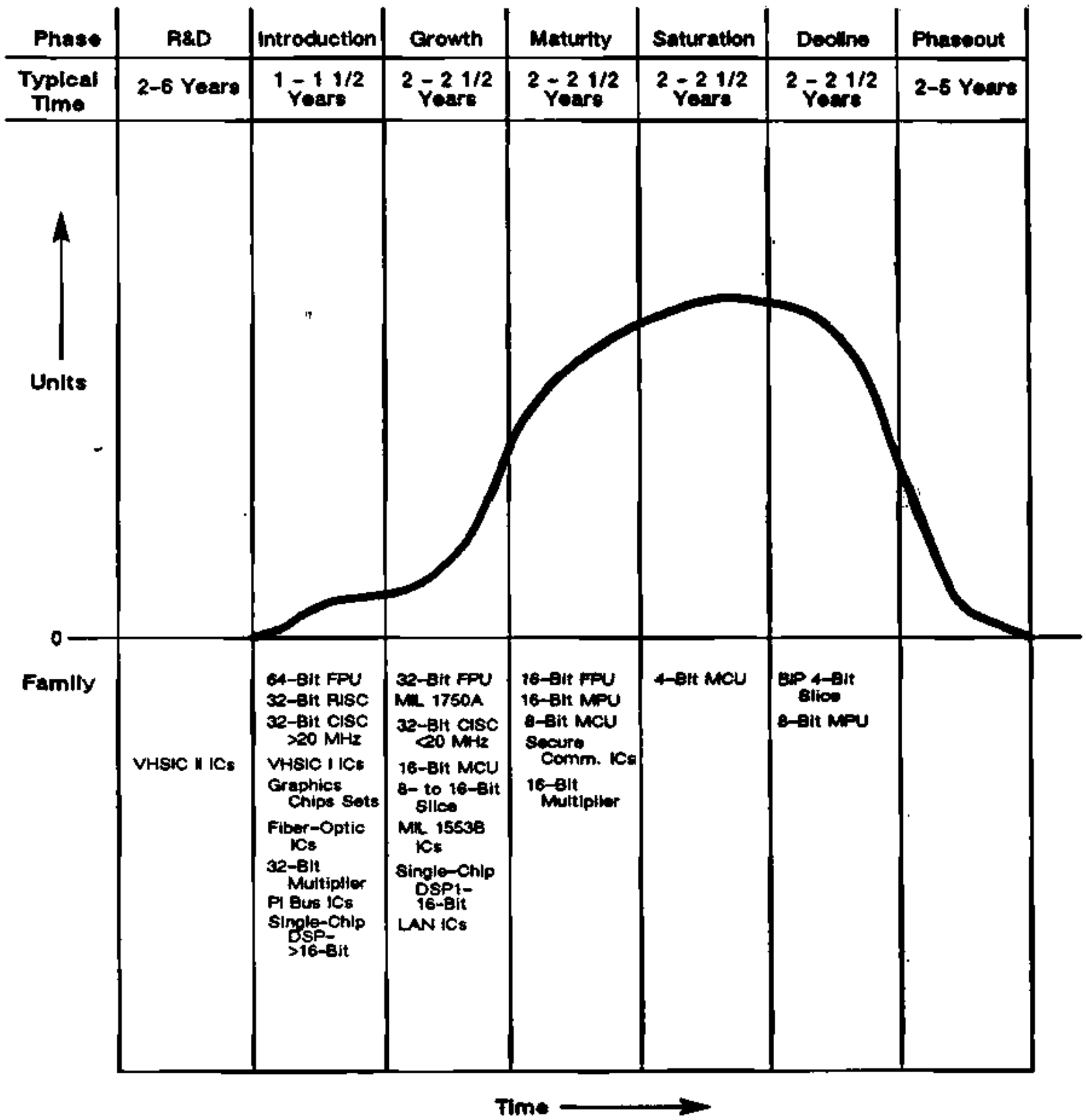
0006768-16

Source: Dataquest May 1990

©1990 Dataquest Incorporated May

Figure 17

Microcomponent Life Cycle



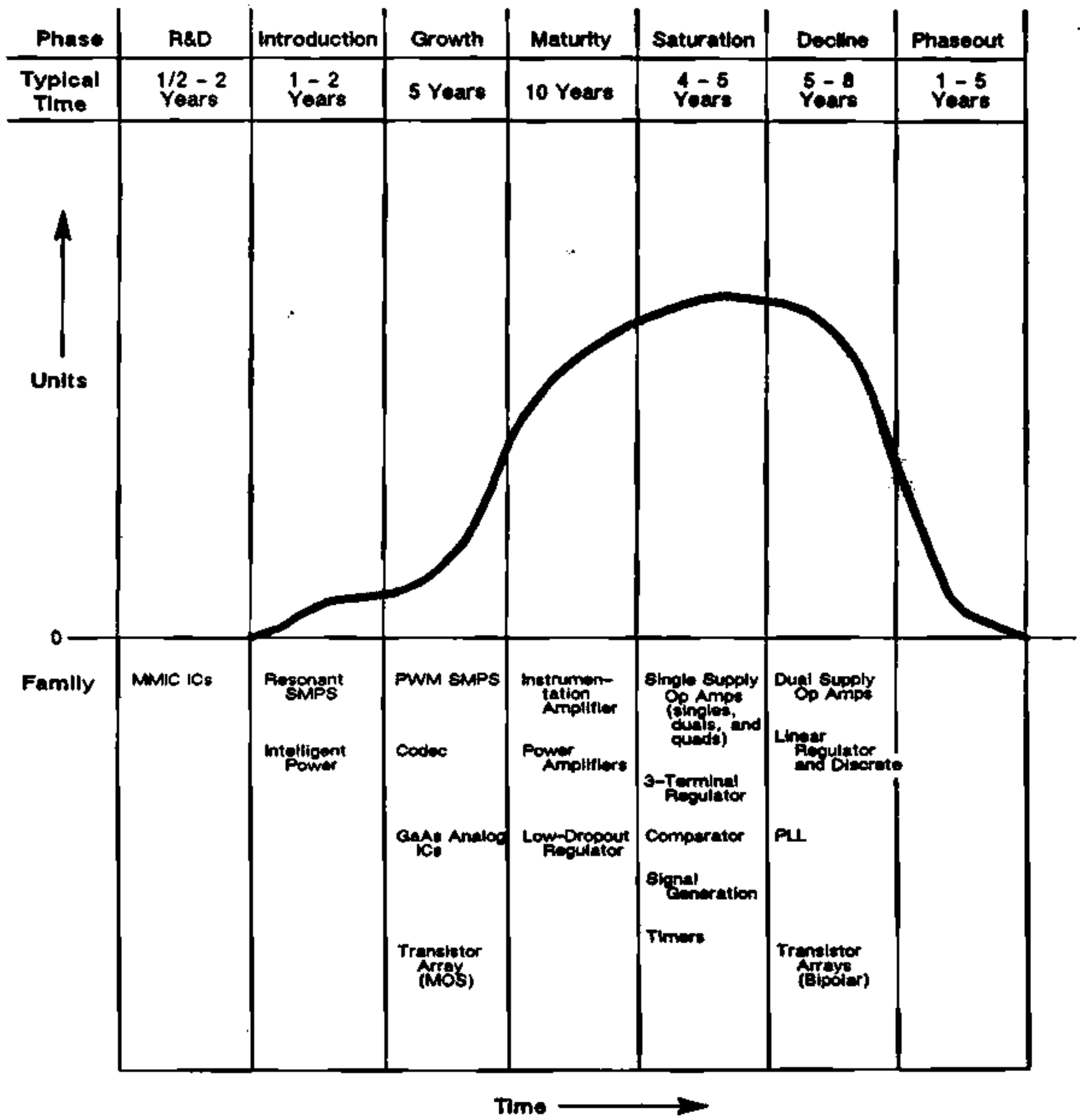
0006768-17

Source: Dataquest
May 1990

©1990 Dataquest Incorporated May

Figure 18

Standard Analog IC Life Cycle

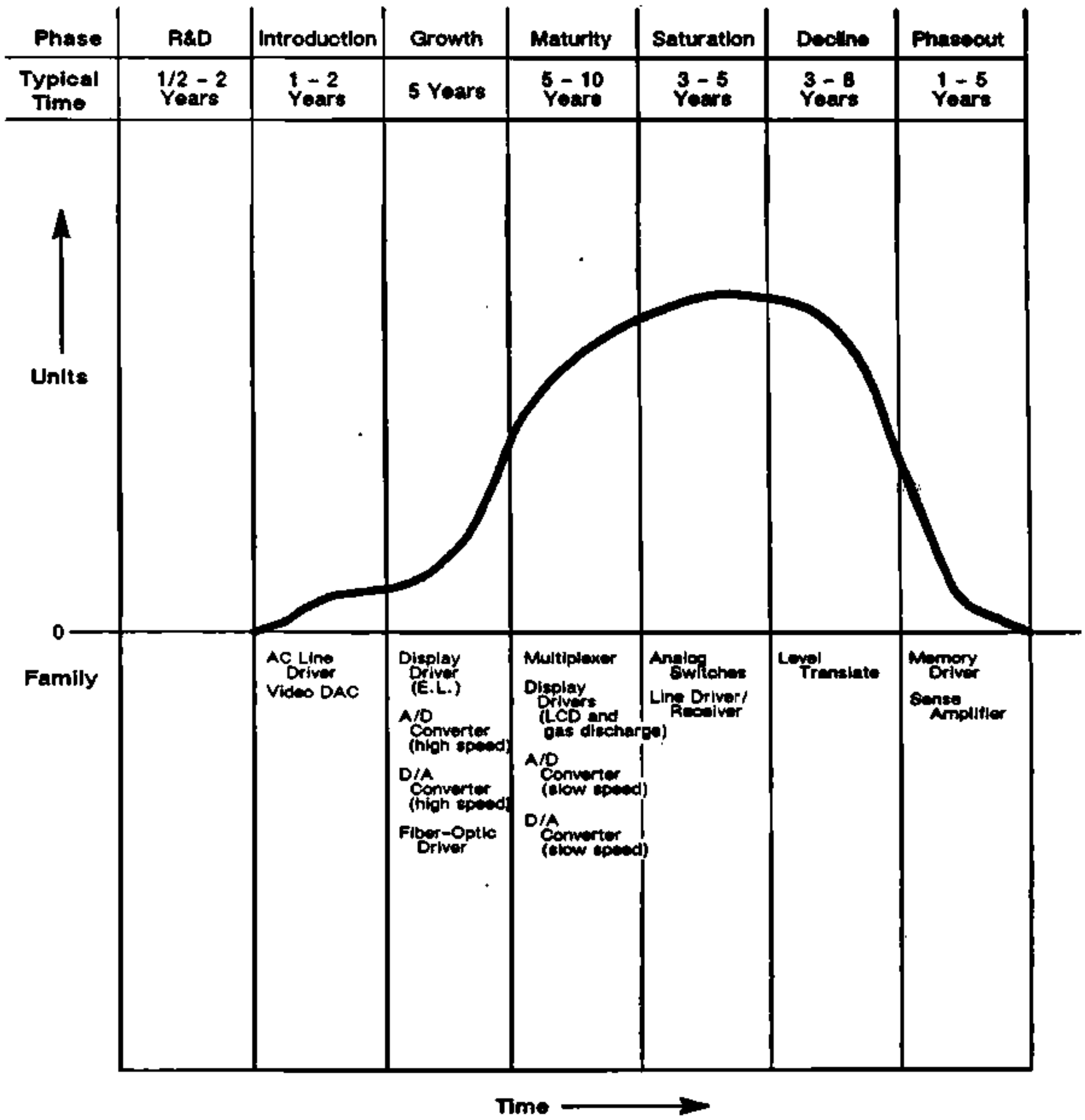


0006768-18

Source: Dataquest
May 1990

Figure 19

Analog Interface IC Life Cycle



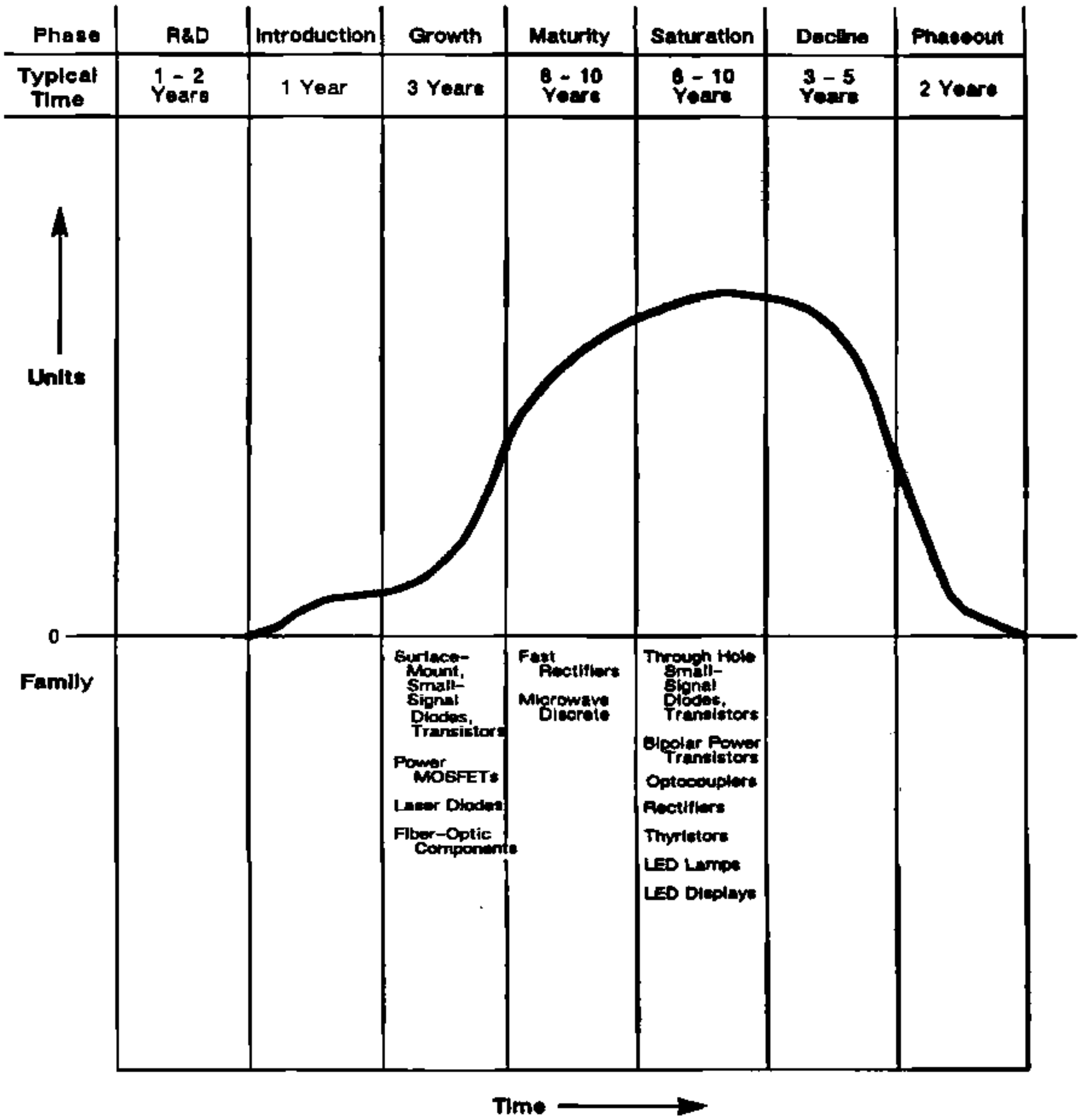
0006768-19

Source: Dataquest
May 1990

©1990 Dataquest Incorporated May

Figure 20

Discrete and Optoelectronic Life Cycle



0006768-20

Source: Dataquest
May 1990

©1990 Dataquest Incorporated May

Quality and Reliability

INTRODUCTION

Anyone connected with the semiconductor industry has been witnessing a quality control revolution taking place in semiconductor companies. Both users and manufacturers agree that quality control is no longer a competitive distinction, but a requirement of highest priority for future survival in the industry. What is not agreed on universally is what constitutes quality control in the semiconductor industry. As one prominent engineer and developer of quality control theory stated, "To practice quality control is to develop, design, produce, and service a quality product which is most economical, most useful, and always satisfactory to the consumer."

To meet this goal, everyone in the company must participate in and promote quality control, including top executives, all divisions within the company, and all employees. How well semiconductor manufacturers and users implement quality control programs could determine their strength and future direction against worldwide competition.

The objectives of this service section are to discuss the driving forces behind quality control programs and to determine what new methodologies and strategies for improving semiconductor quality are being implemented by manufacturers and users worldwide. Although we will not attempt to recommend any one quality program or technique, we believe that it is important to discuss a few of the major participants and their quality improvement programs. We have chosen the following programs for discussion:

- Vendor performance measurements
- Statistical quality control (SQC)
- Just-in-time (JIT) manufacturing and purchasing
- Zero defect programs

QUALITY CONTROL PROGRAMS

Vendor Performance Measurements

There are three compelling reasons why semiconductor vendors and users are changing the way they do business: demands for high-quality products, better delivery, and lower prices. The vendor and user can meet each other's needs and still make a profit, but this requires closer relationships between vendor and user.

Digital Equipment Corporation established a Vendor Performance Measurement Program. Digital's program objectives are:

- To facilitate better internal decision-making processes
- To provide accurate feedback to vendors as to how they are perceived and measured
- To generate desired vendor performance

Better internal decisions can be made by measuring a vendor's performance on the following:

- Device design—Can the vendor ramp up to the user's system design?
- Product specification—Can the vendor's product meet the user's system specification?

©1990 Dataquest Incorporated August
Reference material—will not be republished

- Ship-to-stock track record—Can the vendor supply test data to the user verifying product quality levels?
- On-time delivery—Can the user plan inventory around the vendor's delivery performance?
- Total cost—Can the user measure the total cost to design in and use a vendor's product in the end system?

The success of a vendor performance measurement program falls on the user's ability to provide feedback to the vendor by:

- Maintaining a current and continuous flow of accurate data to the vendor
- Maintaining weekly, monthly, and quarterly feedback sessions on the vendor's product performance
- Commending the vendor for on-time deliveries and quality of performance

The goal of a vendor performance measurement system is to generate a desired vendor performance whereby the vendor can:

- Set aggressive and achievable product specifications
- Establish predictable and quick prototype turnaround time
- Maintain consistently excellent quality and reliability
- Commit to timely and dependable delivery
- Provide competitive total cost
- Behave like a business partner

Statistical Quality Control (SQC)

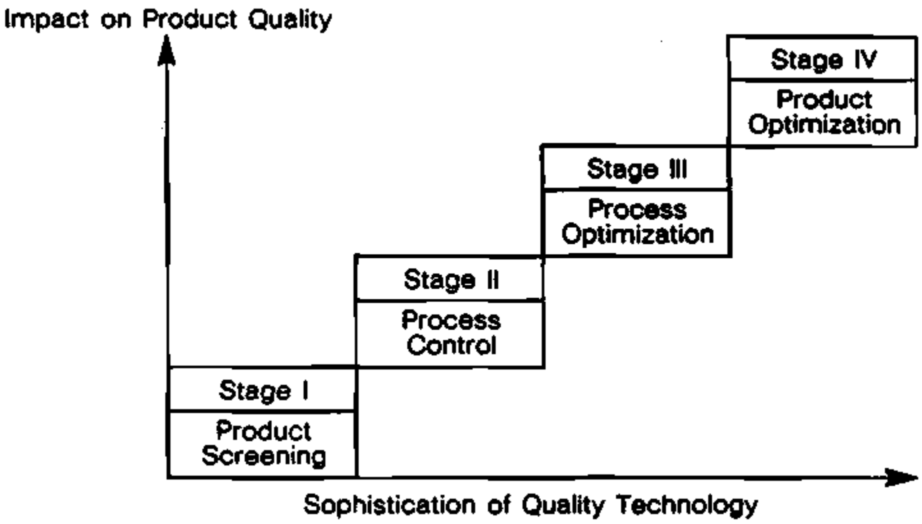
Statistical Quality Control (SQC) is a complex mathematical and statistical technique that, when applied to every step of the manufacturing process, ensures high yields and excellent quality. SQC began in the 1930s with the industrial application of control charts invented by Dr. W.A. Shewhart of the Bell Laboratories. The United States utilized SQC methods during the Second World War to produce military supplies inexpensively and in large volumes. The US method of quality control was introduced to postwar Japan. A major emphasis on quality control in Japan was made during the 1950s when the Japanese implemented the SQC methodologies of the renowned statistician, Dr. W. Edwards Deming.

National Semiconductor Corporation and the semiconductor sector of Harris Corporation are two major manufacturers that have implemented SQC programs in-house and with their suppliers to improve manufacturing operations and to ensure maximum quality in raw materials. As shown in Figure 1, we have divided SQC into four stages, with each stage being an extension of the previous stage.

©1990 Dataquest Incorporated August
Reference material—will not be republished

Figure 1

Stages of Statistical Quality Technology



Source: Harris Corporation

Product Screening

The most rudimentary stage of SQC is product screening. Many of the complex screening and rescreening steps, from incoming inspection through final quality assurance and packaging conformance checks, are still employed by military agencies and contractors. While screening is an effective technique for identifying and eliminating anomalous devices within a given population, it does not prevent device defects, it is not cost effective, and it increases detrimental device handling. During 1984 and 1985, National Semiconductor Corporation discovered that after consolidating all of the military customer returns, more than 67 percent were verified damaged units, mostly from additional handling and testing. Electrostatic discharge (ESD) accounted for more than one-half of the failures.

In an attempt to reduce initial screening, manufacturers have recently implemented environmental stress screening (ESS) programs. ESS is an attempt to control the time and place of system failures caused by defective components, workmanship defects, process errors, or design faults (see Figure 2).

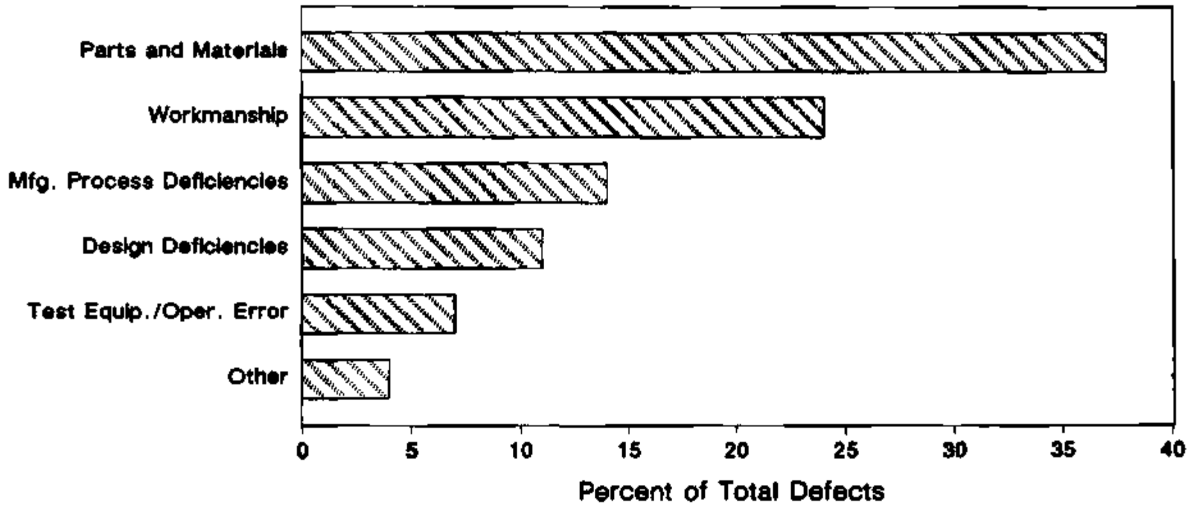
Because most failures are a result of component defects, screening devices prior to assembly can result in significant cost savings. Although the critical nature of some applications necessitates screening of some parts, there are cases where screening is no longer a cost-effective tool for improving quality. These include cases where:

- Parts are screened by the supplier
- A supplier's process and quality performance are closely monitored by the user
- A supplier's field experience is steady
- Device end use is not critical in nature
- Current screening process is not yielding failures

©1990 Dataquest Incorporated August
Reference material—will not be republished

Figure 2

ESS Program Results



Source: Institute of Environmental Sciences

Statistical Process Control (SPC)

SPC is a technique whereby statistics are used to measure process quality in manufacturing at both the vendor and user levels. Various SPC programs already in progress include the use of:

- Control charts—to determine the inherent variation of machines
- Product samples—either consecutive, random, or systematic sampling
- Machine capability studies
- Process capability studies
- Ongoing process control

By utilizing SPC, companies have achieved the following results:

- Machine scrap rates are reduced.
- Production flows improve.
- Raw materials meet tighter specifications.
- Product yields improve.
- Vendor/user relationships improve.
- Sources of supply are reduced.
- Costs are reduced.
- Employee motivation and attitude improve.

©1990 Dataquest Incorporated August
Reference material—will not be republished

SPC is a basic W. Edwards Deming method. Japanese manufacturers applied Deming's methods with Dr. J. M. Juran's quality control and quality circle methodologies throughout their industry in the 1960s. The success of these methods propelled Japan to world leadership status in high-quality products in the 1980s. US manufacturers recently have begun using these same methods in their operations. Forty-five General Electric Company (GE) locations have aggressively implemented SPC during the past few years. As a result, GE was able to reduce reject rates on ICs by more than 65 percent in one year.

Westinghouse started forming quality circles in 1979. By 1981, they had established 660 quality circles operating with approximately 6,000 employees solving quality problems. Companies that have implemented the formation of quality circles have discovered that:

- All levels of the work force involved are voicing their opinions.
- Tremendous improvements in quality and productivity have been achieved.
- Quality circle participants achieve increased self-esteem, dignity, and pride in their company.

Process Optimization

Process optimization utilizes advanced statistical techniques, including the use of multivariate analysis, control charts, and design of experiments (DOX). At this stage, the emphasis is on studying the interactions of the many parameters of a manufacturing process and then finding the optimum relationship of these parameters to minimize the inherent variabilities of the process. Process optimization is preventive control in that its influence is before the fact rather than during or after the fact.

Product Optimization

Product optimization is designing products for producibility or designing in quality from the start. Although the basic concepts exist and elements of the technology exist, the tools that are needed to implement the technology are just emerging. Hewlett-Packard, IBM, and Tektronix are currently leading the way in product optimization through the use of computer-integrated manufacturing (CIM). CIM links all phases of design, manufacturing, and automation, as well as quality, cost, and inventory control into a single computer-centered distributed communications network. Because of the enormous potential of this technology, the United States has the opportunity to leapfrog the competition by actively developing and using product optimization to produce high-quality, low-cost products.

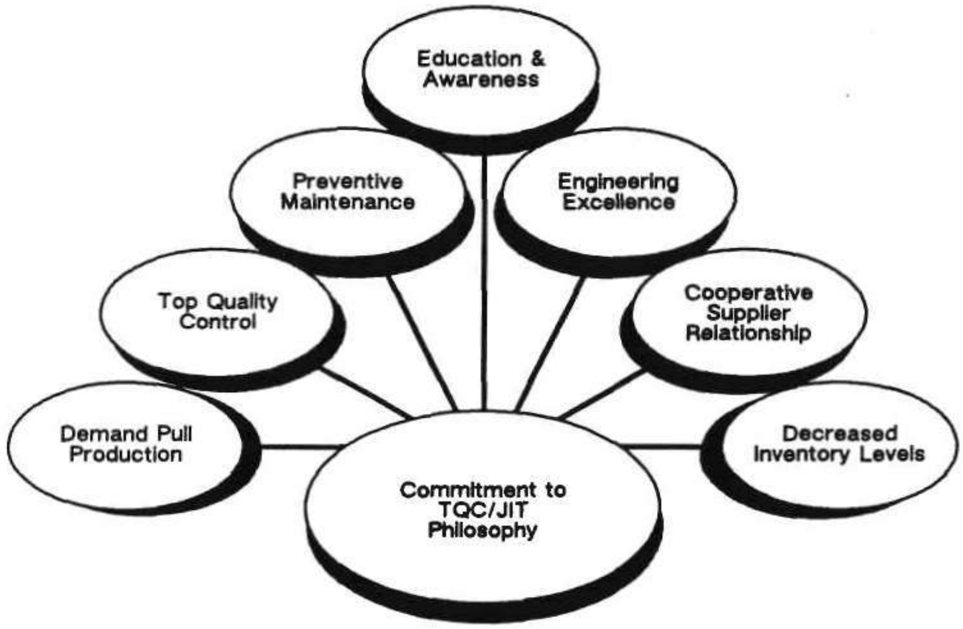
Just-in-Time (JIT) Manufacturing and Purchasing

JIT or "demand-pull" manufacturing and purchasing is a philosophy that requires total management commitment to production and quality improvement across all operational departments in a company's supply chain. JIT has been implemented in the automotive, consumer electronics, computer, and semiconductor industries. Elements of the JIT method are shown in Figure 3.

©1990 Dataquest Incorporated August
Reference material—will not be republished

Figure 3

Elements of the Just-in-Time Method



Source: Hewlett-Packard Company

When fully implemented, JIT programs benefit both users and manufacturers. Benefits to the manufacturers include:

- Reduced inventory
- Better space utilization
- Improved budget control
- More efficient labor utilization
- Reduced manufacturing cost
- Closer vendor/user relationships
- Long-term productivity gains
- A potentially automated environment
- Improved raw material quality
- Daily delivery of component materials
- Tightly controlled manufacturing flow

©1990 Dataquest Incorporated August
Reference material—will not be republished

Benefits to the users include:

- Single sourcing
- Longer-term contracts
- Shorter lead times
- Monthly rolling forecasts to vendors (one year out)
- Frequent deliveries—daily/weekly
- 100 percent good quality—on-time, right quantity, no inspection
- Engineering aids, if required
- Frequent visits—minimum one per year
- Use of local sources where possible
- Freight consolidation program
- Minimum paperwork
- Vendor training
- Standard packaging
- End of adversarial relationship

JIT requires a teamwork attitude between vendors and users for success. As more and more companies implement JIT inventory techniques, the role of purchasing will expand. Hewlett-Packard began introducing JIT purchasing at its Greeley Division, Colorado, in 1982; by 1984, the following had been achieved:

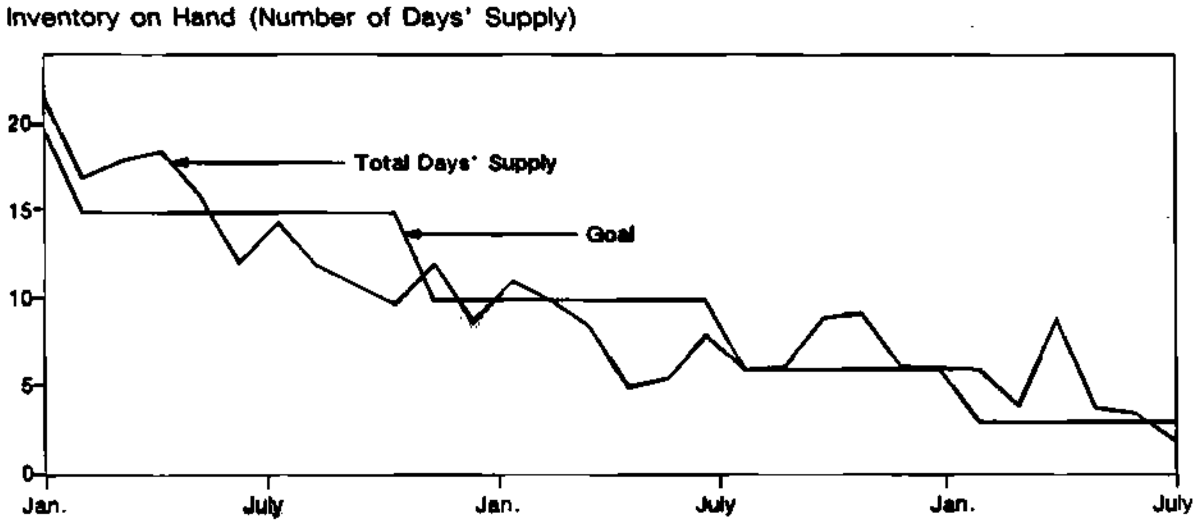
- Inventory was reduced from 2.8 months to 1.3 months.
- Stockroom space was reduced 50 percent.
- Twenty vendors were supplying 45 parts on JIT.
- All employees were trained and aware of the JIT program.
- A task force was formed to address JIT system needs.
- Several lines were converted to progressive build.
- Many production efficiency and quality problems were exposed and solved.

Figure 4 illustrates the changes occurring from 1982 through 1984 in inventory control at the Hewlett-Packard Greeley Division.

©1990 Dataquest Incorporated August
Reference material—will not be republished

Figure 4

Hewlett-Packard Company
Greeley, Colorado
JIT Program



	1982	1984
Production Output	$40 Million	$120 Million
Production Space Utilized	86,000 Square Feet	67,000 Square Feet
Number of Vendors	384	200

Source: Hewlett-Packard Company

JIT Transportation

Successful JIT manufacturing involves lean inventories. Skyway Systems, Inc., located in Santa Cruz, California, is one of a limited number of transportation companies that understands and specializes in JIT delivery. Skyway Systems relies on an extensive computerized system to determine the customers' needs in terms of quantity, delivery time, and location. Skyway estimates that it can save its customers 30 to 40 percent of the total material transportation expenses.

Companies currently enjoying the benefits of JIT transportation include:

- Apple Computer, Inc.
- Hewlett-Packard Company
- IBM Corporation
- National Semiconductor Corporation
- Tandem Computers, Inc.

©1990 Dataquest Incorporated August
Reference material—will not be republished

Zero Defect Programs

In order to achieve outgoing levels of quality on the order of 100 parts per million (ppm), down from an industry practice of 10,000 ppm, Signetics Corporation began implementing its Zero Defect Program in 1979. At this time, only 75 to 85 percent of all raw materials met Signetics' incoming specifications. The company was waiving 15 percent of all raw materials, even though this would possibly be detrimental to yield and could possibly cause field reliability failures. Signetics actually returned only about 5 percent to the supplier and then only after long negotiations. It was not uncommon to have as much as a $500,000 in potential returns lying around for four months. The company received approximately five complaints per week from various assembly plants and fab areas about the use of bad material that had either been waived or passed during incoming inspection. Material procurement priorities were rated in the following order:

- Buy at the lowest price
- Buy according to delivery schedules
- Buy according to quality

Signetics formed a quality improvement team that would work with suppliers to ship defect-free materials. The team developed six major programs to deal with the following:

- Vendor specifications
- Vendor certification
- Vendor corrective action
- Vendor communications
- Vendor rating
- File code system

Vendor Specifications

Under this program, Signetics determined which of its vendors could meet Signetics' specifications and requirements prior to making purchase orders.

Vendor Certification

This program consists of five phases. Phase one involves agreement between the vendor and Signetics on inspection measurement procedures, techniques, and the frequency of inspection equipment calibration. Every supplier completing three consecutive months of 100 percent sample and data delivery with each shipment is certified.

Phase two involves material conformance control analysis. Control charts are used to track the vendor's performance to specification. When a vendor exhibits consistent control for a three-month period, the vendor proceeds to phase three.

During phase three, the vendor pulls all of the samples and does a complete outgoing inspection. At Signetics' discretion, the vendor's samples are used—either in part or in total. A vendor exhibiting three-month consistent control in this phase can move on to the next phase.

©1990 Dataquest Incorporated August
Reference material—will not be republished

In phase four, Signetics' incoming inspection team audits the vendor's samples and data for preshipment or skip-lot inspection. In this phase, the vendor supplies control samples and data, complete lot inspection samples and data, and a certificate of compliance. All the data supplied are reviewed for inspection correlation and conformance.

During phase five, the incoming quality control group identifies the continuous monitoring and auditing of phases one through four. Any nonconformance issues and/or inspection correlation problems result in an immediate stop to flexible lot sampling. Resumption occurs when all issues are resolved.

In 1981, 3 out of 20 suppliers chosen by Signetics had completed correlation with Signetics' incoming inspection. By 1986, 46 out of 52 of its vendors were certified.

Vendor Corrective Action

In this program, meetings chaired by the purchasing department are held to review specific shipments of nonconforming material and to determine which suppliers are to be solicited for formal, documented corrective action. The suppliers' responses are thoroughly reviewed to ensure that the true cause of the problem has been addressed and corrected. Band-aid responses are immediately rejected and resolicited. Evidence that permanent solutions are in place is tracked. Vendors are rewarded by way of increased business or penalized by reduced business as a means of highlighting the importance of the company's quality program.

Vendor Communications

The fourth program permits and encourages open lines of communication between Signetics and its suppliers. This program is administered by the purchasing department, and the program provides reports and graphs that track a supplier's quality performance through the following:

- Performance graphs—illustrating vendor year-to-date lot acceptance and defects in ppm
- Performance summaries—measuring the vendor's on-time delivery by month and year-to-date
- Purchase order history performance
- Quality history performance by purchase order
- Defects history performance by purchase order
- Vendor certification correlation graphs

This information advises suppliers of the quality history for the current month, year-to-date quality history, and trend information aimed at a goal of defect prevention. In addition, quality improvement presentations are developed prior to vendor presentations to redefine quality standards and reaffirm the zero-defect commitment. Open lines of communication keep Signetics and its suppliers aware of quality and availability issues. Defect prevention rather than appraisal is emphasized.

©1990 Dataquest Incorporated August
Reference material—will not be republished

Vendor Rating

Vendor rating was developed to evaluate quality, delivery, and processing costs equally. The numerical rating compares each vendor within a commodity area. Monthly ratings are developed by incoming quality control departments. Quarterly ratings are mailed to suppliers to notify them of their rankings. Signetics devised the following vendor rating formula:

VQR = Vendor quality rating
Q = Quality of material measured at incoming inspection
P = Quality of performance or on-time delivery
C = Cost of inspection and all nonconformance correction time costs

Thus:
$Q + P + C = VQR$

Vendors with the lowest score in each commodity area are recognized twice each year with a plaque and a letter of appreciation. Those scoring well are further awarded by additional business activity. Those scoring poorly are approached to reaffirm their defect-prevention commitment or face the possibility of losing their share of the business.

File Code System

This system was established to monitor the raw-material performance at Signetics' fab, plating, and assembly operations. The percentage of material that is acceptable and usable in the process, with zero defects, according to specifications, is measured. The formula used is the quantity found defective, divided by the total quantity received, multiplied by 100.

In 1983, Signetics' Zero Defect Program was three years old and deemed successful. The incoming raw material was defect-free and always on time; however, inventory was excessive. Although Signetics had achieved massive improvements in the material quality system, the decision was made to apply a JIT philosophy. Signetics called its JIT program "When It's Needed" (WIN). Signetics created a seven-step approach to implement its WIN program. The steps included:

- Management commitment—Visible management support necessary to meet WIN inventory targets
- A statement of purpose—A policy to form a team to plan, direct, and manage the WIN inventory program worldwide
- Measurement—The measure and display of current and past performance in terms of inventory effectiveness
- Awareness—To ensure that all involved personnel are aware of the ramifications and objectives of the WIN program
- Corrective action—To provide a formal, systematic method of resolving forever the problem identified in the other steps
- Training—To ensure that all directly involved employees completely understand their roles in the WIN program along with its effects, benefits, and requirements
- Goal setting—To set time goals to achieve the WIN objectives

©1990 Dataquest Incorporated August
Reference material—will not be republished

When fully implemented, zero defect programs can benefit both users and manufacturers. Benefits to Signetics' suppliers include:

- Guaranteed long-term unchanging schedules
- Improved invoice payment schedules
- Immediate feedback on any quality-related issues
- Improved supplier/vendor relationships

Benefits to Signetics include:

- The lot acceptance rate steadily increased from 80.0 percent in 1980 to 98.1 percent in 1985.
- Lot waivers dropped from 134 in 1980 to none by 1982.
- Less than 0.5 percent of accepted material was found unsuitable.
- Ninety percent of all scheduled deliveries now meet a five-day window; the other 10 percent of deliveries are held up by ship dockage and/or foreign customs clearance.
- Delinquencies to end customers, caused by a lack of raw material, currently are less than 0.5 percent.
- Inventory turns increased from 28 initially to more than 80.
- As a percent of sales, materials fell from 3.5 percent in 1983 to 1.5 percent in 1986.

FUTURE DEVELOPMENTS

In the next few years, automation and robotics will play an increasingly more important role in the semiconductor industry. A computer hierarchy will control the automated assembly areas, and the robots will perform the tasks.

Computer-Integrated Manufacturing (CIM)

CIM is a computer-centered distributed communications network that links all phases of design, manufacturing, and automation, as well as quality, cost, and inventory control. Dataquest believes that the driving forces behind implementation of CIM include:

- International competition
- Demand for cost reduction
- Demand for improved customer service
- Demand for quality
- Need for flexibility in manufacturing
- Decreasing costs of data processing and storage

Currently, only a small percent of all semiconductor fabs have committed to a commercially available CIM system. Some of the perceived barriers causing the lag in semiconductor automation include:

- High cost of system integration

©1990 Dataquest Incorporated August
Reference material—will not be republished

- Lack of user understanding
- Lack of interface standards
- Need for in-plant sharing of responsibilities

Capabilities of the standard CIM software packages include:

- Work-in-process tracking and management
- Inventory status management
- Equipment status management
- Data collection and storage
- Statistical quality control
- Out-of-specification warnings
- Production reporting
- Complete on-line documentation
- Revision level control of processing specifications
- Engineering analysis

Several major semiconductor manufacturers and users are employing CIM and CIM applications software in assembly areas. National Semiconductor Corporation and Digital Equipment Corporation have recently signed an agreement to jointly develop a factory automation software project, called Odyssey, for semiconductor manufacturing. The Odyssey software is designed to automate the entire IC production process using the Semiconductor Equipment and Materials Institute's (SEMI's) equipment communications standard called SECS.

Other software systems being used for factory management and automation in the semiconductor industry are COMETS and PROMIS. COMETS (Comprehensive On-line Manufacturing and Engineering Tracking System) is produced by Consilium of Palo Alto, California. PROMIS (Process Management and Information Systems) is produced by I.P. Sharp Associates of Canada and marketed by the PROMIS Group of Santa Clara, California. Both software programs allow semiconductor manufacturers to obtain more control over their manufacturing processes with an end result of increased yields in the fabrication of semiconductors. Enhansys, Inc., produces a software system being used by semiconductor manufacturers and users in conjunction with COMETS and PROMIS. The Enhansys system provides extensive mathematical and statistical analysis functions that extend the analysis capability of COMETS and PROMIS.

MILITARY SPECIFICATION PROCESSING FLOWS

Overview

Table 1 covers one company's process flows for JAN, Standard Military Drawings (SMD), MIL-STD-883C, and various military temperature range flows (e.g., MEP). Table 2 shows the Class B and Class S differences, along with a custom S or level S methodology for a particular company.

©1990 Dataquest Incorporated August
Reference material—will not be republished

Table 1

Product Flows Screening and Quality Conformance Testing Requirements

SCREEN (Class B Product)	METHOD (All screens per 5004 Class B)	MIL-M-38510 JAN	STANDARD MIL DRAWING SMD/DESC	MIL STD 883C	MEP 1	MEP 2	MEP 3
Internal Visual (Precap)	2010 Condition B and 38510	100%	100%	100%	Assembly and Screens per MPO 12MRY01742		
Temperature Cycling Constant Acceleration	1010 Condition C 2001 Condition E (min) in Y1 Plane	100% 100%	100% 100%	100% 100%	Assembly and Screen per MPO 12MRY01742		
Seal Fine & Gross	1014, Conditions B & C	100%	100%	100%	100%	100%	100%
Interim Electrical	Optional	MPO uses JAN Slash Sheet	MPO uses SMD/ DESC Dwg.	Per Applicable Device Electrical Specification Listed In Test Program Column in 883 Section			
Burn-in Test	1015 160 hours @ 125°C or equivalent	100%	100%	100%	100%	100%	-----
PIND	2020 Cond. A	-----	-----	-----	100%	-----	-----
Final Electrical Tests	Jan Slash Sheet or SMD/DESC Dwg or Motorola Spec	Per Jan Slash Sheet Electrical Spec	Per SMD/DESC Dwg Electrical Spec	Per Applicable Device Electrical Specification Listed In Test Program Column in 883 Section			
(A) Static Tests							
(1) 25°C (96 hr Req't and PDA Apply)	Subgroup 1,Table 1 5005	100%	100%	100%	100%	100%	100%
(2) Max &Min rated oper. temperatures	Subgroups 2 & 3 Table 1, 5005	100%	100%	100%	100%	100%	100%
(B) Dynamic Tests or Switching Tests 25°C	Subgroup 4 or 9 Table 1, 5005	100%	100%	100%	100%	100%	100%
(C) Functional Test 25°C	Subgroup 7, Table 1, 5005	100%	100%	100%	100%	100%	100%
Quality Conformance Inspection: Group A (A)Static Tests (1) 25°C (2)Max & Min Rated Oper Temps (B)Dynamic or Switching Tests (1) 25 C (2)Max & Min Rated Oper Temps (C)Functional Tests (1) 25 C	QCI per 5005 Class B Table 1 Subgroup 1 Subgroup 2 & 3 Subgroup 4 or 9 Subgroup 5 & 6 or 10 & 11 Subgroup 7	The sample size/rejects allowed defined in Table 1 Method 5005 is 116/0 for each subgroup or predefined set of subgroups (tests defined in appropriate device specification) Motorola utilizes a considerably tightened sampling plan of 500/0 for all +25°C tests and 250/0 for all min/max oper. temp. tests			The sample size/rejects allowed is 116/0 per 5005 for each subgroup or predefined set of subgroups (tests defined in appropriate device specification in Test Pgm column in 883 section)		
Group B (B02,B03,B05)	5005 Class B	Each Insp Lot	Each Insp. Lot		Each Inspection Lot (Except no B05 MEP3)		
Group C (Die Related)	5005 Class B	Every Quarter	Every Quarter		Not Required		
Group D (Package Related)	5005 Class B	Every 36 weeks	Every 52 weeks		Not Required		
External Visual	2009	100%	100%	100%	100%	100%	100%
Assembly Test Location		Tempe Az	Malaysia	Malaysia	Malaysia	Malaysia	Malaysia
Certification		DESC	DESC/MPO	MPO	MPO	MPO	MPO
Data		C of C, Summary Data	C of C, Summary Data	C of C Summ.Data	C of C	C of C	C of C

Source: Motorola Military Products Organization (MPO)

©1990 Dataquest Incorporated August
Reference material—will not be republished

Table 2

Class Band "S" Flow Product Assurance Requirements

Requirements	JAN 38510 Class "S"	JAN 38510 Class "B"	Motorola Class "S" (12MRM51815A)
Qualification, General	X	X	X (by MPO)
Line Certification	X	X	X (by MPO)
Device (Groups A,B,C,D,E of 5005)	X	X	X
Wafer Lot Acceptance	X		X (per internal spec. Similar to 5007. SEM or current density)
Traceability	X	X	X
GSI	X	X	X
In-process inspection	X	X	X
Screening (5004)	X	X	X
Precap Visual	2010A (GSI/CSI) Per 38510	2010B or ALT. or Alt. Per 38510	(CSI/GSI) 2010A
Temp Cycle	X	X	X (50 cycle min.)
Constant Acceleration	X	X	X
PIND	X		X
Serialization	X		X (Lot size not limited)
Interim Electrical	X		X
Burn-In	240 Hrs.	160 Hrs. or equivalent	240 hours or equivalent
Seal (Fine/Gross Leak)	X	X	X
Final Electrical	X	X	X
Radiographic	X		X
External Visual	X	X	X
Nondestruct 100% Bond Pull	X		
Quality Conformance (5005)	X	X	X
Group A (Each Lot/Sublot)	X	X	X
Group B (Each Lot)	X	X or ALT B	X or ALT B
Group C (Periodic-Die Related)	X	X	X
Group D (Periodic Package Related)	X	X	X

(X indicates requirement)
Shipment Prior to completion of Groups C, D.
Remarking okay.
Change control per Motorola procedure-meets 38510 intent.
Source: Motorola

Figure 5 presents the overview of the Qualified Manufacturer's List (QML) qualification flow; Table 3 defines some of the important concepts of QML. Figure 6 highlights the Cenelec Electronic Components Committee (CECC) 9000 (ICs) Class B and D processing flows for European programs.

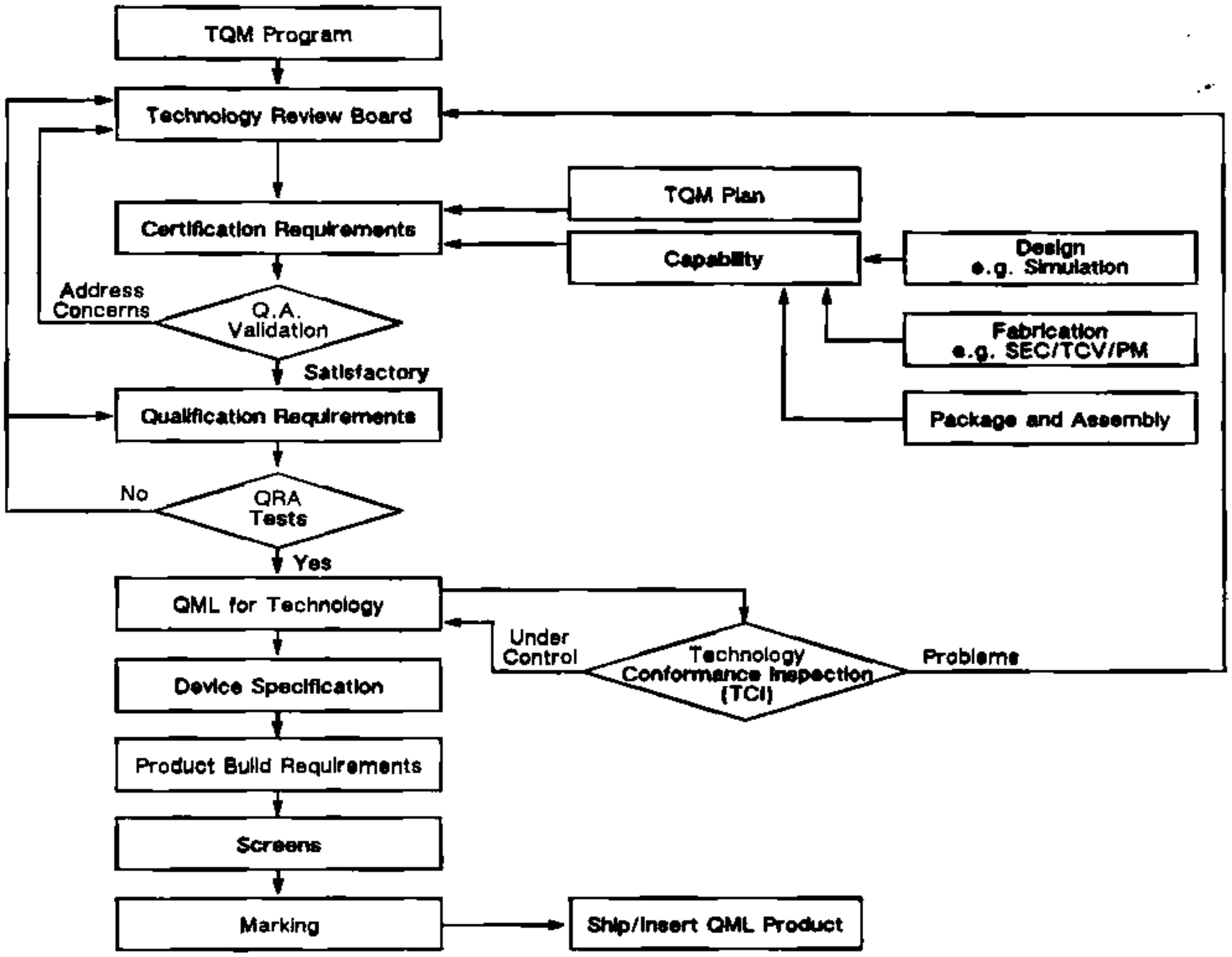
Terminology

A Mil/aero products glossary is shown in Appendix A.

©1990 Dataquest Incorporated August
Reference material—will not be republished

Figure 5

General QML Qualification Flow Diagram



Source: US Department of Defense

©1990 Dataquest Incorporated August
Reference material—will not be republished

Table 3

QML Concepts

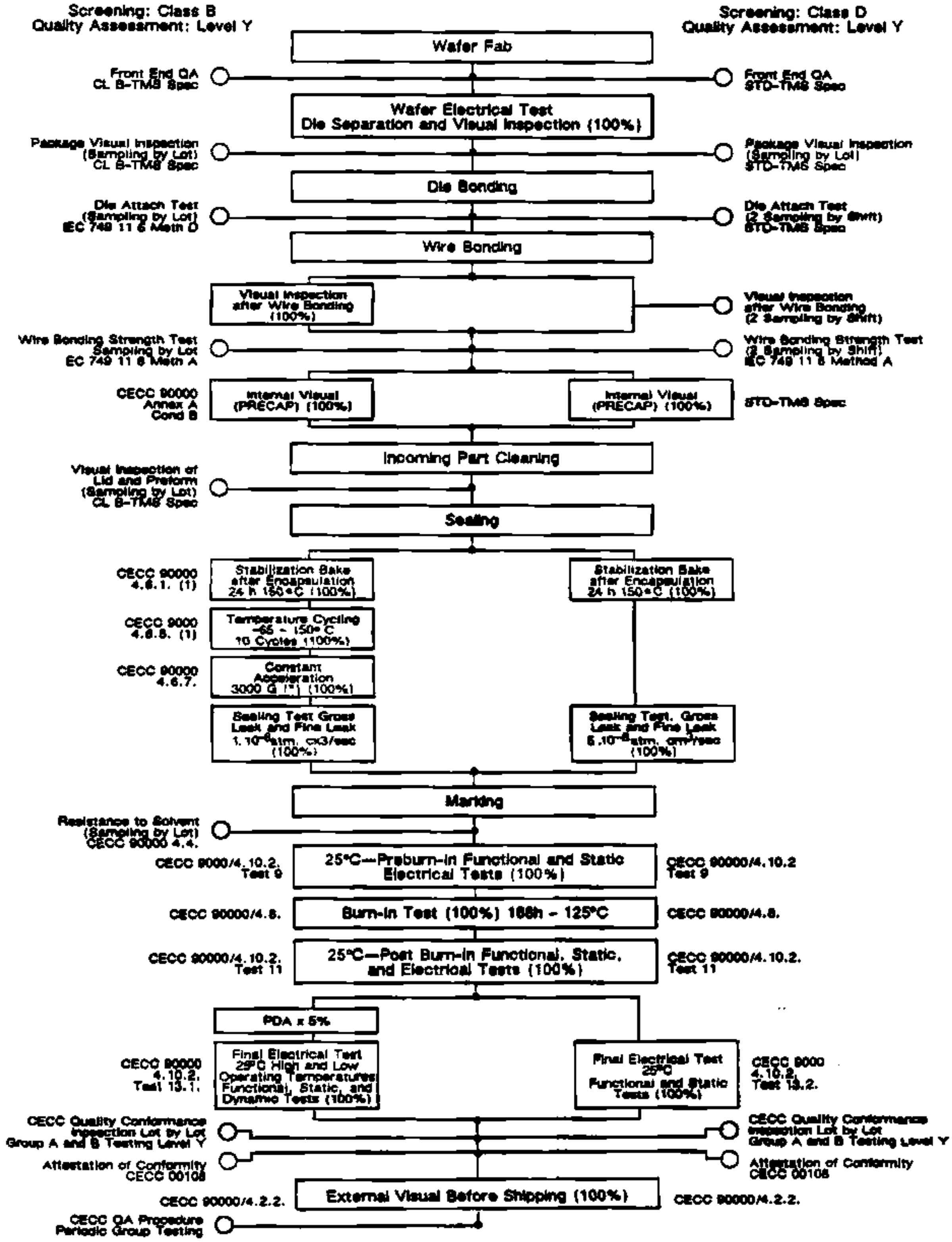
- The philosophy of generic qualification incorporates the idea that high-quality and reliable microcircuits can be obtained without excessive testing if the processes are properly monitored and controlled at each step of the manufacturing line. The following paragraphs describe the monitors and controls that may be used:
- The design procedure and tools are controlled in such a manner that the ensuing microcircuit design performs only with limits that have been shown to be reliable for the technology being used, within the constraints of established design rules (electrical, geometric, and reliability).
- The mask fabrication facility is controlled such that an error-free mask is produced from the microcircuit design database. Monitoring, controlling, and reducing defect density is helpful in obtaining error-free masks.
- The wafer fabrication process is controlled with the following: use of in-line statistical control; a Parametric Monitor (PM) structure for measuring electrical parameters; a Technology Characterization Vehicle (TCV) structure to study intrinsic reliability mechanisms; and a Standard Evaluation Circuit (SEC) to monitor the fabrication process and to serve as a surrogate microcircuit for reliability testing.
- The package/assembly facility is controlled with emphasis on in-line statistical process control of all assembly steps and package certification prior to microcircuit assembly.
- The test area controls consist of test equipment accuracy and calibration as well as a controlled interface to the microcircuit design center.
- The overall control of the processes are under the auspices of a Technology Review Board (TRB), which is established by the manufacturer. The TRB is solely responsible for the QML flow that has been certified and qualified.
- For radiation-hard devices (hereby designated as RHA), procedures and requirements are integrate into the document for establishing and demonstrating a Radiation-Hardened Assurance Capability Level (RHACL) for the technology. Many device-oriented tests can be reduced or eliminated when correlation data for models and test structures have been established by the TRB. The main concern in the RHA community is whether the device specification accurately describes the device performance in the radiation environment specified. Until such models and test structures are developed, some actual device radiation testing will be required.

Source: US Department of Defense

©1990 Dataquest Incorporated August
Reference material—will not be republished

Figure 6

CECC 90000 Flow Diagram



Source: Thomson Military & Space (TMS)

©1990 Dataquest Incorporated August
Reference material—will not be republished

Appendix A

ACCELERATED BURN-IN

Same as burn-in except a higher temperature (nominally at +150°C) is used over a reduced time period. Accelerated testing is not allowed for Class S devices.

ATTRIBUTES DATA

Go-No-Go data; pass/fail and number of rejects recorded; typical requirements for post-burn-in electrical tests on Class B devices. (See **Variables Data** definition.)

BURN-IN

A screening operation subjecting devices to high temperature (commonly at +125°C) and normal power and operation of 160 hours (Class B) or 240 hours (Class S).

CLASSES S AND B

Product assurance levels of screening, sampling, and documentation control requirements. Sometimes referred to as Levels S and B.

Class S: For manned space flight or extremely high-reliability aerospace applications requiring condition A precap visual, SEM, 240-hour burn-in, and elaborate qualification and quality-conformance testing. Normally requires much data/documentation/program planning. Class S processing incurs considerable costs.

Class B: For unmanned flight applications or high-reliability ground support systems. These devices are the most frequently procured military ICs. Class B processing requires burn-in, precap visual, and other tests.

DESC DRAWINGS

Initiated in 1976 to standardize the screening requirements for military components, the DESC drawing was viewed as a preliminary specification prior to JAN approval. As such, it ranks second in the order of purchasing hierarchy to JAN. The current evolution of the DESC drawing is now called Standard Military Drawing. (See **Standard Military Drawing** definition.)

DPA (DESTRUCTIVE PHYSICAL ANALYSIS)

Finished products are opened and analyzed.

©1990 Dataquest Incorporated August
Reference material—will not be republished

GENERIC DATA

Data pertaining to a device family—not necessarily on a specific part but representative of it. Group C and D generic data can be supplied in lieu of qualification or quality conformance when applicable.

GROUP A

Electrical test sampling performed on each lot. Testing is performed on all subgroups as defined in Test Method 5005.

GROUP B

Environmental/wear-and-tear/visual sample tests defined in Test Method 5005.

GROUP C

Operating life sample testing for die reliability. Defined in Test Method 5005 and performed every 3 months per MIL-M-38510.

GROUP D

Environmental sample tests to verify die and package reliability. Performed every 6 months per MIL-M-38510.

JAN (JOINT ARMY NAVY)

Registered trademark of the U.S. government indicating that a device is fully compliant to MIL-M-38510.

MIL-M-38510

General specification for ICs. Revision H is the current revision.

M38510/XXXXXXX:

Detail specification or "slash sheets" for ICs.

MIL-STD-883:

Test methods for ICs covering various mechanical, environmental, and electrical processing. Revision C is the current version of MIL-STD-883.

NDBP

Nondestructive Bond Pull.

©1990 Dataquest Incorporated August
Reference material—will not be republished

OPERATING LIFE TEST

Sample test (Qualification and Quality Conformance) using the same conditions as burn-in, but duration is usually 1,000 hours.

PDA (PERCENT DEFECTIVE ALLOWABLE)

Criteria sometimes applied to a burn-in screen. A 5 percent PDA per MIL-STD-883 means that if more than 5 percent of a sampled lot fails post-burn-in electrical tests, the lot is considered failing the percent defective allowable.

PIND TESTING (PARTICLE IMPACT NOISE DETECTION)

An audio/visual screening test that identifies devices containing internal loose particles. Repeatability of test results is questionable. This test is required for Class S ICs.

PRESEAL VISUAL

Screening procedure involving microscopic inspection of the die prior to encapsulation.

PRODUCT QUALITY

Quality level of a product at any given time; can be simply stated as the percentage of the defective units found in a given lot. AQL (Acceptance Quality Level) and LTPD (Lot Tolerance Percent Defective) are commonly used sampling-plan measurement criteria.

PRODUCT RELIABILITY

Quality level of a product over a specific time span. Reliability is usually expressed and measured in terms of Failure Rate (e.g., 0.002 percent per 1,000 hours at 60 percent confidence level at +25°C) or MTBF (Mean Time Between Failure) in hours.

QUALIFICATION TESTING

Initial one-time sample tests that determine the effectiveness and reliability of the device design and fabrication process. Usually means Groups A, B, C, and D testing for ICs.

QUALITY CONFORMANCE TESTING

Sample tests performed at prescribed intervals per MIL-M-38510 and MIL-STD-883 to assure that the processes are in control to ensure the continuing quality level of the product under test.

READ AND RECORD DATA

Same as **Variables Data.**

©1990 Dataquest Incorporated August
Reference material—will not be republished

SEM INSPECTION (SCANNING ELECTRON MICROSCOPE)

Photographic inspection for metalization effects on die surfaces taken at very high magnification. Required inspection for Class S devices.

SCREENING

Operation performed on devices on a 100 percent basis, such as precap visual, burn-in, hermeticity, and 10 percent electrical test. Test Method 5004 defines the screening flow.

SOURCE CONTROL DRAWINGS (SCDS)

User-generated drawings containing processing and electrical test requirements generally in accordance with MIL-M-38510 and MIL-STD-883.

SOURCE INSPECTION

A customer or government representative witnessing or performing an in-process operation (test) on a specific production lot. Commonly identified process points for source inspection are precap visual, final test, and pre-ship.

STANDARD MILITARY DRAWING

Evolved from the ESC Drawing Program to control the proliferation of nonstandard Source Control Drawings. The Standard Military Drawing provides standardized MIL-STD-883 processing in conjunction with non-JAN devices as specified in Para. 1.2.1 or MIL-STD-883.

VARIABLES DATA

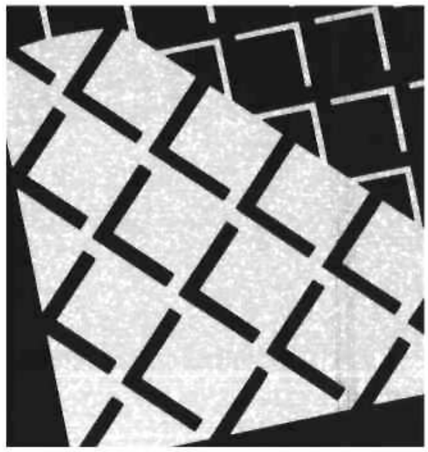
Electrical parameters recorded before and after burn-in for certain tests in Groups B, C, and D or any recorded data obtained during a screening test, i.e., bond pull—record pull strength at time of break (in grams).

WAFER LOT ACCEPTANCE

A combination of physical and electrical testing performed, on a sample basis, on a wafer lot to determine acceptance for use as Class S devices.

Source: Precision Monolithics

©1990 Dataquest Incorporated August
Reference material—will not be republished



Military Semiconductor Pricing

Dataquest

a company of
The Dun & Bradstreet Corporation

Published by Dataquest Incorporated

The content of this report represents our interpretation and analysis of information generally available to the public or released by knowledgeable individuals in the subject industry, but is not guaranteed as to accuracy or completeness. It does not contain material provided to us in confidence by our clients.

Printed in the United States of America. All rights reserved. No part of this publication may be reproduced, stored in retrieval systems, or transmitted, in any form or by any means—mechanical, electronic, photocopying, duplicating, microfilming, videotape, or otherwise—without the prior written permission of the publisher.

© 1991 Dataquest Incorporated
February 1991

Chapter 1

Military Semiconductor Pricing

INTRODUCTION

This booklet provides a price forecast and analysis for military specification semiconductor products. The first part of this booklet presents a general overview of the nature and dynamics of military pricing; the second part is our price forecast and analysis.

INFLUENTIAL FACTORS

There are numerous influences on the market price of military specification semiconductor components. However, a handful of common recurring factors are helpful when projecting estimates of price movements. These factors are the business cycle, the life cycle position, and key extraordinary events.

Business Cycle

Cyclical swings in the electronic equipment industry affects the semiconductor price structure. In the case of military-grade semiconductors, their prices can be affected by conditions in both the commercial electronic industry and the defense industry. This is because military-grade merchant products are typically derived from commercial R&D and production lines.

Business cycles disturb the delicate balance of supply and demand for semiconductors. Prices usually are driven up when demand exceeds supply, as shown by what happened to DRAM prices in 1988. Prices can be driven down when demand slackens and pipeline inventory (including distributors) increases and suppliers drop prices to continue moving products.

Industry capacity utilization also has a pronounced impact on pricing. During periods of high utilization, prices are usually forced up, and likewise are forced down during periods of low utilization.

Another manifestation of the business cycle is the effect on the commercial-military production mix coming out of vendor factories. For example, if the commercial semiconductor sector is strong, this strength can sometimes starve off supply to the military customers. This results in raising prices to military customers because of their unique requirements.

Life Cycle Position

Semiconductor product categories have a market life that can be as short as 3 years or as long as 20 years. Prices typically trend down as the technology matures and competitive products emerge, as shown in Figure 1.1. Improvements in yield and manufacturing techniques are often a prerequisite to downward price trends. If effective second sourcing or product substitution is accomplished, it creates a condition in which prices can move downward because of competitive positioning for market share. Often during the sunset phase of a product, when the supply base is thinning, prices can rise because of slackened competitive bidding and increased opportunity costs for the vendors.

Extraordinary Factors

These are the various nonmarket-derived factors that can impact pricing. For example, the recent fair market value (FMV) price system with the Japanese semiconductor companies has had a significant effect on certain memory IC categories.

Military Specific Factors

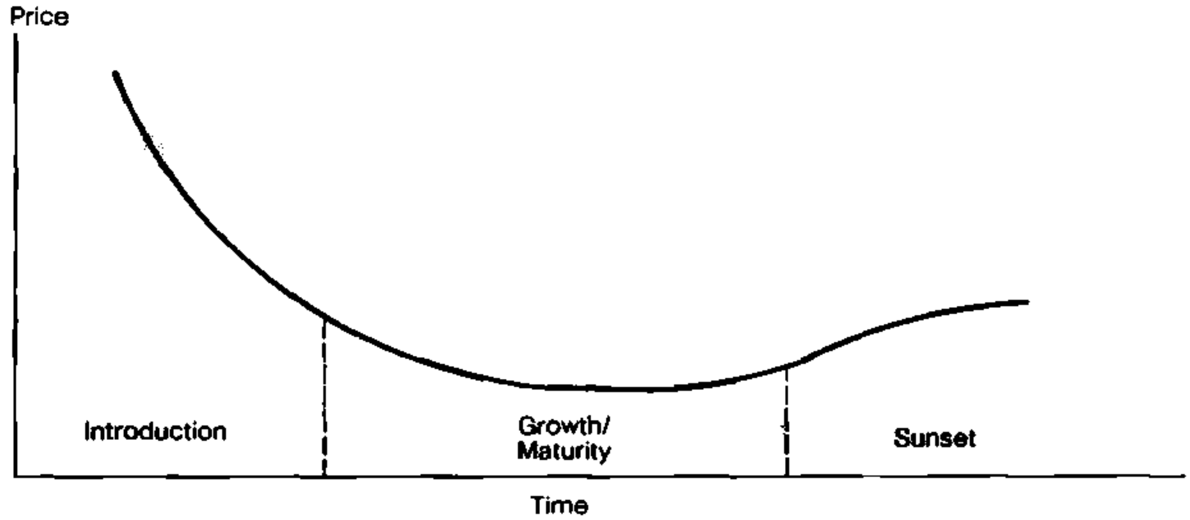
Most merchant semiconductor products are derived from commercial fabrication lines, and thus variations in commercial pricing can affect JAN MIL-STD-883C BS-9000 and CECC pricing significantly. However, there are certain dynamics to the high-reliability market that can force prices to deviate from the commercial starting point. Most of these dynamics are the same as those mentioned above, but they are derived from business conditions and procurement practices peculiar to the military/aerospace industries. These dynamics include the following:

- Defense Spending—Impacts the demand for products in general
- SMD/883/QPL/CECC Qualifications—Breadth of supply base affects competitive factor.
- Life Cycle Position—Similar effect as for commercial product, except learning curve knowledge extends to additional military design features (e.g., radiation tolerance), manufacturing (e.g., ceramic packaging) and mil-spec screening and documentation.

©1991 Dataquest Incorporated February—Reproduction Prohibited

Figure 1.1

Generic Semiconductor Price Life Cycle



Source: Dataquest (February 1991)

GENERAL MILITARY PRICING ATTRIBUTES

Figure 1.2 presents a generic price comparison for different grades of semiconductor products. With commercial-grade (commercial temperature range and plastic package) equal to one on a price index, a MIL-STD-883C Class B product is typically 6, JAN product is 15, and Class S product is 50. The premium for military-grade pricing is justified because of the relatively expensive ceramic packaging and assembly techniques, extensive screening to precise electrical and mechanical specifications, burn-in charges, quality conformance checks, and the documentation that accompanies each lot. JAN products have the additional requirement of being assembled entirely in the high-labor cost United States or selected NATO countries. It should be noted that we have found little evidence that standard military drawing (SMD) prices varied significantly from MIL-STD-883C prices.

Figure 1.3 lists a similar index that compares various product categories for MIL-STD-883C product categories. Currently, commodity standard logic, EPROMs, and EEPROMs have the lowest multipliers, at four times commercial plastic prices. The reason for this relatively low multiplier is that each of these products is experiencing intensive competition, and, in the standard logic case, it is being displaced extensively by ASICs.

Gate arrays and microprocessors have multipliers of greater than 10. The gate-array multiplier exists because of the emerging nature of that technology in military applications. The high multiplier for microprocessors is due to the relatively small order quantities that must amortize the fixed expenses of supporting the mil-spec business.

Our surveys show that there are adders for small order quantities, surface-mount packaging, and special radiation-tolerant features. On average, the surface-mount premium can run anywhere from 10 to 40 percent, depending on the pin count and availability. Products with radiation-tolerant features that are purchased expressly from manufacturers can fetch as much as 10 times the price of the normal 883C Class B version.

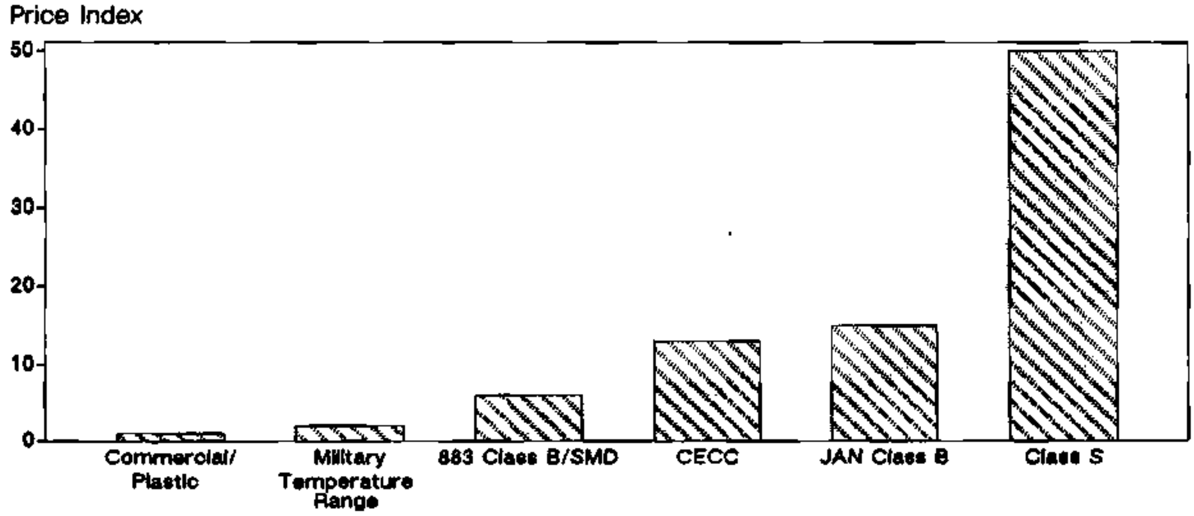
Military Semiconductor Pricing

Tables 1.1 through 1.14 present military-grade semiconductor pricing estimates and forecasts. These are based on surveys of suppliers and users, as well as Dataquest model results.

©1991 Dataquest Incorporated February—Reproduction Prohibited

Figure 1.2

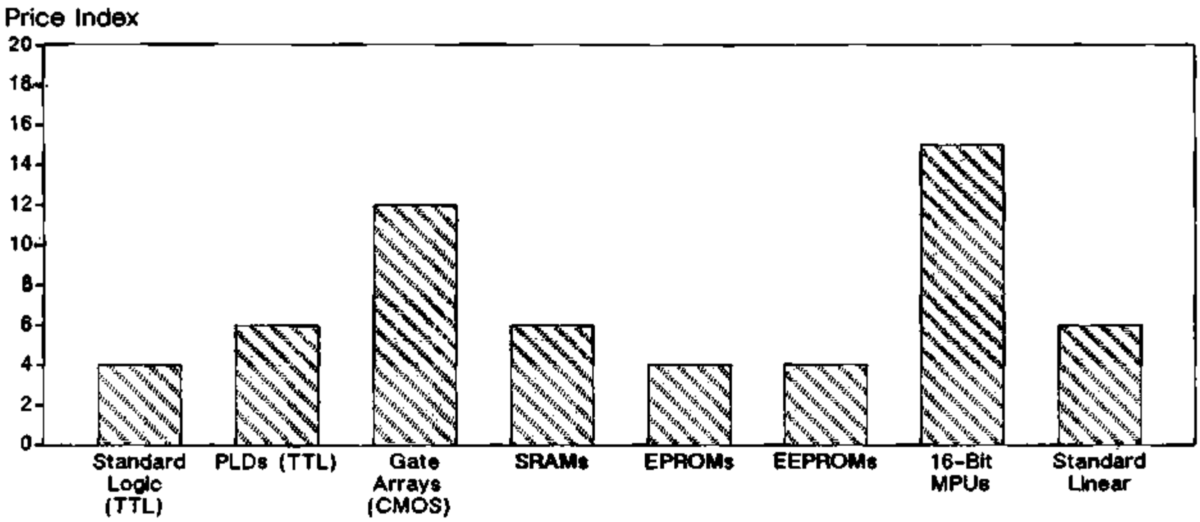
Generic Semiconductor Price Comparisons by Grade



Source: Dataquest (February 1991)

Figure 1.3

MIL-STD-883C versus Commercial Plastic



Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.1

Standard Logic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

	1989	1990	1991	1992	1993	Lead Time (Weeks)
54LS TTL						
54LS00 (Quad 2 input nand)						
38510	0.95	0.97	1.05	1.14	1.23	8
883/SMD	0.42	0.43	0.46	0.49	0.52	
54LS74 (Dual D flip-flop)						
38510	0.94	0.96	1.04	1.12	1.21	
883/SMD	0.49	0.49	0.53	0.56	0.61	
54LS245 (Octal noninverting bus transceiver)						
38510	1.85	1.85	1.98	2.12	2.28	
883/SMD	1.08	1.09	1.15	1.21	1.28	
54S TTL						10
54S00 (Quad 2 input nand)						
38510	1.63	1.65	1.70	1.75	1.81	
883/SMD	0.62	0.63	0.67	0.69	0.71	
54S74 (Dual D flip-flop)						
38510	1.82	1.83	1.87	1.92	1.97	
883/SMD	0.73	0.71	0.73	0.74	0.76	
54S240 (Octal inverting buffer/driver)						
883/SMD	1.64	1.86	1.92	1.98	2.04	
54F TTL						10
54F00 (Quad 2 input nand)						
38510	1.12	1.12	1.14	1.18	1.21	
883/SMD	0.64	0.64	0.66	0.68	0.70	

(Continued)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.1 (Continued)

Standard Logic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

	1989	1990	1991	1992	1993	Lead Time (Weeks)
54F74 (Dual D flip-flop)						
38510	1.19	1.19	1.21	1.23	1.25	
883/SMD	0.67	0.67	0.68	0.70	0.72	
54F373 (Octal D transparent latch)						
38510	2.55	2.50	2.47	2.45	2.45	
883/SMD	1.63	1.59	1.57	1.55	1.55	10
4000/54C CMOS						
4001A (Quad 2 input nor)						
38510	3.85	4.20	4.53	4.85	5.25	
883/SMD	0.64	0.73	0.80	0.86	0.94	
4049A (Hex inverting buffer/driver)						
38510	4.15	4.45	4.70	4.95	5.30	
883/SMD	0.67	0.75	0.82	0.87	0.95	8
54HC CMOS						
54HC00 (Quad 2 input nand)						
38510	3.12	3.05	3.15	3.25	3.30	
883/SMD	0.57	0.51	0.56	0.62	0.66	
54HC74 (Dual D flip-flop)						
883/SMD	0.62	0.55	0.58	0.62	0.64	
54HC245 (Octal noninverting bus transceiver)						
883/SMD	1.50	1.45	1.48	1.50	1.55	10
54AC/FCT CMOS						
54AC00 (Quad 2 input nand)						
38510	NA	3.80	3.42	3.05	2.75	
883/SMD	1.36	1.05	0.92	0.84	0.79	

(Continued)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.1 (Continued)

Standard Logic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

	1989	1990	1991	1992	1993	Lead Time (Weeks)
54AC74 (Dual D flip-flop)						
38510	NA	4.23	3.85	3.41	3.25	
883/SMD	2.06	1.32	1.20	1.15	1.13	
54AC373/54FCT373 (Octal D transparent latch)						
38510	NA	12.70	10.95	8.85	7.25	
883/SMD	6.27	4.85	3.90	3.40	3.20	
54ALS TTL						10
54ALS00 (Quad 2 input nand)						
38510	2.62	2.77	2.79	2.79	2.82	
883/SMD	0.71	0.51	0.52	0.54	0.55	
54ALS74 (Dual D flip-flop)						
883/SMD	1.02	1.03	1.06	1.09	1.12	
54ALS373 (Octal D transparent latch)						
38510	8.80	8.65	8.61	8.61	8.53	
883/SMD	3.32	2.91	2.91	2.93	2.97	
54AS TTL						10
54AS00 (Quad 2 input nand)						
883/SMD	1.08	1.05	1.05	1.05	1.05	
54AS373 (Octal D transparent latch)						
883/SMD	4.21	4.18	4.18	4.18	4.18	
Average Price Adders						
1,000 Volume (%)—25						
SMT (%)—20 to 40						
Class S—10 to 12 times more						
Rad Hard—2 to 5 times more						

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as product quality, special features, service, delivery, performance, or other factors that may enhance or detract from the value of a company's product. These prices are intended for use as price guidelines.
NA = Not available
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.2

CMOS Gate Array/Cell-Based IC Pricing* (Dollars per Gate)
Military Specification: Class B
Annual Volume: 100 ≤ 500 Units
(NRE in Thousands of Dollars)

883/SCD	1989	1990	1991	1992	1993
<2,000 Gates					
1.5 Micron (1.3 to 1.7 Micron Drawn)					
<28 Pin CDIP	0.083	0.080	0.078	0.077	0.076
29-50 CDIP	0.088	0.086	0.083	0.083	0.083
51-100 CPGA	0.097	0.095	0.093	0.090	0.089
NRE—Maximum	20,500	20,000	22,000	23,500	23,500
NRE—Average	15,500	14,250	17,000	18,250	18,250
NRE—Minimum	12,250	11,200	14,000	15,250	15,250
1.0- to 1.2-Micron (Drawn) Adders					
Production (%)	30	10	5	0	0
NRE (%)	50	35	10	0	0
2,000 to 4,999 Gates					
1.5 Micron (1.3 to 1.7 Micron Drawn)					
≤28-Pin CDIP	0.027	0.027	0.025	0.024	0.023
29-50 CDIP	0.027	0.027	0.026	0.025	0.025
51-100 CPGA	0.037	0.036	0.034	0.033	0.033
101-200 CPGA	0.044	0.043	0.041	0.039	0.039
NRE—Maximum	27,250	25,750	28,750	31,250	31,250
NRE—Average	19,750	19,750	22,000	23,500	24,000
NRE—Minimum	16,000	15,500	18,000	19,000	19,000
1.0- to 1.2-Micron (Drawn) Adders					
Production (%)	35	15	5	0	-5
NRE (%)	55	40	10	0	0

(Continued)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.2 (Continued)

CMOS Gate Array/Cell-Based IC Pricing* (Dollars per Gate)
Military Specification: Class B
Annual Volume: 100 ≤ 500 Units
(NRE in Thousands of Dollars)

883/SCD	1989	1990	1991	1992	1993
5,000 to 9,999 Gates					
1.5 Micron (1.3 to 1.7 Micron Drawn)					
≤28-Pin CDIP	0.018	0.017	0.015	0.014	0.014
29-50 CDIP	0.020	0.018	0.017	0.015	0.015
51-100 CPGA	0.027	0.025	0.024	0.023	0.022
101-200 CPGA	0.037	0.035	0.034	0.033	0.032
NRE—Maximum	51,000	49,000	43,500	47,000	47,000
NRE—Average	37,000	35,250	28,250	33,750	33,750
NRE—Minimum	27,000	25,250	22,500	23,500	23,500
1.0- to 1.2-Micron (Drawn) Adders					
Production (%)	35	25	5	0	-5
NRE (%)	55	40	15	0	0
10,000 to 19,999 Gates					
1.5 Micron (1.3 to 1.7 Micron Drawn)					
Gate Array					
50-100 CPGA	0.012	0.011	0.010	0.009	0.009
101-200 CPGA	0.015	0.014	0.012	0.012	0.011
Cell-Based IC—Production					
Adder/Discount (%)	28	28	23	20	20
NRE—Maximum	79,000	74,000	70,200	75,400	75,400
NRE—Average	60,400	56,800	49,000	52,400	52,400
NRE—Minimum	45,400	41,400	32,800	34,400	34,400

(Continued)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.2 (Continued)

CMOS Gate Array/Cell-Based IC Pricing* (Dollars per Gate)
Military Specification: Class B
Annual Volume: 100 ≤ 500 Units
(NRE in Thousands of Dollars)

883/SCD	1989	1990	1991	1992	1993
1.0- to 1.2-Micron (Drawn) Adders					
Production (%)	35	25	5	0	-5
NRE (%)	35	25	5	0	0
20,000 to 49,999 Gates					
1.5 Micron (1.3 to 1.7 Micron Drawn)					
Gate Array					
50-100 CPGA	0.010	0.010	0.011	0.011	0.011
101-200 CPGA	0.011	0.011	0.010	0.009	0.009
Cell-Based IC—Production					
Adder/Discount (%)	18	13	10	8	6
NRE—Maximum	124,000	120,000	127,000	138,200	138,200
NRE—Average	96,000	94,800	80,400	86,400	86,400
NRE—Minimum	65,000	62,600	51,800	55,200	55,200
Cell-Based—NRE					
Adder/Discount (%)	40	40	35	30	25
1.0- to 1.2-Micron (Drawn) Adders					
Production (%)	35	25	5	0	-5
NRE (%)	35	30	20	10	0
50,000 to 80,000 Gates					
1.0 Micron					
Gate Array					
50-100 CPGA	0.009	0.009	0.007	0.006	0.006
101-200 CPGA	0.010	0.007	0.007	0.007	0.007
201-300 CPGA	0.012	0.011	0.008	0.008	0.008
Cell-Based IC—Production					
Adder/Discount (%)	35	30	20	15	10
NRE—Maximum	258,000	250,000	227,000	204,000	203,200

(Continued)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.2 (Continued)

CMOS Gate Array/Cell-Based IC Pricing* (Dollars per Gate)
Military Specification: Class B
Annual Volume: 100 ≤ 500 Units
(NRE in Thousands of Dollars)

883/SCD	1989	1990	1991	1992	1993
NRE—Average	156,000	152,000	118,000	107,000	105,800
NRE—Minimum	117,000	113,400	91,000	83,000	82,200
Cell Based—NRE					
Adder/Discount (%)	50	50	35	30	25
Lead Time (Weeks)					
Production					
Gate Array (1.5 micron)	18				
Gate Array (1.0-1.2 micron)	18				
Cell Based (1.5 micron)	20				
Cell Based (1.0-1.2 micron)	20				
Prototypes					
Gate Array (1.5 micron)	3				
Gate Array (1.0-1.2 micron)	4				
Cell Based (1.5 micron)	6				
Cell Based (1.0-1.2 micron)	8				
Average Package Price Adders					
(assuming CPGA as base)					
LCC Package (%)		16			15
LDCC (%)		50			50
Flatpack (%)		35			30
Quad Flatpack (%)		40			25

(Continued)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.2 (Continued)

CMOS Gate Array/Cell-Based IC Pricing* (Dollars per Gate)
Military Specification: Class B
Annual Volume: 100 ≤ 500 Units
(NRE in Thousands of Dollars)

883/SCD	1989	1990	1991	1992	1993
Average Processing Adders					
Class S (%)		8-10x			8-10x
Rad Hard (%)		1.3-3.5x			1.3-3.5x
Average Volume Adders/Discount					
(for Gate Arrays)					
<100 units (%)	45				
500 to <1,000 units (%)	-12				
>1,000 to 5,000 units (%)	-30				

*Data in this table exclude proprietary core architectures, mixed signal technology, and BiCMOS. Pricing is for usable gates only.
NRE Maximum = Full service, design to prototype, provided by ASIC manufacturer.
NRE Minimum = OEM does complete design through layout; ASIC manufacturer assists with layout and subsequent steps to prototype delivery.
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as product quality, special features, service, delivery, performance, or other factors that may enhance or detract from the value of a company's product. These prices are intended for use as guidelines.
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.3

Gate Array Pricing (Dollars per Gate)
Military Specification: Class B
Annual Volume: 2,500 Units
(NRE in Thousands of Dollars)

883/SCD	1989	1990	1991	1992	1993	Lead Time (Weeks) Production/Prototypes
ECL						
1.5 Micron						16/6
0-999	0.2450	0.2400	0.2400	0.2400	0.2300	
NRE	23	22	22	22	22	
1,000-1,999	0.1150	0.1100	0.1100	0.1100	0.1050	
NRE	38	37	37	37	36	
2,000-4,999	0.1200	0.1150	0.1150	0.1150	0.1100	
NRE	44	43	43	43	43	
5,000-9,999	0.1000	0.0980	0.098	0.0970	0.0960	
NRE	60	60	60	60	60	
10,000-20,000	0.1070	0.1050	0.1050	0.1050	0.1000	
NRE	102	100	100	100	100	
Average Price Adders						
1,000 Volume (%)—5						
SMT (%)—20 to 40						
Class S—6 to 10 times more						
Rad Hard—1.5 to 3 times more						

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as product quality, special features, service, delivery, performance, or other factors that may enhance or detract from the value of a company's product. These prices are intended for use as guidelines.
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.4

Programmable Logic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 1,000 Units

883/SMD	1989	1990	1991	1992	1993	Lead Time (Weeks)
Bipolar						
Pin Count = 20						
*10-14.9ns	7.65	7.25	6.40	5.60	4.95	10
15-19.9ns	5.10	4.05	3.85	3.60	3.40	10
20-29.9ns	4.10	3.82	3.63	3.45	3.30	10
≥30ns	3.60	3.50	3.38	3.26	3.18	10
Pin Count = 24 (except 22V10)						
*10-14.9ns	10.70	9.70	9.10	8.60	8.50	10
15-19.9ns	7.80	7.50	7.40	7.30	7.30	10
20-29.9ns	6.50	6.35	6.20	6.05	5.90	10
≥30ns	4.75	4.65	4.65	4.65	4.65	10
22V10						
12-19.9ns	51.00	45.50	40.50	32.50	27.00	12
20-24.9ns	15.50	14.00	12.00	11.50	11.00	12
≥25ns	10.95	10.70	10.45	10.20	9.95	12
CMOS (Includes All Reprogrammable)						
Pin Count = 20						
15-19.9ns	NA	25.00	21.00	17.50	14.50	12
20-24.9ns	15.20	13.30	12.35	11.40	10.45	10
25-30ns	9.00	9.00	9.00	9.00	9.00	10
≥30ns	8.55	8.55	8.55	8.55	8.55	10

(Continued)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.4 (Continued)

Programmable Logic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 1,000 Units

883/SMD	1989	1990	1991	1992	1993	Lead Time (Weeks)
Pin Count = 24 (except 22V10)						
15-19.9ns	NA	NA	26.95	18.48	15.40	12
20-24.9ns	NA	18.03	15.75	13.55	11.62	10
25-30ns	NA	13.86	12.08	10.85	9.69	10
≥30ns	NA	12.29	11.13	10.22	9.07	10
22V10						
15-19.9ns	NA	NA	38.50	26.40	22.00	12
20-24.9ns	NA	25.75	22.50	19.35	16.60	12
25-29.9ns	NA	19.80	17.25	15.50	13.85	12
≥30ns	NA	17.55	15.90	14.60	12.95	12
Average Price Adders						
<100 (%)—35						
100 to <1,000 (%)—15						
SMT (%)—20						
JAN—1.5 to 2 times more						
Class S—10 times more						

*10ns version runs at a 30 percent to 50 percent premium
NA = Not available
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as product quality, special features, service, delivery, performance, or other factors that may enhance or detract from the value of a company's product. These prices are intended for use as guidelines.
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited.

Table 1.5

Field-Programmable Gate Array Pricing (Dollars)
Military Specification: Class B
Annual Volume: 1,000 Units

883/SMD	1989	1990	1991	1992	1993	Lead Time (Weeks)
CMOS 1.0-1.2 Micron (Drawn)						
Usable Gates						
<2,000	185.00	145.00	122.00	100.00	79.00	2-4
2,000<4,000	345.00	283.00	244.00	201.00	175.00	2-4
4,000<6,000	800.00	655.00	500.00	430.00	355.00	2-4
Average Price Adders						
<100 (%)—50						
100<1,000 (%)—35						
≥1,000 (%)—10						
SMT (%)—20						
Class S—1.5 to 2 times more						
Rad Hard—10 times more						

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as product quality, special features, service, delivery, performance, or other factors that may enhance or detract from the values of a company's product. These prices are intended for use as guidelines.
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.6

DRAM Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

883/SMD	1989	1990	1991	1992	1993	Lead Time (Weeks)
64K, 64Kx1, 150ns	6.85	7.10	7.85	8.25	8.70	14
256K, 256Kx1, 150ns	22.45	19.05	17.10	16.25	15.50	16
1Mb, 1Mbx1, >=100ns	75.00	55.00	45.00	31.00	27.50	14
Average Price Adders						
0-100, volume (%)—50						
>100 to 1,000 volume (%)—30						
>1,000 to 5,000 volume (%)—15						
>5,000 to 10,000*—10						
SMT (%)—15						
JAN (%)—2 to 3 times more						
MIL Temp* (%)—30						

*Discount
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as product quality, special features, service, delivery, performance, or other factors that may enhance or detract from the value of a company's product. These prices are intended for use as guidelines.
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.7

SRAM Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

883/SMD[1]	1989	1990	1991	1992	1993	Lead Time (Weeks)
4K, 4Kx1, 35ns	16.50	16.50	16.25	16.00	16.00	11
16K, 4Kx4, 25ns	27.45	20.35	16.10	15.15	14.80	8
16K, 4Kx4, 35ns	24.20	16.85	14.00	13.25	12.95	8
16K, 4Kx4, 45ns	19.10	13.70	11.75	11.15	10.90	8
64K, 8Kx8, 120-150ns	23.95	21.65	21.10	20.75	20.10	12
64K, 16Kx4, 35ns	27.50	21.30	19.90	18.40	17.25	8
64K, 8Kx8, 45ns	31.50	21.55	19.85	19.15	18.35	8
64K, 64Kx1, 25ns	51.20	32.50	22.50	20.80	20.25	10
256K, 32Kx8, 100ns	47.45	37.05	32.15	28.50	25.85	8
256K, 32Kx8, 70ns	44.25	39.05	36.10	31.40	29.20	10
256K, 256Kx1, 45ns	84.00	63.55	43.20	36.50	32.55	10
256k, 256kx1, 25ns	115.00	98.25	70.50	58.75	52.30	10
1Mb, 256Kx4, 45ns	NA	125.00	95.20	80.50	71.05	12
1Mb, 1Mbx1, 45ns	NA	180.00	135.00	108.00	90.00	12

(Continued)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.7 (Continued)

SRAM Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

883/SMD[1]	1989	1990	1991	1992	1993	Lead Time (Weeks)
Average Price Adders						
0-100 Volume (%)—50						
>100 to 1,000 Volume (%)—30						
>1,000 to 5,000 Volume (%)—15						
>5,000 to <10,000 Volume (%)—10						
SMT (%)—20						
JAN—3-5						
Class S—x 8-15						
Rad Hard—x 1.5-5						
MIL Temp[2] (%)—32						
Commercial (%)—6 to 12						

[1]Hermetic Dip
[2]Discount
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as product quality, special features, service, delivery, performance, or other factors that may enhance or detract from the value of a company's product. These prices are intended for use as guidelines.
NA = Not available
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.8

EPROM Pricing (Dollars)
Military Specification: Class B
Annual Volume: >1,000 to 5,000 Units

883/SMD	1989	1990	1991	1992	1993	Lead Time (Weeks)
64K, ≥150ns	11.45	11.50	11.50	11.70	11.75	10
64K, 55ns	NA	NA	26.45	23.20	21.40	12
128K, ≥150ns	14.30	14.05	13.90	13.70	13.50	12
256K, ≥150ns	18.45	15.05	14.70	14.45	14.15	12
512K, ≥150ns	31.30	25.05	21.10	19.55	18.70	12
1Mb, ≥150ns	135.00	84.50	61.45	46.50	40.75	12
Average Price Adders						
0 to 100 Volume (%)—50						
>110 to 1,000 Volume (%)—30						
>10,000 Volume (%)—12%						
SMT (%)—25%						
JAN—1.5 to 3 times more						
Class S—10 to 12 times more						

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as product quality, special feature, service, delivery, performance, or other factors which may enhance or detract from the value of a company's product. These prices are intended for use as price guidelines.
NA = Not available
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.9

PROM Pricing (Dollars)
Military Specification: Class B
Annual Volume: >1,000 to 5,000 Units

883/SMD	1989	1990	1991	1992	1993	Lead Time (Weeks)
64K, 55ns	17.25	15.15	14.50	14.15	15.00	16
64K, 55ns	16.50	14.45	12.80	12.20	11.90	10
Average Price Adders						
0 to 100 Volume (%)—50						
>100 to 1,000 Volume (%)—20						
>10,000 Volume (%)—15						
SMT (%)—50						
JAN—1.3 to 1.7 times more						
Class S—12 to 15 times more						

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as product quality, special features, service, delivery, performance, or other factors that may enhance or detract from the value of a company's product. These prices are intended for use as guidelines.
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.10

EEPROM Pricing (Dollars)
Military Specification: Class B
Annual Volume: >1,000 to 5,000 Units

883/SMD	1989	1990	1991	1992	1993	Lead Time (Weeks)
16K, >150ns	13.20	12.04	11.24	10.60	9.75	8
64K, >150ns	21.67	18.46	17.12	16.12	15.62	10
256K, >150ns	84.00	56.05	46.95	39.80	36.50	12
256K, 90ns	NA	152.30	109.25	86.40	71.25	12
1Mb, >150ns	NA	618.00	423.00	290.00	226.50	16
Average Price Adders						
0 to 100 Volume (%)—35						
>100 to 1,000 Volume (%)—25						
>10,000* Volume (%)—10						
SMT (%)—25						
JAN—3 to 5 times more						
Class S—6 to 10 times more						
Commercial Die* (%)—6 to 12						

*Discount
NA = Not available
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as product quality, special features, service, delivery, performance, or other factors that may enhance or detract from the value of a company's product. These prices are intended for use as guidelines.
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.11

Flash Memory Pricing (Dollars)
Military Specification: Class B
Annual Volume: >1,000 to 5,000 Units

883/SMD	1989	1990	1991	1992	1993	Lead Time (Weeks)
"EEPROM," 5-12V, Sector Erase						
1Mb, ≥150ns	NA	NA	270.00	196.00	156.00	12
2Mb, ≥150ns	NA	NA	NA	390.00	280.00	16
"EPROM," 12V, Bulk Erase						
1Mb, ≥150ns	NA	178.00	148.00	118.00	95.00	12
2Mb, ≥150ns	NA	NA	275.00	198.00	130.00	16
Average Price Adders						
0 to 100 Volume (%)—35						
100 to 1,000 Volume (%)—25						
>10,000* Volume (%)—10						
SMT (%)—18						
JAN—1.5 to 3 times more						
Class S—10 times more						
Commercial Die* (%)—6 to 10						

*Discount
Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as product quality, special features, service, delivery, performance, or other factors that may enhance or detract from the value of a company's product. These prices are intended for use as price guidelines.
NA = Not available
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.12

Microcomponent Pricing (Dollars)
Military Specification: Class B
Annual Volume: 1,000 to 5,000 Units

883/SMD	1989	1990	1991	1992	1993	Lead Time (Weeks)
8-Bit MPU						
8085A	24.20	24.20	25.60	26.85	27.70	12
8088	32.50	35.20	37.75	39.60	41.00	12
Z80	60.00	55.00	53.85	51.50	49.50	12
16-Bit MPU						
8086-8	65.45	59.50	55.00	51.50	50.00	12
68000-8	125.00	102.00	90.00	82.00	78.00	12
80186-8	110.00	104.00	99.00	95.00	90.00	12
80286-10	315.00	250.00	240.00	230.00	220.00	10
1750A	675.00	575.00	475.00	425.00	425.00	10
32-Bit MPU						
CISC ≤20 MHz	625.00	580.00	545.00	510.00	490.00	8
CISC >20 MHz	1,260.00	1,080.00	870.00	735.00	620.00	16
25-MHz R3000	NA	1,000.00	750.00	600.00	400.00	16
Other 25-MHz RISC with FPU		2,000.00	1,500.00	1,150.00	900.00	16
8-Bit MCU						
8048	22.15	26.00	30.00	30.00	30.00	15
8051	31.00	27.00	26.00	24.00	24.00	
80C51	47.00	42.00	37.50	33.00	30.00	12
16-Bit MCU	380.00	358.00	335.00	310.00	295.00	16
DSP MPU (16-Bit Fixed Point)	325.00	274.00	232.00	210.00	200.00	8

(Continued)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.12 (Continued)

Microcomponent Pricing (Dollars)
Military Specification: Class B
Annual Volume: 1,000 to 5,000 Units

883/SMD	1989	1990	1991	1992	1993	Lead Time (Weeks)
MPR						
16-Bit FPU (Second Generation)	310.00	270.00	245.00	225.00	210.00	8
32-Bit FPU (First Generation)	850.00	755.00	695.00	670.00	650.00	12
16x16 Multiplier (55ns)	59.00	47.00	40.50	35.35	30.20	12
16x16 Multiplier/Acc. (55ns)	81.50	65.10	57.05	51.65	46.75	12
1553B Single-Chip Controller	476.00	432.00	393.00	365.00		24
Average Price Adders						
0 to 100 Volume (%)—30						
>100 to 1,000 Volume (%)—20						
SMT (%)—15						
JAN—2 to 5 times more						
Class S—8 to 12 times more						
Rad Hard—2 to 5 times more						

Note: Actual negotiated market prices may vary from these price because of manufacturer-specific factors such as product quality, features, service, delivery, performance, or other factors that may enhance or detract from the value of a company's product. These prices are intended for use as guidelines.
NA = Not available
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.13

Analog Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

883/SMD	1989	1990	1991	1992	1993	Lead Time (Weeks)
Voltage Regulators						
7805 (Positive, 5V)	3.56	3.48	3.45	3.45	3.45	15
Comparators						
111 (Single, Bipolar)	1.16	1.10	1.08	1.10	1.10	13
139 (Quad, Bipolar)	1.45	1.15	1.13	1.16	1.18	13
Amplifiers						
101 (Dual, Bipolar)	1.28	1.24	1.24	1.24	1.24	13
156 (Single, BiFET)	2.15	2.02	1.95	1.87	1.80	13
733 (Video)	2.15	2.12	2.12	2.12	2.12	15
Interface						
26LS32 (Quad RS-422 Receiver)	3.24	2.72	2.55	2.38		13
Data Conversion						
565 (12-Bit DAC)	82.60	75.80	75.55	75.55	75.55	20
574 (12-Bit A/D)	74.65	70.65	70.65	70.65	70.65	20
Timer						
555	1.68	1.63	1.63	1.63	1.63	12
Additional Price Adders						
1,000 Volume (%)—30						
SMT (%)—10 to 50						
JAN—1.5 to 3 times more						
Class S—10 times more						
Rad Hard—2 to 5 times more						

Note: Actual negotiated market prices may vary from these price because of manufacturer-specific factors such as product quality, features, service, delivery, performance, or other factors that may enhance or detract from the value of a company's product. These prices are intended for use as guidelines.
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.14

Discrete and Optoelectronic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

	1989	1990	1991	1992	1993	Lead Time (Weeks)
Transistors						
Small/Medium Signal						
2N2907A (NPN, 40V, 1.8W)						
JAN	0.23	0.23	0.24	0.26	0.28	10-40
JANTX	0.48	0.52	0.54	0.57	0.60	
JANTXV	1.45	1.47	1.50	1.52	1.56	
2N4856 (JFET, 40V, 360mW)						20-45
JANTX	0.79	0.84	0.87	0.91	0.95	
JANTXV	4.50	4.50	4.57	4.70	4.85	
Bipolar Power						
2N3772 (NPN, 400V, 100W)						15-40
JANTX	8.50	8.42	8.25	8.05	7.99	
JANTXV	14.76	14.74	14.27	14.05	13.85	
MOSFET Power						
2N6756 (100V, 14A, 75W)						18-40
JAN	3.04	2.98	2.98	2.98	2.98	
JANTX	8.00	7.78	7.65	7.50	7.38	
JANTXV	14.10	13.71	13.45	13.05	12.90	
Diodes						
Small Signal						
1N4150 (Switching, 200mA)						
JANTX	0.41	0.45	0.51	0.58	0.65	
JANTXV	0.67	0.73	0.82	0.93	1.05	

(Continued)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 1.14 (Continued)

Discrete and Optoelectronic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

	1989	1990	1991	1992	1993	Lead Time (Weeks)
Rectifier						
1N3891 (12A, 200V, 200ns)						16
JAN	2.73	2.70	2.75	2.82	2.85	
JANTX	4.50	4.47	4.55	4.60	4.65	
JANTXV	12.00	11.92	11.95	12.09	12.20	
Zener						
1N829 (6.2V, 250mW)						20
JAN	1.25	1.24	1.24	1.24	1.24	
JANTX	1.85	1.92	1.92	1.92	1.92	
JANTXV	2.29	2.29	2.29	2.29	2.29	
Optoelectronic						
LED						
T1, Standard, Red						12
JAN	0.20	0.18	0.18	0.18	0.18	
JANTX	0.56	0.53	0.53	0.53	0.53	
Optocoupler						
4N23A (1kV, tr/tf 15us)						12-18
JAN	0.75	0.73	0.73	0.73	0.73	
JANTX	2.08	2.04	2.04	2.04	2.04	
JANTXV	5.22	5.18	5.18	5.18	5.18	
Additional Price Adders						
1,000 Volume—30						
SMT (%)—10-50						
Class S—10 times more						
Rad Hard—2 to 5 times more						

Note: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as product quality, special features, service, delivery, performance, or other factors that may enhance or detract from the value of a company's product. These prices are intended for use as guidelines.
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

©1991 Dataquest Incorporated February—Reproduction Prohibited

Chapter 2

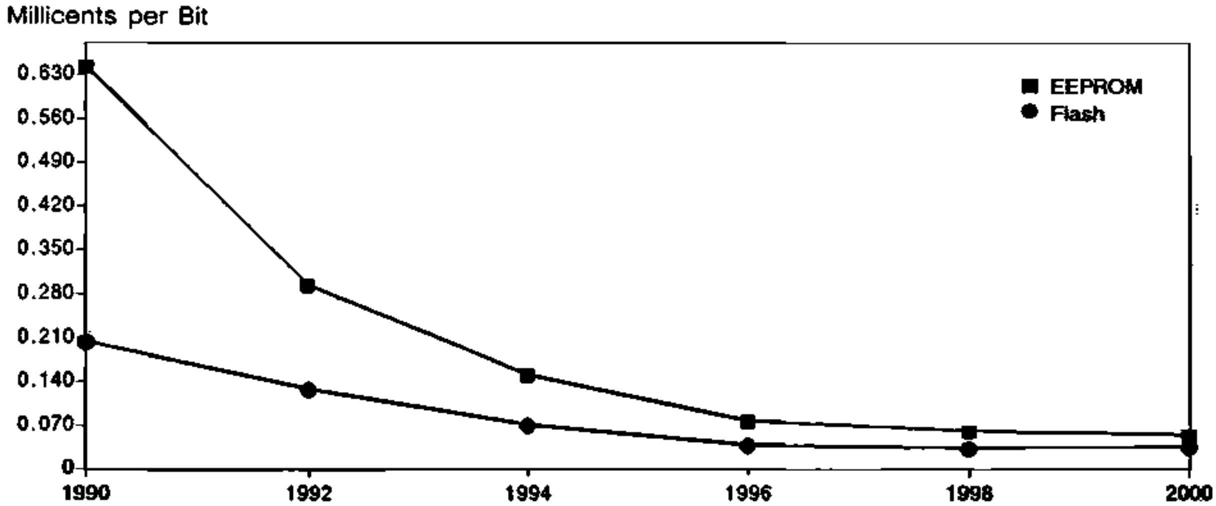
Long-Range Military Memory Pricing Average Selling Price Estimates 1990-2000

INTRODUCTION

Tables 2.1 through 2.8 and Figure 2.1 show long-term average selling prices (ASPs). The ASPs are a composite of all products and volume breaks sold in a given category.

Figure 2.1

Nonvolatile Memory ASPs (883 Class B)



Source: Dataquest (February 1991)

Source: Dataquest (February 1991)

Table 2.1

Military (MIL-STD-883C) EEPROM Memory
ASP Estimates (Actual Dollars)

Density	1990	1992	1994	1996	1998	2000
256K	61	45	38	32	32	34
1Mb	645	295	152	78	62	55
4Mb*	NA	1,495	550	320	180	130
8Mb*	NA	NA	NA	1,575	760	380

*Investment at this density might not take place—prices are based on historical modeling.
NA = Not available
Source: Dataquest (February 1991)

Table 2.2

Military (MIL-STD-883C) Flash Memory
ASP Estimates

Density	1990	1992	1994	1996	1998	2000
1Mb	205	129	72	39	34	36
2Mb	NA	265	126	59	36	34
4Mb	NA	575	310	115	68	48
8Mb	NA	NA	NA	365	165	89

NA = Not available
Source: Dataquest (February 1991)

Table 2.3

Military (MIL-STD-883C) Fast* SRAM Memory
ASP Estimates

Density	1990	1992	1994	1996	1998	2000
256K	71.50	44.70	38.40	34.90	33.20	35.50
1Mb	264.80	118.50	71.50	39.50	37.00	37.00
4Mb	NA	685.00	280.00	126.00	102.00	82.00
16Mb	NA	NA	NA	795.00	240.00	134.00

*Average 25 to 70ns access time.
NA = Not available
Source: Dataquest (February 1991)

Table 2.4

Military (MIL-STD-883C) DRAM Memory
ASP Estimates

Density	1990	1992	1994	1996	1998	2000
256K	22.50	17.80	16.00	16.50	17.50	17.50
1Mb	71.50	38.50	31.00	24.00	24.50	26.00
4Mb	NA	215.00	84.50	49.00	39.00	39.00
16Mb	NA	NA	675.00	170.50	82.50	70.50

NA = Not available
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Table 2.5

Military (MIL-STD-883C) Fast* SRAM Memory
ASP Estimates (Millicents per Bit)

Density	1990	1992	1994	1996	1998	2000
256K	0.279	0.175	0.150	0.136	0.130	0.139
1Mb	0.265	0.119	0.072	0.040	0.037	0.037
4Mb	NA	0.171	0.070	0.032	0.026	0.021
16Mb	NA	NA	NA	0.050	0.015	0.008

*Average 25 to 70ns access time.
NA = Not available
Source: Dataquest (February 1991)

Table 2.6

Military (MIL-STD-883C) DRAM Memory
ASP Estimates (Millicents per Bit)

Density	1990	1992	1994	1996	1998	2000
256K	0.088	0.070	0.063	0.064	0.068	0.068
1Mb	0.072	0.039	0.031	0.024	0.025	0.026
4Mb	NA	0.054	0.021	0.012	0.010	0.010
16Mb	NA	NA	0.042	0.011	0.005	0.004

NA = Not available
Source: Dataquest (February 1991)

Table 2.7

Military (MIL-STD-883C) EEPROM Memory
ASP Estimates (Millicents per Bit)

Density	1990	1992	1994	1996	1998	2000
256K	0.238	0.176	0.148	0.125	0.125	0.133
1Mb	0.645	0.295	0.152	0.078	0.062	0.055
4Mb	NA	0.374	0.138	0.080	0.045	0.033
16Mb	NA	NA	NA	0.197	0.095	0.048

*Investment at this density might not take place—prices are based on historical modeling.
NA = Not available
Source: Dataquest (February 1991)

Table 2.8

Military (MIL-STD-883C) Flash Memory
ASP Estimates (Millicents per Bit)

Density	1990	1992	1994	1996	1998	2000
1Mb	0.205	0.129	0.072	0.039	0.034	0.036
2Mb	NA	0.133	0.063	0.030	0.018	0.017
4Mb	NA	0.288	0.078	0.029	0.017	0.012
8Mb	NA	NA	NA	0.046	0.021	0.011

*Investment at this density might not take place—prices are based on historical modeling.
NA = Not available
Source: Dataquest (February 1991)

©1991 Dataquest Incorporated February—Reproduction Prohibited

Dataquest Research and Sales Offices:

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
Phone: (408) 437-8000
Telex: 171973
Fax: (408) 437-0292

Technology Products Group
Phone: (800) 624-3280

Dataquest Incorporated
Ledgeway/Dataquest
The Corporate Center
550 Cochituate Road
Framingham, MA 01701
Phone: (508) 370-5555
Fax: (508) 370-6262

Dataquest Incorporated
Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
Phone: (714) 957-0171
Telex: 5101002189 ICCDQ
Fax: (714) 957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: (02) 959 4544
Telex: 25468
Fax: (02) 929 0635

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
West Germany
Phone: 011 49 89 93 09 09 0
Fax: 49 89 930 3277

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
Phone: 0895-835050
Telex: 266195
Fax: 0895 835260/1/2

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: (1) 48 97 31 00
Telex: 233 263
Fax: (1) 48 97 34 00

Dataquest Hong Kong
Rm. 401, Connaught Comm. Bldg.
185 Wanchai Rd.
Wanchai, Hong Kong
Phone: 8387336
Telex: 80587
Fax: 5722375

Dataquest Israel
59 Mishmar Ha'yarden Street
Tel Aviv, Israel 69865
or
P.O. Box 18198
Tel Aviv, Israel
Phone: 52 913937
Telex: 341118
Fax: 52 32865

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo 104 Japan
Phone: (03) 5566-0411
Fax: (03) 5566-0425

Dataquest Korea
Daeheung Bldg. 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul, Korea 135
Phone: (02) 556-4166
Fax: (02) 552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 4597181
Telex: 38257
Fax: 4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sect. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: (02) 501-7960
Telex: 27459
Fax: (02) 505-4265

Dataquest West Germany
In der Schneithohl 17
6242 Kronberg 2
West Germany
Phone: 06173/61685
Telex: 418089
Fax: 06173/67901

© 1991 Dataquest Incorporated 2/91
0009426

Military Semiconductor Pricing

INTRODUCTION

This section provides a price forecast and analysis for military specification semiconductor products. The first part of this section presents a general overview of the nature and dynamics of military pricing; the second part is our price forecast and analysis.

INFLUENTIAL FACTORS

There are numerous influences on the market price of military specification semiconductor components. However, a handful of common recurring factors are helpful when projecting estimates of price movements. These factors are the business cycle, the life cycle position, and key extraordinary events.

Business Cycle

Cyclical swings in the electronic equipment industry affect the semiconductor price structure. In the case of military-grade semiconductors, their prices can be affected by conditions in both the commercial electronic industry and the defense industry. This is because military-grade merchant products are typically derived from commercial R&D and production lines.

Business cycles disturb the delicate balance of supply and demand for semiconductors. Prices usually are driven up when demand exceeds supply, as shown by what happened to DRAM prices in 1988. Prices can be driven down when demand slackens and pipeline inventory (including distributors) increases and suppliers drop prices to continue moving products.

Industry capacity utilization also has a pronounced impact on pricing. During periods of high utilization, prices are usually forced up, and likewise are forced down during periods of low utilization.

Another manifestation of the business cycle is the effect on the commercial-military production mix coming out of vendor factories. For example, if the commercial semiconductor sector is strong, this strength can sometimes starve off supply to the military customers. This results in raising prices to military customers because of their unique requirements.

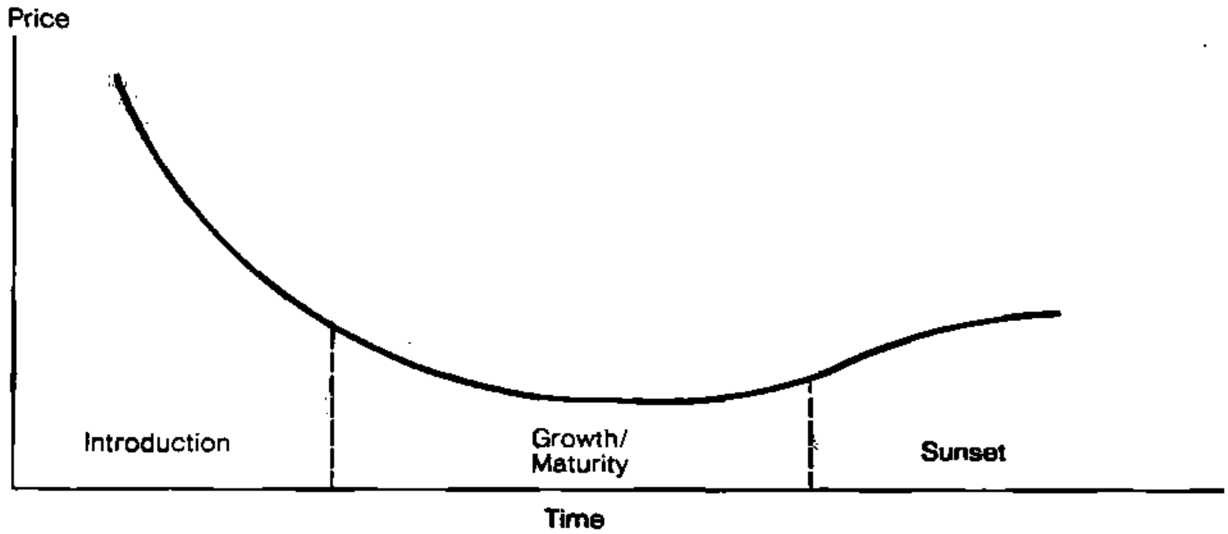
Life Cycle Position

Semiconductor product categories have a market life that can be as short as 3 years or as long as 20 years. Prices typically trend down as the technology matures and competitive products emerge, as shown in Figure 1. Improvements in yield and manufacturing techniques are often a prerequisite to downward price trends. If effective second sourcing or product substitution is accomplished, it creates a condition in which prices can move downward because of competitive positioning for market share. Often during the sunset phase of a product, when the supply base is thinning, prices can rise because of slackened competitive bidding and increased opportunity costs for the vendors.

©1990 Dataquest Incorporated April

Figure 1

Generic Semiconductor Price Life Cycle



0006627-1

Source: Dataquest
April 1990

Extraordinary Factors

These are the various nonmarket-derived factors that can impact pricing. For example, the recent FMV price system with the Japanese semiconductor companies has had a significant effect on certain memory IC categories.

Military Specific Factors

Most merchant semiconductor products are derived from commercial fabrication lines, and thus variations in commercial pricing can affect JAN MIL-STD-883C BS-9000 and CECC pricing significantly. However, there are certain dynamics to the high-reliability market that can force prices to deviate from the commercial starting point. Most of these dynamics are the same as those mentioned above, but they are derived from business conditions and procurement practices peculiar to the military/aerospace industries. These dynamics include the following:

- Defense Spending—This impacts the demand for products in general.
- SMD/883/QPL/CECC Qualifications—Breadth of supply base affects competitive factor.
- Life Cycle Position—Similar effect as for commercial product, except learning curve knowledge extends to additional military design features (e.g., radiation tolerance), manufacturing (e.g., ceramic packaging), and mil-spec screening and documentation.

©1990 Dataquest Incorporated April

GENERAL MILITARY PRICING ATTRIBUTES

Figure 2 presents a generic price comparison for different grades of semiconductor products. With commercial-grade (commercial temperature range and plastic package) equal to one on a price index, a MIL-STD-883C Class B product is typically 6, JAN product is 15, and Class S product is 50. The premium for military-grade pricing is justified because of the relatively expensive ceramic packaging and assembly techniques, extensive screening to precise electrical and mechanical specifications, burn-in charges, quality conformance checks, and the documentation that accompanies each lot. JAN products have the additional requirement of being assembled entirely in the high-labor cost United States or selected NATO countries. It should be noted that we have found little evidence that standard military drawing (SMD) prices varied significantly from MIL-STD-883C prices.

Figure 3 lists a similar index that compares various product categories for MIL-STD-883C product categories. Currently, commodity standard logic, EPROMs, and EEPROMs have the lowest multipliers, at four times commercial plastic prices. The reason for this relatively low multiplier is that each of these products is experiencing intensive competition, and, in the standard logic case, it is being displaced extensively by ASICs.

Gate arrays and microprocessors have multipliers of greater than 10. The gate-array multiplier exists because of the emerging nature of that technology in military applications. The high multiplier for microprocessors is due to the relatively small order quantities that must amortize the fixed expenses of supporting the mil-spec business.

Our surveys show that there are adders for small order quantities, surface-mount packaging, and special radiation-tolerant features. On average, the surface-mount premium can run anywhere from 10 to 40 percent, depending on the pin count and availability. Products with radiation-tolerant features that are purchased expressly from manufacturers can fetch as much as 10 times the price of the normal 883C Class B version.

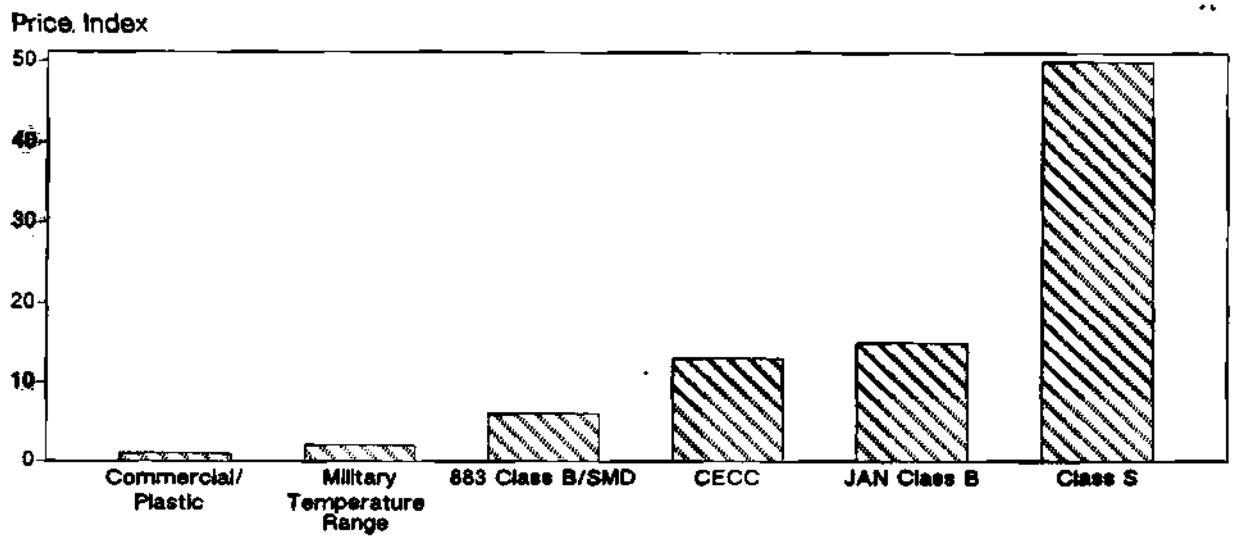
Military Semiconductor Pricing

Tables 1 through 12 present military-grade semiconductor pricing estimates and forecasts.

©1990 Dataquest Incorporated April

Figure 2

Generic Semiconductor Price Comparisons by Grade

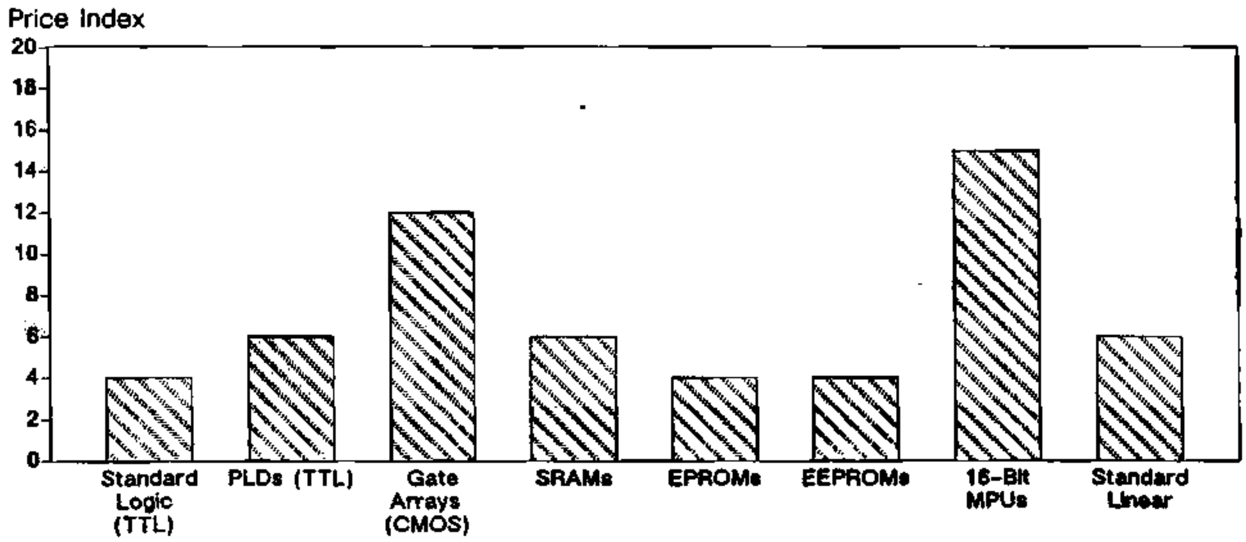


0006627-2

Source: Dataquest April 1990

Figure 3

MIL-STD-883C versus Commercial Plastic



0006627-3

Source: Dataquest April 1990

©1990 Dataquest Incorporated April

Table 1

Standard Logic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

	1989	1990	1991	1992	Lead Time
54LS TTL					
54LS00 (quad 2 input nand)					10 weeks
38510	0.95	1.03	1.08	1.12	
883/SMD	0.42	0.45	0.47	0.49	
54LS74 (dual D flip-flop)					
38510	0.94	0.98	1.03	1.06	
883/SMD	0.49	0.51	0.53	0.55	
54LS245 (octal noninverting bus transceiver)					
38510	1.85	1.91	1.96	2.01	
883/SMD	1.08	1.09	1.09	1.11	
54S TTL					
54S00 (quad 2 input nand)					10 weeks
38510	1.63	1.70	1.73	1.75	
883/SMD	0.62	0.65	0.70	0.72	
54S74 (dual D flip-flop)					
38510	1.82	1.82	1.82	1.84	
883/SMD	0.73	0.76	0.78	0.79	
54S240 (octal inverting buffer/driver)					
38510	N/A	N/A	N/A	N/A	
883/SMD	1.64	1.70	1.76	1.82	
54F TTL					
54F00 (quad 2 input nand)					12 weeks
38510	1.12	1.07	1.02	1.00	
883/SMD	0.64	0.62	0.60	0.59	
54F74 (dual D flip-flop)					
38510	1.19	1.14	1.12	1.10	
883/SMD	0.67	0.66	0.64	0.63	
54F373 (octal D transparent latch)					
38510	2.55	2.50	2.47	2.45	
883/SMD	1.63	1.59	1.57	1.55	

(Continued)

©1990 Dataquest Incorporated April

Table 1 (Continued)

Standard Logic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

	1989	1990	1991	1992	Lead Time
4000/54C CMOS					11 weeks
4001A (quad 2 input nor)					
38510	3.85	4.10	4.40	4.75	
883/SMD	0.64	0.70	0.75	0.79	
4049A (hex inverting buffer/driver)					
38510	4.15	4.45	4.70	4.95	
883/SMD	0.67	0.71	0.75	0.78	
54HC CMOS					11 weeks
54HC00 (quad 2 input nand)					
38510	3.12	3.00	2.98	3.00	
883/SMD	0.51	0.49	0.47	0.47	
54HC74 (dual D flip-flop)					
38510	5.45	5.35	5.35	5.40	
883/SMD	0.62	0.60	0.60	0.61	
54HC245 (octal noninverting bus transeiver)					
38510	N/A	N/A	N/A	N/A	
883/SMD	1.50	1.50	1.50	1.52	
54AC/FCT CMOS					12 weeks
54AC00 (quad 2 input nand)					
38510	N/A	3.80	3.42	3.05	
883/SMD	1.36	1.08	0.94	0.86	
54AC74 (dual D flip-flop)					
38510	N/A	4.23	3.85	3.41	
883/SMD	2.06	1.95	1.82	1.57	
54AC373/54FCT373 (octal D transparent latch)					
38510	N/A	12.70	10.95	8.85	
883/SMD	6.27	5.25	4.13	3.45	
54ALS TTL					10 weeks
54ALS00 (quad 2 input nand)					
38510	2.62	2.75	2.77	2.77	
883/SMD	0.71	0.72	0.72	0.72	

(Continued)

©1990 Dataquest Incorporated April

Table 1 (Continued)

Standard Logic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

	1989	1990	1991	1992	Lead Time
54ALS TTL (Continued)					
54ALS74 (dual D flip-flop)					
38510	N/A	N/A	N/A	N/A	
883/SMD	1.02	1.06	1.09	1.10	
54ALS373 (octal D transparent latch)					
38510	8.80	8.76	8.72	8.70	
883/SMD	3.32	3.24	3.24	3.24	
54AS TTL					11 weeks
54AS00 (quad 2 input nand)					
38510	N/A	N/A	N/A	N/A	
883/SMD	1.08	1.08	1.08	1.08	
54AS373 (octal D transparent latch)					
38510	N/A	N/A	N/A	N/A	
883/SMD	4.21	4.21	4.21	4.21	

Average Price Adders:

1,000 volume	35%
SMT	20 to 40%
Class S	x 10
Rad hard	x 2 to 4

N/A = Not Available

Source: Dataquest
April 1990

Table 2

Gate Array Pricing (Dollars per Gate)
Military Specification: Class B
Annual Volume: 2,500 Units
NRE in Thousands of Dollars

883/SCD	1989	1990	1991	1992	Lead Time Production/ Protos
CMOS					
2 micron					16/4 weeks
0-999	0.0450	0.0450	0.0460	0.0480	
NRE	16	15	15	15	
1,000-1,999	0.0300	0.0290	0.0300	0.0320	
NRE	18	18	18	18	
2,000-4,999	0.0210	0.0200	0.0200	0.0210	
NRE	21	21	21	20	
5,000-10,000	0.0230	0.0230	0.0230	0.0240	
NRE	31	31	30	29	
1.5 micron (1.3 to 1.7 micron)					17/3 weeks
0-999	0.0560	0.0520	0.0480	0.0440	
NRE	14	13	12	12	
1,000-1,999	0.0450	0.0410	0.0380	0.0360	
NRE	17	16	16	16	
2,000-4,999	0.0220	0.0210	0.0200	0.0190	
NRE	26	25	25	25	
5,000-9,999	0.0230	0.0220	0.0200	0.0190	
NRE	41	40	40	40	
10,000-20,000	0.0320	0.0310	0.0290	0.0290	
NRE	62	61	61	61	
1.0 micron (1.0 to 1.2 micron)					16/8 weeks
0-999	N/A	N/A	N/A	N/A	
NRE	60	55	45	33	
1,000-1,999	N/A	N/A	N/A	N/A	
NRE	63	58	48	35	
2-4999	N/A	N/A	N/A	N/A	
NRE	63	58	48	35	
5-9,999	N/A	N/A	N/A	N/A	
NRE	75	68	58	50	
10,000-19,900	N/A	N/A	N/A	N/A	
NRE	90	90	75	63	
20,000-50,000	N/A	N/A	N/A	N/A	
NRE	98	98	80	75	

(Continued)

©1990 Dataquest Incorporated April

Table 2 (Continued)

Gate Array Pricing (Dollars per Gate)
Military Specification: Class B
Annual Volume: 2,500 Units
NRE in Thousands of Dollars

883/SCD	1989	1990	1991	1992	Lead Time Production/ Protos
ECL					16/6 weeks
1.5 micron					
0-999	0.2450	0.2400	0.2400	0.2400	
NRE	23	22	22	22	
1-1,999	0.1150	0.1100	0.1100	0.1100	
NRE	38	37	37	37	
2-4,999	0.1200	0.1150	0.1150	0.1150	
NRE	44	43	43	43	
5-9,999	0.1000	0.0980	0.0980	0.0970	
NRE	60	60	60	60	
10-20,000	0.1070	0.1050	0.1050	0.1050	
NRE	102	100	100	100	

Average Price Adders:

1,000 volume	5%
SMT	20 to 40%
Class S	x6 to 10
Rad hard	x1.5 to 3.0

Source: Dataquest
April 1990

©1990 Dataquest Incorporated April

Table 3

Cell-Based IC Pricing (Dollars per Gate)
Military Specification: Class B
Annual Volume: 2,500 Units
NRE in Thousands of Dollars

883/SCD	1989	1990	1991	1992	Lead Time Production/ Protos
CMOS 2 micron					22/6 weeks
0-999	0.0480	0.0480	0.0480	0.0500	
NRE	34	33	33	33	
1-1,999	0.0390	0.0380	0.0380	0.0390	
NRE	36	35	35	35	
2-4,999	0.0240	0.0230	0.0240	0.0250	
NRE	42	41	41	41	
5-9,999	0.0220	0.0210	0.0210	0.0220	
NRE	63	62	61	61	
10,000-19,9000	0.0290	0.0280	0.0280	0.0300	
NRE	83	82	81 81		
20,000-50,000	0.0340	0.0330	0.0340	0.0360	
NRE	141	138	136	135	
CMOS 1.5 micron					23/6 weeks
0-999	0.0750	0.0650	0.0580	0.0540	
NRE	33	30	29	28	
1-1,999	0.0480	0.0440	0.0420	0.0420	
NRE	35	33	31	30	
2-4,999	0.0270	0.0250	0.0230	0.0220	
NRE	41	38	37	36	
5-9,999	0.0260	0.0240	0.0230	0.0230	
NRE	62	60	58	58	
10,000-19,900	0.0340	0.0320	0.0310	0.0310	
NRE	89	85	81	78	
20,000-50,000	0.0420	0.0390	0.0370	0.0360	
NRE	146	142	139	136	
CMOS 1.0 micron (1.0 to 1.2 micron)					23/8 weeks
0-999*	0.0900	0.0750	0.0620	0.0560	
NRE*	36	32	30	28	
1,000-1,999*	0.0560	0.0490	0.0450	0.0430	
NRE*	38	35	32	30	
2,000-4,999*	0.0320	0.0280	0.0250	0.0230	
NRE*	45	41	39	37	

(Continued)

©1990 Dataquest Incorporated April

Table 3 (Continued)

Cell-Based IC Pricing (Dollars per Gate)
Military Specification: Class B
Annual Volume: 2,500 Units
NRE in Thousands of Dollars

883/SCD	1989	1990	1991	1992	Lead Time Production/ Protos
CMOS 1.0 micron (1.0 to 1.2 micron)					
5,000-9,999*	0.0310	0.0280	0.0250	0.0240	
NRE*	67	64	61	60	
10,000-19,900	0.0410	0.0370	0.0340	0.0330	
NRE*	95	90	84	81	
20,000-50,000	0.0500	0.0450	0.0410	0.0380	
NRE*	154	149	145	141	

Average Price Adders	
1,000 volume	5%
SMT	20 to 40%
Class S	x8 to 10
Rad hard	x2.0 to 4.0

*Estimates

Source: Dataquest
April 1990

©1990 Dataquest Incorporated April

Table 4

Programmable Logic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 2,500 Units

883/SMD	1989	1990	1991	1992	Lead Time
TTL—Fuse Link					
Pin Count ≤20					10 weeks
10.1-14.9ns	7.65	7.25	6.90	6.65	
15.0-24.9ns	5.65	5.15	4.85	4.70	
≥25ns	5.20	4.60	4.30	4.30	
Pin Count 22, 24					12 weeks
10.1-14.9ns	17.10	14.50	12.45	11.05	
15.0-24.9ns	7.35	6.75	6.25	5.90	
≥25ns	6.75	6.10	5.60	5.30	
CMOS—U.V. Reprogrammable					
Pin Count ≤20					10 weeks
25.0-34.9ns	14.75	13.15	11.75	10.60	
35.0-44.9ns	11.25	10.00	8.90	8.25	
≥45ns	8.55	8.15	7.55	7.20	
Pin Count 22, 24					12 weeks
25.0-34.9ns	38.50	31.45	26.85	23.15	
35.0-44.9ns	29.45	24.10	20.75	18.70	
≥45ns	15.50	13.45	11.60	9.85	

Average Price Adders:

1,000 Volume	30%
SMT	15%
JAN	x1.5 to 2.0
Class S	x10

Source: Dataquest
April 1990

©1990 Dataquest Incorporated April

Table 5

DRAM Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

883/SMD	1989	1990	1991	1992	Lead Time
64K, 64Kx1, 150ns	6.85	7.10	7.45	7.65	14 weeks
256K, 256Kx1, 150ns	22.45	20.15	18.00	16.05	16 weeks
1Mb, 1Mx1, 120ns	112.35	98.50	77.30	59.60	14 weeks

Average Price Adders:	
1,000 volume	30%
SMT	15%
JAN	x2 to 3

Source: Dataquest
April 1990

Table 6

SRAM Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

883/SMD	1989	1990	1991	1992	Lead Time
CMOS					
4K, 4Kx1, 35ns	14.50	13.65	13.50	13.50	11 weeks
16K, 4Kx4, 25ns	27.45	23.35	19.75	16.50	8 weeks
16K, 4Kx4, 35ns	24.20	20.30	16.80	13.50	7 weeks
16K, 4Kx4, 45ns	19.10	15.45	13.20	12.45	8 weeks
16K, 2Kx8, 150ns	14.50	12.30	12.00	12.25	15 weeks
64K, 8Kx8, 120-150ns	23.95	21.65	21.10	21.10	15 weeks
64K, 16Kx4, 35ns	27.50	24.60	21.75	20.10	12 weeks
64K, 8Kx8, 45ns	31.50	28.75	26.20	24.65	12 weeks
64K, 64Kx1, 25ns	58.30	46.50	36.80	29.45	12 weeks
256K, 32Kx8, 100ns	47.45	41.45	36.25	32.45	16 weeks
256K, 32Kx8, 70ns	N/A	54.50	49.40	44.00	20 weeks
256K, 256Kx1, 45ns	N/A	84.00	69.75	56.50	20 weeks

Average Price Adders:	
1,000 volume	25%
SMT	12%
JAN	x3 to 5
Class S	x8 to 15
Rad hard	x3 to 5

Source: Dataquest
April 1990

©1990 Dataquest Incorporated April

Table 7

EPROM Pricing (Dollars)
Military Specification: Class B
Annual Volume: 5,000 Units

883/SMD	1989	1990	1991	1992	Lead Time
64K	11.45	11.50	11.50	11.70	10 weeks
128K	14.30	14.05	13.90	13.70	12 weeks
256K	18.45	14.85	14.25	14.25	12 weeks
512K	31.30	25.85	21.50	19.55	12 weeks
1Mb	135.00	84.50	61.45	46.50	17 weeks

Average Price Adders:	
1,000 volume	30%
SMT	25%
JAN	x1.5 to 3.0
Class S	x10 to 12

Source: Dataquest
April 1990

Table 8

PROM Pricing (Dollars)
Military Specification: Class B
Annual Volume: 5,000 Units

883/SMD	1989	1990	1991	1992	Lead Time
Bipolar TTL					
4K	4.86	4.65	4.55	4.55	12 weeks
8K	4.79	4.75	4.75	4.80	12 weeks
16K	7.55	7.05	6.95	6.90	14 weeks
32K	11.65	11.35	11.10	11.10	15 weeks
64K	17.25	15.15	14.50	14.15	16 weeks
CMOS TTL					
64K	17.60	15.50	14.80	14.50	12 weeks

Average Price Adders:	
1,000 volume	30%
SMT	20%
JAN	x1.3 to 1.5
Class S	x12 to 15

Source: Dataquest
April 1990

Table 9

EEPROM Pricing (Dollars)
Military Specification: Class B
Annual Volume: 2,500 Units

883/SMD	1989	1990	1991	1992	Lead Time
16K	13.20	12.04	11.24	10.60	8 weeks
64K	21.67	18.46	17.12	16.12	10 weeks
256K	84.00	71.00	64.50	58.00	16 weeks
Average Price Adders:					
1,000 volume	5%				
SMT	25%				
JAN	x3 to 5				
Class S	x6				

Source: Dataquest
April 1990

©1990 Dataquest Incorporated April

Table 10

Microcomponent Pricing (Dollars)
Military Specification: Class B
Annual Volume: 1,000-5,000 Units

883/SMD	1989	1990	1991	1992	Lead Time
8-bit MPU					8 weeks
8085A	24.20	24.20	25.20	26.00	
8088	32.50	35.20	37.50	39.00	
Z80	60.00	55.00	56.00	52.00	
16-bit MPU					16 weeks
8086-8	65.45	59.50	55.00	51.50	
68000-8	125.00	114.00	102.00	96.00	
80186-8	110.00	104.00	99.00	95.00	
80286-10	315.00	250.00	225.00	205.00	
1750A	675.00	625.00	565.00	515.00	
32-bit MPU					24 weeks
CISC ≤20 MHz	625.00	580.00	545.00	520.00	
CISC ≥20 MHz	1,260	1,110	950.00	780.00	
RISC	1,500	1,200	980.00	825.00	
8-bit MCU					15 weeks
8048	22.15	22.15	23.25	24.00	
8051	31.00	26.00	25.00	23.00	
DSP MPU (16-bit)	325.00	274.00	232.00	205.00	15 weeks
MPR					
16-Bit FPU	238.00	212.00	198.00	185.00	18 weeks
32-bit FPU	553.00	495.00	435.00	395.00	24 weeks
16x16 Multiplier (55ns)	59.00	51.25	44.50	37.50	15 weeks
16x16 Mult./Acc. (55ns)	81.50	70.50	63.75	55.75	15 weeks
1553B Single-Chip Controller	476.00	432.00	393.00	365.00	24 weeks
Average Price Adders:					
1,000 Volume	30%				
SMT	20%				
JAN	x2 to 5				
Class S	x12				
Rad hard	x2 to 5				

Source: Dataquest
April 1990

©1990 Dataquest Incorporated April

Table 11

Analog Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

883/SMD	1989	1990	1991	1992	Lead Time
Voltage Regulators					
7805 (positive, 5V)	3.56	3.48	3.45	3.45	15 weeks
1524 (switching)	4.11	3.91	3.76	3.65	15 weeks
Comparators					
111 (single, bipolar)	1.16	1.10	1.08	1.10	13 weeks
139 (quad, bipolar)	1.45	1.15	1.13	1.18	13 weeks
Amplifiers					
101 (dual, bipolar)	1.23	1.18	1.18	1.20	13 weeks
156 (single, BiFET)	2.15	2.02	1.95	1.87	13 weeks
733 (Video)	2.15	2.12	2.12	2.12	15 weeks
Interface					
26LS32 (quad RS-422 receiver)	3.24	2.72	2.55	2.38	13 weeks
Data Conversion					
565 (12-bit DAC)	82.60	75.80	75.55	76.10	20 weeks
574 (12-bit A/D)	74.65	70.65	70.65	71.25	20 weeks
Timer					
555	1.68	1.63	1.63	1.65	12 weeks
Transistor Array					
3045 (quad NPN)	1.91	1.85	1.85	1.85	12 weeks
Additional Price Adders:					
10,000 volume	15%				
1,000 volume	30%				
SMT	10 to 50%				
JAN	x1.5 to 3.0				
Class S	x10				
Rad hard	x2 to 7				

Source: Dataquest
April 1990

©1990 Dataquest Incorporated April

Table 12

Discrete and Optoelectronic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

	1989	1990	1991	1992	Lead Time
Transistors					
Small/Medium Signal					
2N2907A (NPN, 40V, 1.8W)					
JAN	0.23	0.25	0.26	0.27	10-40 weeks
JANTX	0.48	0.48	0.50	0.54	
JANTXV	1.45	1.45	1.47	1.50	
2N4856 (JFET, 40V, 360mW)					20-45 weeks
JAN	0.64	0.62	0.60	0.60	
JANTX	0.79	0.77	0.76	0.76	
JANTXV	2.17	2.14	2.07	2.07	
Bipolar Power					
2N3772 (NPN, 400V, 100W)					15-40 weeks
JAN	3.21	3.00	3.00	3.05	
JANTX	8.50	8.42	8.35	8.28	
JANTXV	14.76	14.35	14.04	13.85	
MOSFET Power					
2N6756 (100V, 14A, 75W)					18-40 weeks
JAN	3.04	2.98	2.98	2.98	
JANTX	8.00	7.78	7.65	7.50	
JANTXV	14.10	13.71	13.45	13.05	
Diodes					
Small Signal					
1N4150 (switching, 200mA)					15 weeks
JAN	0.05	0.05	0.04	0.04	
JANTX	0.41	0.41	0.41	0.41	
JANTXV	0.67	0.67	0.67	0.67	
Rectifier					
1N3891 (12A, 200V, 200ns)					16 weeks
JAN	2.73	2.70	2.75	2.82	
JANTX	7.09	7.05	7.11	7.20	
JANTXV	12.00	11.92	11.95	12.09	

(Continued)

 ©1990 Dataquest Incorporated April

Table 12 (Continued)

Discrete and Optoelectronic Pricing (Dollars)
Military Specification: Class B
Annual Volume: 10,000 Units

	1989	1990	1991	1992	Lead Time
Diodes (Continued)					
Zener					
1N829 (6.2V, 250mW)					20 weeks
JAN	1.25	1.24	1.24	1.24	
JANTX	1.85	1.92	1.92	1.92	
JANTXV	2.29	2.29	2.29	2.29	
Optoelectronic					
LED					
T1, Standard, Red					12 weeks
JAN	0.20	0.18	0.18	0.19	
JANTX	0.56	0.53	0.53	0.53	
Optocoupler					
4N23A (1kV, tr/tf, 15us)					12-18 weeks
JAN	0.75	0.73	0.73	0.73	
JANTX	2.08	2.04	2.04	2.04	
JANTXV	5.22	5.18	5.18	5.18	

Additional Price Adders:

10,000 volume	15%
1,000 volume	30%
SMT	10 to 50%
Class S	x10
Rad hard	x2 to 5

Source: Dataquest
April 1990

©1990 Dataquest Incorporated April

(Page intentionally left blank)

System Manufacturers

The following is a list of material in this section:

- OEM Overview

 © 1990 Dataquest Incorporated April

OEM Overview

OVERVIEW

The military and aerospace electronic equipment market today is principally centered in North America and Europe, as are the majority of its OEMs. Of the top 10 companies in revenue, 8 are in the United States and 2 are in Europe. Emerging, however, are strong commercial and technology-driven companies that are starting to have an impact on the world market. We expect further consolidations both within and between countries as the demand for military systems decreases after the high-growth years of the early 1980s. Table 1 presents military and aerospace electronic equipment revenue estimates of the top 50 worldwide military suppliers.

Table 1

Estimated Worldwide Military/Aerospace Electronic Equipment Revenue (Millions of Dollars)

Company	1985	1986	1987	1988	1989	CAGR 1985-1989
GM Hughes Electronics	5,128	5,635	5,847	6,060	5,664	2.5%
Thomson-CSF	3,801	4,011	4,236	4,166	4,235	2.7%
GE	3,215	3,818	4,209	4,273	4,215	7.0%
Raytheon	2,844	3,253	3,569	3,760	4,015	9.0%
GEC	2,280	2,667	2,976	3,110	3,240	9.2%
Lockheed	2,243	2,519	3,169	3,184	3,054	8.0%
TRW	2,370	2,434	2,906	2,985	2,990	6.0%
Unisys	2,488	2,765	2,354	2,365	2,255	(2.4%)
Martin Marietta	1,571	1,745	1,869	2,078	2,238	9.2%
Rockwell	2,035	2,384	2,370	2,135	2,197	1.9%
Texas Instruments	1,480	1,717	1,967	2,142	2,148	9.8%
Litton	1,916	2,172	2,231	2,291	2,143	2.8%
Honeywell	1,119	1,219	1,899	1,840	2,004	15.7%
Westinghouse	1,605	1,720	1,807	1,936	1,982	5.4%
IBM	1,501	1,821	2,130	1,977	1,921	6.4%
ITT	1,122	1,279	1,280	1,387	1,580	8.9%
Deutsche Aerospace	NA	NA	NA	NA	1,575	NA
E-Systems	926	1,135	1,227	1,301	1,470	12.2%
Ford Aerospace	1,100	1,165	1,200	1,180	1,210	2.4%
Northrop	1,120	1,512	1,595	1,569	1,203	1.8%
General Dynamics	1,120	1,210	1,175	1,182	1,165	1.0%
Harris	1,025	1,030	1,100	1,080	1,155	3.0%
Plessey	743	796	828	870	1,140	11.3%
Loral	472	625	638	1,072	1,121	24.1%
GTE	787	1,050	1,100	1,145	1,080	8.2%
Ferranti	592	673	983	1,032	1,050	15.4%
Boeing	705	853	990	1,050	1,040	10.2%
British Aerospace	831	981	1,154	1,110	1,005	4.9%
Allied-Signal	475	745	820	825	908	17.6%
Philips	1,475	1,605	1,643	1,300	855	(12.7%)

(Continued)

©1990 Dataquest Incorporated August

Table 1 (Continued)

Estimated Worldwide Military/Aerospace Electronic Equipment Revenue
(Millions of Dollars)

Company	1985	1986	1987	1988	1989	CAGR 1985-1989
Thorn-EMI	490	578	685	712	801	13.1%
Mitsubishi	313	577	655	672	740	24.0%
Motorola	496	526	540	648	698	8.9%
AT&T	485	545	570	580	610	5.9%
Siemens	344	495	599	595	610	15.4%
Sextant Avionique	NA	NA	NA	NA	610	NA
Smiths Industries	NA	NA	NA	555	608	NA
ESD	314	424	533	550	585	16.8%
AIL Systems	NA	NA	944	768	557	NA
Toshiba	251	410	510	525	550	21.7%
Emerson Electric	555	561	545	552	540	(0.7%)
NEC	103	206	325	485	510	49.2%
Ericsson	266	477	547	420	505	17.4%
McDonnell Douglas	330	378	435	480	495	10.7%
IAI/Elta	NA	NA	NA	NA	495	NA
Racal	461	447	490	475	468	0.4%
Grumman	220	483	617	514	446	19.3%
Selenia	NA	NA	NA	NA	445	NA
Tadiran/Elisra	NA	NA	NA	NA	440	NA
Matra	NA	NA	NA	415	435	NA

NA = Not available
Source: Dataquest (August 1990)

TOP 50 ANALYSIS

It should be noted that there is double counting involved in adding up the revenue of these companies to obtain a number to compare with worldwide production. This is because of the subcontracting that occurs between companies, thus causing the value of the subcontract to be counted twice. Dataquest estimates that 20 percent of the revenue of the top 50 companies is double counted among themselves.

PRODUCT LINES

Table 2 presents a summary profile of the types of equipment produced by the top 50. In general, the bigger companies are broad line, developing and producing almost all types of equipment; the smaller companies tend to specialize. The larger companies tend to seek balance in their technological portfolio and broaden themselves to take advantage of prime contractor opportunities, and the smaller companies usually tend to focus on one product type and secure subcontracts.

The types of electronics most commonly produced include voice and data communication, missile and weapon guidance and control, and electronic warfare including signal detection and countermeasures. Radar and sonar tend to be the most specialized of the general equipment types. Other types of specialized equipment (which is usually produced by specialized houses) include microwave subsystems, embedded processing modules, and mil-spec and ruggedized computers and peripherals.

©1990 Dataquest Incorporated August

Table 2

Principal Military/Aerospace Electronic Equipment Producers

Company	Radar Airborne	Radar Ship/Ground	Sonar	Missile Weapon	Space	Navigation	Communications	Electronic Warfare
GM Hughes Electronics	X	X	X	X	X		X	X
Thomson-CSF	X	X	X	X	X		X	X
GE	X	X		X	X		X	X
Raytheon		X	X	X			X	X
GEC	X	X	X	X	X	X	X	X
Lockheed		X	X	X	X			X
TRW					X	X	X	X
Unisys		X				X	X	
Martin Marietta	X			X	X	X		
Rockwell	X			X	X	X	X	X
Texas Instruments	X			X		X		X
Litton				X		X	X	X
Honeywell			X	X	X	X	X	X
Westinghouse	X	X	X	X	X		X	X
IBM	X		X		X			
ITT		X			X	X	X	X
Deutsche Aerospace		X	X	X	X	X		X
E-Systems					X	X	X	X
Ford Aerospace				X	X			
Northrop				X		X		X
General Dynamics				X	X		X	
Harris					X		X	
Plessey		X	X	X		X	X	X
Loral	X			X	X		X	X
GTE							X	X
Ferranti	X	X			X	X		
Boeing	X			X	X			X
British Aerospace				X	X	X	X	X
Allied-Signal	X			X	X	X	X	
Philips				X	X	X	X	
Thorn-EMI	X	X		X				
Mitsubishi	X	X	X	X	X	X		
Motorola				X	X		X	X
AT&T			X		X		X	X
Siemens	X	X					X	X
Sextant Avionique						X	X	
Smiths Industries					X	X	X	
ESD	X	X		X	X			X
AIL Systems	X	X					X	X
Toshiba				X	X			
Emerson Electric	X	X				X	X	X
NEC					X	X	X	
Ericsson	X	X			X		X	X
McDonnell Douglas				X	X		X	
IAI/Elta	X	X	X	X	X	X		X
Racal						X	X	X
Grumman	X			X	X			
Selenia	X	X	X	X	X	X		X
Tadiran/Elisra							X	X
Matra				X	X			

(Continued)

Table 2 (Continued)

Principal Military/Aerospace Electronic Equipment Producers

Company	ElectroOptic	Aircraft Systems	Computer	Simulat. Trainers	Test	Other
GM Hughes Electronics	X	X	X	X	X	Semicond., microwave subsys.
Thomson-CSF	X	X	X	X	X	Semicond., microwave, CCD
GE	X	X	X	X	X	Semiconductors
Raytheon			X			Semiconductors
GEC	X			X	X	Semicond., microwave subsys.
Lockheed	X	X	X	X	X	Semicond., microwave subsys.
TRW	X	X	X	X		Semicond., microwave subsys.
Unisys		X	X	X		
Martin Marietta	X					
Rockwell	X	X	X		X	Semiconductors
Texas Instruments	X		X		X	Semicond., microwave subsys.
Litton	X		X			Microwave subsys.
Honeywell	X	X	X	X		Semiconductors
Westinghouse	X	X	X			Semiconductors
IBM		X	X	X		Semiconductors
ITT	X	X				Semicond., microwave subsys.
Deutsche Aerospace	X					
B-Systems				X		
Ford Aerospace	X		X			Semiconductors
Northrop	X	X			X	
General Dynamics		X		X	X	
Harris		X	X	X		Semicond., microwave subsys.
Plessey			X		X	Semiconductors
Loral	X	X	X	X	X	Semicond., microwave subsys.
GTE	X					
Ferranti	X	X				
Boeing	X	X		X	X	
British Aerospace	X	X	X	X	X	
Allied-Signal		X			X	Semiconductors
Philips						Semiconductors
Thorn-EMI	X		X	X		Semiconductors
Mitsubishi		X		X	X	Semiconductors
Motorola		X	X		X	Semiconductors
AT&T	X	X	X			Semicond., microwave subsys.
Siemens		X	X			Semiconductors
Sextant Avionique		X	X			
Smiths Industries	X	X	X			
ESD	X		X			
AIL Systems			X			
Toshiba						Semiconductors
Emerson Electric	X	X	X		X	
NEC			X			Semiconductors
Ericsson	X	X	X	X	X	Semiconductors
McDonnell Douglas	X	X		X		
IAI/Elta	X	X		X	X	
Racal	X	X	X			
Grumman		X		X	X	
Selenia	X					
Tadiran/Elisra			X			
Matra	X					

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Semiconductor
Share Estimates

Mil/Aero Semiconductor Market Share Estimates

1990

Dataquest

a company of
The Dun & Bradstreet Corporation

Published by Dataquest Incorporated

The content of this report represents our interpretation and analysis of information generally available to the public or released by knowledgeable individuals in the subject industry, but is not guaranteed as to accuracy or completeness. It does not contain material provided to us in confidence by our clients.

Printed in the United States of America. All rights reserved. No part of this publication may be reproduced, stored in retrieval systems, or transmitted, in any form or by any means—mechanical, electronic, photocopying, duplicating, microfilming, videotape, or otherwise—without the prior written permission of the publisher.

© 1991 Dataquest Incorporated
May 1991

Mil/Aero Semiconductor Market Share Estimates 1990

Tables 1 through 12 present estimates of worldwide dollar semiconductor shipments, by company, for military/aerospace electronic equipment end use. Tables 13 and 14 present North American and European market shipment breakouts.

Table 1

Estimated Worldwide Military/Aerospace Semiconductor Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	2,482	2,632	2,768	2,858	2,846	
Harris	268	280	271	269	263	9.2
Motorola	201	201	182	185	191	6.7
National Semiconductor	282	241	196	183	175	6.1
Texas Instruments	251	230	207	182	154	5.4
Advanced Micro Devices	157	161	151	138	124	4.4
GEC Plessey	0	0	0	0	120	4.2
Analog Devices	68	80	92	103	108	3.8
LSI Logic	37	56	82	91	100	3.5
SGS-Thomson/Thomson TMS	77	83	92	101	94	3.3
Intel	60	68	73	75	77	2.7
Raytheon	56	56	63	74	73	2.6
IDT	38	50	63	71	56	2.0
Philips	101	83	69	61	56	2.0
Cypress Semiconductor	13	19	28	38	42	1.5
Siliconix	31	37	38	39	40	1.4
MHS	9	14	18	28	39	1.4
Microsemi	24	23	36	38	38	1.3
Solitron	17	21	23	30	36	1.3
Atmel	2	8	13	21	35	1.2
Hewlett-Packard	22	24	26	31	35	1.2
M/A-Com	29	31	35	35	35	1.2
Fujitsu	20	22	27	34	35	1.2
Mitsubishi	21	23	28	33	33	1.2
Precision Monolithics	29	31	32	32	32	1.1
Honeywell	35	46	53	29	31	1.1
NEC	21	27	29	34	30	1.1
Hughes	27	33	27	26	29	1.0
Toshiba	20	24	26	28	28	1.0
Unitrode	46	37	31	30	27	.9

(Continued))

Table 1 (Continued)

Estimated Worldwide Military/Aerospace Semiconductor Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
General Instrument	16	18	19	26	26	.9
Electronic Design	3	7	15	25	25	.9
International Rectifier	21	25	31	27	25	.9
Siemens	14	19	21	21	24	.8
VLSI Technology	4	7	14	21	24	.8
Xicor	17	24	26	29	24	.8
Silicon General	12	14	18	23	23	.8
Kulite	7	10	14	20	22	.8
UTMC	6	8	14	15	19	.7
ITT	14	16	17	16	18	.6
Performance Semiconductor	2	4	9	14	17	.6
Optek	14	15	17	19	17	.6
Micron Technology	2	4	13	20	17	.6
Avantek	7	12	16	16	17	.6
Oki	13	15	17	19	17	.6
Powerex	0	0	0	16	16	.6
Linear Technology	11	13	16	13	16	.6
Burr-Brown	12	14	16	15	15	.5
Zilog	11	13	15	17	15	.5
TRW	30	29	15	14	15	.5
Alpha Industries	7	10	12	12	14	.5
Others	297	346	422	421	304	10.7

Dataquest (May 1991)

©1991 Dataquest Incorporated May—Reproduction Prohibited

Table 2

Estimated Worldwide Military/Aerospace IC Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	1,956	2,084	2,191	2,296	2,305	
Harris	237	248	251	249	243	10.5
National Semiconductor	262	220	181	171	163	7.1
Texas Instruments	217	194	170	148	129	5.6
Motorola	133	129	113	118	124	5.4
Advanced Micro Devices	157	161	151	138	124	5.4
GEC Plessey	0	0	0	0	118	5.1
Analog Devices	68	80	92	103	108	4.7
LSI Logic	37	56	82	91	100	4.3
Intel	60	68	73	75	77	3.3
SGS-Thomson/Thomson TMS	61	65	72	81	73	3.2
Raytheon	46	46	53	63	66	2.9
IDT	38	50	63	71	56	2.4
Philips	80	63	50	47	43	1.9
Cypress Semiconductor	13	19	28	38	42	1.8
MHS	9	14	18	28	39	1.7
Atmel	2	8	13	21	35	1.5
Precision Monolithics	28	30	32	32	32	1.4
Mitsubishi	19	21	25	30	30	1.3
Fujitsu	19	21	23	29	30	1.3
Honeywell	31	42	49	28	30	1.3
Electronic Design	3	7	15	25	25	1.1
Toshiba	18	21	23	25	25	1.1
Xicor	17	24	26	29	24	1.0
VLSI Technology	4	7	14	21	24	1.0
NEC	18	23	24	28	24	1.0
Siliconix	18	23	24	23	23	1.0
Silicon General	12	14	18	23	23	1.0
Kulite	7	10	14	20	22	1.0
Hughes	18	21	14	14	21	.9
UTMC	6	8	14	15	19	.8
Micron Technology	2	4	13	20	17	.7
Oki	13	15	17	19	17	.7
Performance Semiconductor	2	4	9	14	17	.7
Linear Technology	11	13	16	13	16	.7
M/A-Com	3	4	7	9	15	.7
Zilog	11	13	15	17	15	.7
Burr-Brown	12	14	16	15	15	.7
TRW	17	16	15	14	15	.7

(Continued)

Table 2 (Continued)

Estimated Worldwide Military/Aerospace IC Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
SEEQ Technology	15	19	24	14	13	.6
Solitron	5	7	9	12	12	.5
Others	227	282	325	365	261	11.3

Dataquest (May 1991)

©1991 Dataquest Incorporated May—Reproduction Prohibited

Table 3

Estimated Worldwide Military/Aerospace Digital Bipolar Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	735	647	574	519	472	
Advanced Micro Devices	136	135	123	111	97	20.6
Texas Instruments	177	144	116	88	65	13.8
National Semiconductor	151	121	94	76	64	13.6
Harris	42	33	47	55	61	12.9
Raytheon	34	33	43	50	53	11.2
GEC Plessey	0	0	0	0	31	6.6
Motorola	64	55	30	28	27	5.7
Philips	47	32	21	19	13	2.8
Fujitsu	11	10	11	11	12	2.5
TRW	4	4	5	7	8	1.7
Others	69	80	84	74	41	8.7

Source: Dataquest (May 1991)

Table 4

Estimated Worldwide Military/Aerospace Digital Bipolar Memory Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	143	117	96	94	69	
Advanced Micro Devices	56	52	44	42	35	50.7
Raytheon	12	12	11	17	15	21.7
National Semiconductor	28	23	18	15	8	11.6
Fujitsu	6	6	8	7	7	10.1
Texas Instruments	5	5	4	4	4	5.8
Others	36	19	11	9	0	.0

Source: Dataquest (May 1991)

©1991 Dataquest Incorporated May—Reproduction Prohibited

Table 5

Estimated Worldwide Military/Aerospace Digital Bipolar Logic Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	592	530	478	425	403	
Advanced Micro Devices	80	83	79	69	62	15.4
Texas Instruments	172	139	112	84	61	15.1
Harris	25	26	44	55	61	15.1
National Semiconductor	123	98	76	61	56	13.9
Raytheon	22	21	32	33	38	9.4
GEC Plessey	0	0	0	0	31	7.7
Motorola	62	54	30	28	27	6.7
Philips	34	24	16	14	13	3.2
TRW	4	4	5	7	8	2.0
Lansdale Semiconductor	7	8	9	8	6	1.5
Others	63	73	75	66	40	9.9

Source: Dataquest (May 1991)

©1991 Dataquest Incorporated May—Reproduction Prohibited

Table 6

Estimated Worldwide Military/Aerospace Digital MOS Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	714	874	1,038	1,191	1,208	
Harris	125	119	114	114	106	8.8
LSI Logic	37	56	82	91	100	8.3
Intel	58	66	71	73	76	6.3
Motorola	42	49	60	67	73	6.0
SGS-Thomson/Thomson TMS	49	53	60	70	62	5.1
GEC Plessey	0	0	0	0	57	4.7
IDT	38	50	63	70	54	4.5
National Semiconductor	35	36	39	48	48	4.0
Cypress Semiconductor	13	19	28	38	42	3.5
MHS	9	14	18	28	39	3.2
Texas Instruments	11	18	25	33	39	3.2
Atmel	2	8	13	19	29	2.4
Advanced Micro Devices	21	26	28	27	27	2.2
Electronic Design	3	7	15	25	25	2.1
Xicor	17	24	26	29	24	2.0
Honeywell	13	22	31	22	24	2.0
VLSI Technology	4	7	14	21	24	2.0
Hughes	17	18	14	14	21	1.7
NEC	17	20	21	23	21	1.7
UTMC	6	8	14	15	19	1.6
Mitsubishi	11	12	15	19	19	1.6
Fujitsu	8	11	12	18	18	1.5
Micron Technology	2	4	13	20	17	1.4
Performance Semiconductor	2	4	9	14	17	1.4
Toshiba	13	15	16	18	17	1.4
Zilog	11	13	15	17	15	1.2
Oki	13	13	15	17	15	1.2
SEEQ Technology	15	19	24	14	13	1.1
Altera	0	0	7	11	12	1.0
Gould Semiconductor	11	11	8	10	12	1.0
Others	111	152	168	206	143	11.8

Source: Dataquest (May 1991)

©1991 Dataquest Incorporated May—Reproduction Prohibited

Table 7

Estimated Worldwide Military/Aerospace Digital MOS Memory Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	260	328	385	452	411	
IDT	34	44	50	53	35	8.5
Electronic Design	3	7	15	25	25	6.1
SGS-Thomson/Thomson TMS	24	25	27	33	25	6.1
Xicor	17	24	26	29	24	5.8
Intel	27	31	27	25	24	5.8
MHS	2	4	8	18	23	5.6
Harris	40	34	25	26	21	5.1
Cypress Semiconductor	11	15	18	21	21	5.1
Micron Technology	2	4	13	20	17	4.1
Texas Instruments	6	8	10	15	17	4.1
Atmel	2	7	11	12	17	4.1
National Semiconductor	14	14	13	13	14	3.4
SEEQ Technology	15	19	24	14	13	3.2
NEC	12	13	14	16	13	3.2
Advanced Micro Devices	13	15	14	14	13	3.2
Honeywell	0	5	14	10	11	2.7
Motorola	4	6	9	11	11	2.7
Fujitsu	7	9	9	13	11	2.7
Mitsubishi	5	5	6	10	10	2.4
Microchip Technology	3	4	6	8	8	1.9
Others	19	35	46	66	58	14.1

Source: Dataquest (May 1991)

Table 8

Estimated Worldwide Military/Aerospace Digital MOS Logic Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	292	354	406	469	509	
LSI Logic	37	56	81	90	98	19.3
Harris	70	69	60	67	66	13.0
GEC Plessey	0	0	0	0	41	8.1
National Semiconductor	17	18	20	29	28	5.5
VLSI Technology	4	7	13	18	23	4.5
Motorola	17	19	21	23	21	4.1
SGS-Thomson/Thomson TMS	13	14	16	18	18	3.5
Hughes	16	17	14	14	16	3.1
IDT	3	5	11	15	16	3.1
Texas Instruments	5	9	11	12	15	2.9
Cypress Semiconductor	2	4	8	13	15	2.9
Honeywell	13	17	17	12	13	2.6
Altera	0	0	7	11	12	2.4
Atmel	0	1	2	7	12	2.4
UTMC	2	3	5	6	11	2.2
Others	93	115	120	134	104	20.4

Source: Dataquest (May 1991)

Table 9

Estimated Worldwide Military/Aerospace Digital MOS Microcomponent Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	162	192	247	270	288	
Intel	31	34	42	47	51	17.7
Motorola	21	24	30	33	41	14.2
SGS-Thomson/Thomson TMS	12	14	17	19	19	6.6
Harris	15	16	29	21	19	6.6
Zilog	11	13	15	17	15	5.2
Performance Semiconductor	1	2	3	8	10	3.5
Advanced Micro Devices	6	7	8	8	9	3.1
GEC Plessey	0	0	0	0	9	3.1
Texas Instruments	0	1	4	6	7	2.4
UTMC	4	5	8	8	7	2.4
Others	61	76	91	103	101	35.1

Source: Dataquest (May 1991)

©1991 Dataquest Incorporated May—Reproduction Prohibited

Table 10

Estimated Worldwide Military/Aerospace Analog Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	507	563	579	586	625	
Analog Devices	68	79	87	98	103	16.5
Harris	70	96	90	80	76	12.2
National Semiconductor	76	63	48	47	51	8.2
Precision Monolithics	28	30	32	32	32	5.1
GEC Plessey	0	0	0	0	30	4.8
Texas Instruments	29	32	29	27	25	4.0
Motorola	27	25	23	23	24	3.8
Siliconix	18	23	24	23	23	3.7
Philips	29	27	24	22	23	3.7
Kulite	7	10	14	20	22	3.5
Silicon General	12	14	18	19	18	2.9
Linear Technology	11	13	16	13	16	2.6
Burr-Brown	12	14	16	15	15	2.4
Raytheon	12	13	10	13	13	2.1
Solitron	5	7	9	12	12	1.9
Others	103	117	139	142	142	22.7

Source: Dataquest (May 1991)

©1991 Dataquest Incorporated May—Reproduction Prohibited

Table 11

Estimated Worldwide Military/Aerospace Discrete Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	446	456	470	459	443	
Motorola	64	68	68	66	66	14.9
Microsemi	24	23	36	38	38	8.6
General Instrument	16	18	19	26	26	5.9
International Rectifier	21	25	31	27	25	5.6
Solitron	12	14	14	18	24	5.4
M/A-Com	26	27	28	26	20	4.5
Harris	29	31	15	18	18	4.1
Siliconix	13	14	14	16	17	3.8
Powerex	0	0	0	16	16	3.6
Unitrode	44	35	21	18	15	3.4
Texas Instruments	22	23	23	20	15	3.4
Hewlett-Packard	7	8	8	11	13	2.9
Semtech	5	7	9	10	12	2.7
National Semiconductor	20	21	15	12	12	2.7
SGS-Thomson/Thomson TMS	8	9	10	10	11	2.5
Others	135	133	159	127	115	26.0

Source: Dataquest (May 1991)

Table 12

Estimated Worldwide Military/Aerospace Optoelectronic Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	80	92	107	103	98	
Hewlett-Packard	15	16	18	20	22	22.4
Optek	14	15	17	19	17	17.3
Texas Instruments	12	13	14	14	10	10.2
SGS-Thomson/Thomson TMS	8	9	10	10	10	10.2
Siemens	5	7	8	9	9	9.2
Others	26	32	40	31	30	30.6

Source: Dataquest (May 1991)

©1991 Dataquest Incorporated May—Reproduction Prohibited

Table 13

Estimated North America Military/Aerospace Semiconductor Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	1,881	1,921	2,000	2,059	2,038	
Harris	259	270	259	257	251	12.3
National Semiconductor	242	197	153	143	136	6.7
Motorola	151	146	126	131	134	6.6
Texas Instruments	205	180	155	135	114	5.6
Advanced Micro Devices	130	131	119	113	102	5.0
LSI Logic	36	53	76	83	91	4.5
Raytheon	53	53	59	69	69	3.4
Intel	50	55	57	58	60	2.9
Analog Devices	41	45	51	58	58	2.8
IDT	30	38	46	53	43	2.1
GEC Plessey	0	0	0	0	41	2.0
Philips	61	49	41	41	38	1.9
Cypress Semiconductor	13	17	24	34	38	1.9
Microsemi	23	21	34	36	36	1.8
Solitron	16	20	21	28	33	1.6
M/A-Com	29	31	33	33	33	1.6
Honeywell	35	46	53	29	31	1.5
SGS-Thomson/Thomson TMS	25	26	29	33	30	1.5
Atmel	2	8	12	15	28	1.4
Siliconix	22	26	27	28	28	1.4
Precision Monolithics	27	28	27	27	27	1.3
Hughes	26	31	25	24	27	1.3
Hewlett-Packard	18	19	20	23	26	1.3
Unitrode	44	33	26	25	23	1.1
Kulite	7	10	14	20	22	1.1
VLSI Technology	4	7	13	18	21	1.0
General Instrument	12	14	15	21	21	1.0
Xicor	15	21	23	24	20	1.0
Silicon General	12	13	17	19	19	.9
Electronic Design	3	7	15	19	19	.9
Others	290	326	430	462	419	20.6

Source: Dataquest (May 1991)

Table 14

Estimated European Military/Aerospace Semiconductor Shipments (Millions of Dollars)

	1986	1987	1988	1989	1990	1990 Share (%)
Total	481	581	633	647	639	
GEC Plessey	0	0	0	0	70	11.0
SGS-Thomson/Thomson TMS	52	57	63	68	64	10.0
Motorola	48	53	54	51	53	8.3
National Semiconductor	38	42	40	37	36	5.6
Analog Devices	25	30	32	35	35	5.5
Texas Instruments	38	41	42	36	30	4.7
MHS	9	14	18	24	30	4.7
Advanced Micro Devices	27	30	32	23	19	3.0
Philips	40	34	28	20	18	2.8
Siemens	11	14	16	15	17	2.7
Others	193	266	308	338	267	41.8

Source: Dataquest (May 1991)

©1991 Dataquest Incorporated May—Reproduction Prohibited

©1991 Dataquest Incorporated May—Reproduction Prohibited

Dataquest

D&B a company of The Dun & Bradstreet Corporation

Dataquest Research and Sales Offices:

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
Phone: 01 (408) 437-8000
Telex: 171973
Fax: 01 (408) 437-0292

Technology Products Group
Phone: (800) 624-3280

Dataquest Incorporated
Ledgeway/Dataquest
The Corporate Center
550 Cochituate Road
Framingham, MA 01701
Phone: 01 (508) 370-5555
Fax: 01 (508) 370-6262

Dataquest Incorporated
Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
Phone: 01 (714) 957-0171
Fax: 01 (714) 957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: 61 (2) 959 4544
Fax: 61 (2) 929 0635

Dataquest Germany
In der Schneithohl 17
6242 Kronberg 2
Germany
Phone: 49 6173/61685
Fax: 49 6173/67901

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 49 (89) 93 09 09 0
Fax: 49 (89) 930 3277

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
Phone: 44 (895) 835050
Fax: 44 (895) 835260/1/2

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: 33 (1) 48 97 31 00
Telex: 233 263
Fax: 33 (1) 48 97 34 00

Dataquest Hong Kong
Rm. 401, Connaught Comm. Bldg.
185 Wanchai Rd.
Wanchai, Hong Kong
Phone: (852) 8387336
Fax: (852) 5722375

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo 104 Japan
Phone: 81 (3) 5566-0411
Fax: 81 (3) 5566-0425

Dataquest Korea
Daeheung Bldg. 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul, Korea 135
Phone: 82 (2) 556-4166
Fax: 82 (2) 552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 65 4597181
Telex: 38257
Fax: 65 4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sec. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: 886 (2) 501-7960
886 (2) 501-5592
Fax: 886 (2) 505-4265

© 1991 Dataquest Incorporated 5/91

0010332

Semiconductor Suppliers—Competitive Analysis

Tables 1 through 12 present estimates of worldwide dollar semiconductor shipments, by company, for military/aerospace electronic equipment end use. Tables 13 and 14 present North American and European market shipment breakouts.

Table 1

Estimated Worldwide Military/Aerospace Semiconductor Shipments (Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total Semiconductor	2,481	2,636	2,776	2,874	
Harris (GE/RCA)	268	280	271	273	9.5%
Texas Instruments	251	230	207	190	6.6%
Motorola	201	201	182	184	6.4%
National Semiconductor	282	242	196	183	6.4%
AMD	157	161	151	142	4.9%
SGS-Thomson/Thomson TMS	74	90	106	109	3.8%
Philips-Signetics	112	108	103	101	3.5%
Analog Devices	68	80	92	93	3.2%
LSI Logic	37	56	82	91	3.2%
Intel	60	68	73	76	2.6%
IDT	38	50	63	75	2.6%
Plessey	48	53	58	61	2.1%
Raytheon	56	56	63	57	2.0%
Microsemi	24	23	36	40	1.4%
Siliconix	31	37	38	39	1.4%
Cypress	13	19	28	38	1.3%
Unitrode	46	23	45	37	1.3%
Fujitsu	20	22	27	34	1.2%
M/A COMM-Adams Russell	29	31	35	34	1.2%
NEC	NA	NA	23	34	1.2%
Mitsubishi	NA	NA	28	32	1.1%
Precision Monolithics	29	31	32	32	1.1%
Atmel	2	8	13	31	1.1%
International Rectifier	21	25	31	30	1.0%
Xicor	17	24	26	29	1.0%
Hughes	27	33	27	28	1.0%

(Continued)

©1990 Dataquest Incorporated August

Table 1 (Continued)

Estimated Worldwide Military/Aerospace Semiconductor Shipments (Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Marconi Electronic Devices	16	21	28	28	1.0%
Toshiba	NA	NA	24	28	1.0%
Electronic Designs	3	7	15	25	0.9%
Hewlett-Packard	22	24	26	25	0.9%
Honeywell	35	46	53	25	0.9%
Matra Harris	9	14	18	24	0.8%
Silicon General	12	14	18	22	0.8%
Siemens	14	19	21	21	0.7%
VLSI Technology	4	7	14	21	0.7%
SEEQ Technology	15	19	24	20	0.7%
Micron Technology	2	4	13	20	0.7%
TRW	28	26	12	19	0.7%
Oki	NA	NA	14	19	0.7%
Optek	NA	NA	17	19	0.7%
Linear Technology	11	13	16	18	0.6%
Zilog	11	13	15	17	0.6%
ITT	14	16	17	16	0.6%
Powerex	NA	NA	NA	16	0.6%
General Instrument	16	18	19	15	0.5%
Burr-Brown	12	14	16	15	0.5%
UTMC	6	8	14	15	0.5%
Avantek	7	12	16	14	0.5%
Alpha Industries	7	10	14	14	0.5%
Sprague	22	21	16	13	0.5%
Others	293	347	286	317	11.0%

NA = Not available
Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Table 2

Estimated Worldwide Military/Aerospace IC Shipments
(Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total	1,954	2,083	2,190	2,302	
Harris (GE/RCA)	237	248	251	253	11.0%
National Semiconductor	262	221	181	171	7.4%
Texas Instruments	217	194	170	156	6.8%
AMD	157	161	151	142	6.2%
Motorola	133	129	113	117	5.1%
Analog Devices	68	80	92	93	4.0%
LSI Logic	37	56	82	91	4.0%
SGS-Thomson/Thomson TMS	58	70	86	90	3.9%
Philips-Signetics	89	82	75	80	3.5%
Intel	60	68	73	76	3.3%
IDT	38	50	63	75	3.3%
Plessey	43	47	52	55	2.4%
Raytheon	46	46	53	48	2.1%
Cypress	13	19	28	38	1.7%
Precision Monolithics	28	30	32	32	1.4%
Atmel	2	8	13	31	1.3%
Mitsubishi	0	0	25	29	1.3%
Xicor	17	24	26	29	1.3%
Fujitsu	19	21	23	29	1.3%
NEC	NA	NA	18	28	1.2%
Electronic Designs	3	7	15	25	1.1%
Toshiba	0	0	21	25	1.1%
Honeywell	31	42	49	24	1.0%
Matra Harris	9	14	18	24	1.0%
Siliconix	18	23	24	23	1.0%
Silicon General	12	14	18	22	1.0%
Marconi Electronic Devices	11	16	21	21	0.9%
VLSI Technology	4	7	14	21	0.9%
Micron Technology	2	4	13	20	0.9%
SEEQ Technology	15	19	24	20	0.9%
Oki	0	0	14	19	0.8%
TRW	15	13	12	19	0.8%
Linear Technology	11	13	16	18	0.8%
Zilog	11	13	15	17	0.7%
UTMC	6	8	14	15	0.7%
Burr-Brown	12	14	16	15	0.7%

(Continued)

©1990 Dataquest Incorporated August

Table 2 (Continued)

Estimated Worldwide Military/Aerospace IC Shipments (Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Hughes	18	21	14	14	0.6%
Performance Semiconductor	2	4	9	12	0.5%
Unitrode	2	2	10	12	0.5%
Altera	0	0	7	11	0.5%
Others	244	291	230	250	10.9%

NA = Not available
Source: Dataquest (August 1990)

Table 3

Estimated Worldwide Military/Aerospace Digital Bipolar Shipments (Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total	734	647	574	554	
AMD	136	135	123	111	20.0%
Texas Instruments	177	144	116	103	18.6%
National Semiconductor	151	121	94	84	15.2%
Harris (GE/RCA)	42	33	47	56	10.1%
Raytheon	34	33	43	40	7.2%
Philips-Signetics	55	42	31	33	6.0%
Plessey	21	23	26	28	5.1%
Motorola	64	55	30	28	5.1%
Fujitsu	11	10	11	11	2.0%
Lansdale Semiconductor	7	8	9	9	1.6%
Others	36	43	44	43	7.8%

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Table 4

Estimated Worldwide Military/Aerospace Digital Bipolar Memory Shipments (Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total	143	117	96	85	
AMD	56	52	44	42	49.4%
National Semiconductor	28	23	18	15	17.6%
Raytheon	12	12	11	10	11.8%
Philips-Signetics	15	11	7	7	8.2%
Fujitsu	6	6	8	7	8.2%
Others	25	13	8	4	4.7%

Source: Dataquest (August 1990)

Table 5

Estimated Worldwide Military/Aerospace Digital Bipolar Logic Shipments (Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total	592	530	478	468	
Texas Instruments	172	139	112	102	21.8%
National Semiconductor	123	98	76	69	14.7%
AMD	80	83	79	69	14.7%
Harris (GE/RCA)	25	26	44	56	12.0%
Raytheon	22	21	32	30	6.4%
Plessey	21	23	26	28	6.0%
Motorola	62	54	30	28	6.0%
Philips-Signetics	40	31	24	26	5.6%
Atmel	0	0	0	8	1.7%
Lansdale Semiconductor	7	8	9	8	1.7%
Others	40	47	46	37	7.9%

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Table 6

Estimated Worldwide Military/Aerospace Digital MOS Shipments (Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total	714	874	1,037	1,176	
Harris (GE/RCA)	125	119	114	117	9.9%
LSI Logic	37	56	82	91	7.7%
SGS-Thomson/Thomson TMS	48	59	75	79	6.7%
IDT	38	50	63	74	6.3%
Intel	58	66	71	74	6.3%
Motorola	42	49	60	66	5.6%
National Semiconductor	35	37	39	40	3.4%
Cypress	13	19	28	38	3.2%
AMD	21	26	28	31	2.6%
Xicor	17	24	26	29	2.5%
Texas Instruments	11	18	25	26	2.2%
Electronic Designs	3	7	15	25	2.1%
Matra Harris	9	14	18	24	2.0%
NEC	NA	NA	16	23	2.0%
Honeywell	13	22	31	22	1.9%
VLSI Technology	4	7	14	21	1.8%
Marconi Electronic Devices	11	16	21	21	1.8%
Atmel	2	8	13	21	1.8%
SEEQ Technology	15	19	24	20	1.7%
Micron Technology	2	4	13	20	1.7%
Mitsubishi	0	0	15	18	1.5%
Toshiba	0	0	14	18	1.5%
Fujitsu	8	11	12	18	1.5%
Plessey	12	14	15	17	1.4%
Oki	0	0	12	17	1.4%
Zilog	11	13	15	17	1.4%
UTMC	6	8	14	15	1.3%
Hughes	17	18	14	14	1.2%
Performance Semiconductor	2	4	9	12	1.0%
Microchip Technolgy	5	6	9	11	0.9%
Others	150	181	125	146	12.4%

NA = Not available
Source: Dataquest (August 1990)

 ©1990 Dataquest Incorporated August

Table 7

Estimated Worldwide Military/Aerospace Digital MOS Memory Shipments (Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total	260	328	385	448	
IDT	34	44	50	57	12.7%
SGS-Thomson/Thomson TMS	24	28	37	39	8.7%
Xicor	17	24	26	29	6.5%
Intel	27	31	27	27	6.0%
Harris (GE/RCA)	40	34	25	26	5.8%
Electronic Designs	3	7	15	25	5.6%
Cypress	11	15	18	21	4.7%
Micron Technology	2	4	13	20	4.5%
SEEQ Technology	15	19	24	20	4.5%
NEC	NA	NA	12	16	3.6%
Atmel	2	7	11	16	3.6%
Matra Harris	2	4	8	15	3.3%
AMD	13	15	14	14	3.1%
Fujitsu	7	9	9	13	2.9%
National Semiconductor	14	14	13	13	2.9%
Motorola	4	6	9	11	2.4%
Mitsubishi	0	0	6	10	2.2%
Honeywell	NA	5	14	10	2.2%
Oki	0	0	7	9	2.0%
Texas Instruments	6	8	10	9	2.0%
Others	39	54	31	40	8.9%

NA = Not available
Source: Dataquest (August 1990)

Table 8

Estimated Worldwide Military/Aerospace Digital MOS Logic Shipments (Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total	292	354	406	458	
LSI Logic	37	56	81	90	19.7%
Harris (GE/RCA)	70	69	60	61	13.3%
Motorola	17	19	21	22	4.8%
National Semiconductor	17	18	20	21	4.6%
SGS-Thomson/Thomson TMS	9	13	18	19	4.1%

(Continued)

22
12

©1990 Dataquest Incorporated August

Table 8 (Continued)

Estimated Worldwide Military/Aerospace Digital MOS Logic Shipments
(Millions of Dollars)

	1986	1987	1988	1989	1989 Share
VLSI Technology	4	7	13	18	3.9%
Plessey	12	14	15	17	3.7%
Marconi Electronic Devices	11	13	15	16	3.5%
IDT	3	5	11	15	3.3%
Hughes	16	17	14	14	3.1%
Cypress	2	4	8	13	2.8%
Honeywell	13	17	17	12	2.6%
Altera	0	0	7	11	2.4%
Texas Instruments	5	9	11	11	2.4%
Gould Semiconductor	10	10	8	9	2.0%
Others	65	80	80	101	22.1%

Source: Dataquest (August 1990)

Table 9

Estimated Worldwide Military/Aerospace Digital MOS Microcomponent Shipments
(Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total	162	192	247	270	
Intel	31	34	42	44	16.4%
Motorola	21	24	30	33	12.3%
Harris (GE/RCA)	15	16	29	30	11.2%
SGS-Thomson/Thomson TMS	15	18	20	21	7.8%
Zilog	11	13	15	17	6.3%
AMD	6	7	8	9	3.3%
UTMC	4	5	8	8	3.0%
National Semiconductor	4	5	6	6	2.2%
Texas Instruments	0	1	4	6	2.2%
Philips-Signetics	1	3	4	6	2.2%
Analog Devices	0	1	5	5	1.9%
Others	50	61	72	80	29.7%

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Table 10

Estimated Worldwide Military/Aerospace Analog Shipments
(Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total	507	563	579	571	
Analog Devices	68	79	87	88	15.4%
Harris (GE/RCA)	70	96	90	80	14.0%
National Semiconductor	76	63	48	47	8.2%
Philips-Signetics	33	36	38	38	6.7%
Precision Monolithics	28	30	32	32	5.6%
Texas Instruments	29	32	29	27	4.7%
Motorola	27	25	23	23	4.0%
Siliconix	18	23	24	23	4.0%
Silicon General	12	14	18	22	3.9%
Linear Technology	11	13	16	18	3.2%
Burr-Brown	12	14	16	15	2.6%
Unitrode	2	2	10	12	2.1%
SGS-Thomson/Thomson TMS	9	11	11	11	1.9%
TRW	15	13	12	10	1.8%
Plessey	10	10	11	10	1.8%
Others	83	98	107	107	18.7%

Source: Dataquest (August 1990)

Table 11

Estimated Worldwide Military/Aerospace Discrete Shipments
(Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total	446	461	479	469	
Motorola	64	68	68	66	14.1%
Microsemi	24	23	36	40	8.5%
International Rectifier	21	25	31	30	6.4%
M/A COMM-Adams Russell	26	27	28	26	5.6%
Unitrode	44	21	35	25	5.3%
Texas Instruments	22	23	23	20	4.3%
Harris (GE/RCA)	29	31	15	18	3.8%
Philips-Signetics	20	22	24	18	3.8%
Siliconix	13	14	14	16	3.4%

(Continued)

©1990 Dataquest Incorporated August

Table 11 (Continued)

Estimated Worldwide Military/Aerospace Discrete Shipments (Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Powerex	NA	NA	NA	16	3.4%
General Instrument	16	18	19	15	3.2%
Hughes	9	12	13	14	3.0%
Solitron Devices	12	14	14	13	2.8%
National Semiconductor	20	21	15	12	2.6%
Alpha Industries	6	8	12	12	2.6%
Others	114	124	120	117	25.0%

NA = Not available
Source: Dataquest (August 1990)

Table 12

Estimated Worldwide Military/Aerospace Optoelectronic Shipments (Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total	80	92	107	103	
Optek	NA	NA	17	19	18.4%
Hewlett-Packard	15	16	18	18	17.5%
Texas Instruments	12	13	14	14	13.6%
SGS-Thomson/Thomson TMS	8	10	11	9	8.7%
Siemens	5	7	8	9	8.7%
Others	38	42	35	31	30.1%

NA = Not available
Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Table 13

Estimated North America Military/Aerospace Semiconductor Shipments
(Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total Semiconductor	1,881	1,921	2,000	2,059	
Harris (GE/RCA)	259	270	259	261	12.7%
Texas Instruments	199	176	155	143	6.9%
National Semiconductor	238	194	153	143	6.9%
Motorola	151	145	126	130	6.3%
AMD	128	127	116	107	5.2%
LSI Logic	36	53	76	83	4.0%
Intel	48	54	57	59	2.9%
IDT	30	38	46	56	2.7%
Raytheon	51	50	58	54	2.6%
Analog Devices	41	45	51	52	2.5%
Philips-Signetics	58	46	38	41	2.0%
Microsemi	23	21	34	38	1.8%
Cypress	12	17	24	34	1.7%
M/A COMM-Adams Russell	29	31	33	32	1.6%
Unitrode	42	18	40	31	1.5%
SGS-Thomson/Thomson TMS	21	24	29	30	1.5%
Siliconix	22	26	27	28	1.4%
Precision Monolithics	27	28	27	27	1.3%
Atmel	2	8	12	26	1.3%
Hughes	26	31	25	26	1.3%
Honeywell	35	46	53	25	1.2%
Electronic Designs	3	7	15	24	1.2%
Xicor	15	21	24	24	1.2%
International Rectifier	17	19	24	23	1.1%
Hewlett-Packard	18	19	20	19	0.9%
TRW	24	22	12	19	0.9%
Silicon General	12	13	17	19	0.9%
VLSI Technology	4	7	13	18	0.9%
SEEQ Technology	14	17	21	17	0.8%
Micron Technology	2	4	12	17	0.8%
Others	279	328	386	433	21.0%

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Table 14

Estimated European Military/Aerospace Semiconductor Shipments
(Millions of Dollars)

	1986	1987	1988	1989	1989 Share
Total Semiconductor	481	581	633	647	
SGS-Thomson/Thomson TMS	50	63	73	76	11.7%
Philips-Signetics	51	59	62	58	9.0%
Plessey	39	45	49	52	8.0%
Motorola	47	53	54	51	7.9%
National Semiconductor	38	42	40	37	5.7%
Texas Instruments	38	40	40	36	5.6%
Analog Devices	25	30	32	32	4.9%
AMD	25	30	32	32	4.9%
Marconi Electronic Devices	15	18	22	23	3.6%
Matra Harris	8	14	18	22	3.4%
IDT	7	10	13	15	2.3%
Siemens	11	14	16	15	2.3%
Others	127	165	173	186	28.7%

Source: Dataquest (August 1990)

©1990 Dataquest Incorporated August

Semiconductor Suppliers

The following is a list of the material in this section:

- Semiconductor Suppliers--Competitive Analysis

© 1989 Dataquest Incorporated November

Semiconductor Suppliers

The following is a list of the material in this section:

Table 2 (Continued)

Estimated Worldwide Military Aerospace IC Shipments
(Millions of Dollars)

	1986	1987	1988	1988 Share
Motorola	134	131	124	5.7%
Analog Devices	68	80	92	4.2%
LSI Logic	37	56	82	3.7%
Philips-Signetics	89	82	75	3.4%
Intel	60	68	73	3.3%
SGS-Thomson/Thomson TMS	47	59	71	3.2%
IDT	38	50	64	2.9%
Plessey/Ferranti/Interdes.	45	51	55	2.5%
Honeywell	31	42	49	2.2%
Raytheon	39	39	39	1.8%
Precision Monolithics	28	30	32	1.5%
Cypress	13	19	29	1.3%
Xicor	17	24	29	1.3%
Marconi Electronic Devices	11	19	24	1.1%
SEEQ Technology	15	19	24	1.1%
Siliconix	18	23	24	1.1%
Fujitsu	19	21	23	1.1%
Rockwell	12	15	21	1.0%
Matra-Harris	9	14	20	0.9%
Inmos	15	16	18	0.8%
Performance Semiconductor	2	7	16	0.7%
Linear Technology	11	13	16	0.7%
Burr-Brown	12	14	16	0.7%
Silicon General	12	14	15	0.7%
Zilog	11	13	15	0.7%
Electronic Designs	3	7	15	0.7%
GM Hughes	18	21	14	0.6%
VLSI Technology	4	7	14	0.6%
UTMC	6	8	14	0.6%
Atmel	2	8	13	0.6%
TRW	15	13	12	0.5%
AMCC	13	13	12	0.5%
Adams Russell	8	10	12	0.5%
Sprague	18	17	11	0.5%
Micron Technology	2	4	9	0.4%
Lansdale Semiconductor	7	8	9	0.4%
Other	202	247	291	0.4%

Source: Dataquest
September 1989

© 1989 Dataquest Incorporated September

Table 3

Estimated Worldwide Military Aerospace Digital Bipolar Shipments (Millions of Dollars)

	1986	1987	1988	1988 Share
Total	$732	$639	$556	
AMD/MMI	$136	$136	$126	22.7%
Texas Instruments	177	144	118	21.2%
National Semiconductor	151	121	92	16.5%
Motorola	64	55	40	7.2%
Philips-Signetics	55	42	31	5.6%
Harris Semiconductor	50	33	30	5.4%
Raytheon	26	25	27	4.9%
Plessey/Ferranti/Interdes.	18	20	22	4.0%
AMCC	13	13	12	2.2%
Fujitsu	11	10	11	2.0%
Lansdale Semiconductor	7	8	9	1.6%
Honeywell	7	8	6	1.1%
Other	17	24	32	5.8%

Source: Dataquest
September 1989

Table 4

Estimated Worldwide Military Aerospace Digital Bipolar Memory Shipments (Millions of Dollars)

	1986	1987	1988	1988 Share
Total	$143	$110	$92	
AMD/MMI	$ 56	$ 52	$44	47.8%
National Semiconductor	28	23	18	19.6%
Fujitsu	6	6	8	8.7%
Philips-Signetics	15	11	7	7.6%
Raytheon	4	4	4	4.3%
Texas Instruments	5	5	4	4.3%
Harris Semiconductor	25	7	3	3.3%
Motorola	2	1	1	1.1%
Other	2	1	3	3.3%

Source: Dataquest
September 1989

© 1989 Dataquest Incorporated September

Table 5

Estimated Worldwide Military Aerospace Digital Bipolar Logic Shipments
(Millions of Dollars)

	1986	1987	1988	1988 Share
Total	$589	$529	$464	
Texas Instruments	$172	$139	$114	24.6%
AMD/MMI	80	84	82	17.7%
National Semiconductor	123	98	74	15.9%
Motorola	62	54	39	8.4%
Harris Semiconductor	25	26	27	5.8%
Philips-Signetics	40	31	24	5.2%
Raytheon	22	21	23	5.0%
Plessey/Ferranti/Interdes.	18	20	22	4.7%
AMCC	13	13	12	2.6%
Lansdale Semiconductor	7	8	9	1.9%
Honeywell	7	8	6	1.3%
Other	20	27	32	6.9%

Source: Dataquest
September 1989

Table 6

Estimated Worldwide Military Aerospace Digital MOS Shipments
(Millions of Dollars)

	1986	1987	1988	1988 Share
Total	$712	$878	$1,037	
Harris Semiconductor	$125	$119	$ 99	9.5%
LSI Logic	37	56	82	7.9%
Intel	58	66	71	6.8%
IDT	38	50	64	6.2%
Motorola	42	49	59	5.7%
SGS-Thomson/Thomson TMS	36	46	58	5.6%
National Semiconductor	35	37	39	3.8%
Honeywell	13	22	31	3.0%

(Continued)

© 1989 Dataquest Incorporated September

Table 6 (Continued)

Estimated Worldwide Military Aerospace Digital MOS Shipments
(Millions of Dollars)

	1986	1987	1988	1988 Share
Cypress	13	19	29	2.8%
Xicor	17	24	29	2.8%
AMD/MMI	21	26	28	2.7%
Texas Instruments	11	18	25	2.4%
Marconi Electronic Devices	11	19	24	2.3%
SEEQ Technology	15	19	24	2.3%
Plessey/Ferranti/Interdes.	17	21	22	2.1%
Matra-Harris	9	14	20	1.9%
Inmos	15	16	18	1.7%
Performance Semiconductor	2	7	16	1.5%
Zilog	11	13	15	1.4%
Electronic Designs	3	7	15	1.4%
GM Hughes	17	18	14	1.4%
UTMC	6	8	14	1.4%
VLSI Technology	4	7	14	1.4%
Atmel	2	8	13	1.3%
Fujitsu	8	11	12	1.2%
Other	147	178	205	19.8%

Source: Dataquest
September 1989

Table 7

Estimated Worldwide Military Aerospace Digital MOS Memory Shipments
(Millions of Dollars)

	1986	1987	1988	1988 Share
Total	$254	$321	$373	
IDT	$ 34	$ 44	$ 50	13.4%
Xicor	17	24	29	7.8%
Intel	27	31	27	7.2%
SEEQ Technology	15	19	24	6.4%

(Continued)

 © 1989 Dataquest Incorporated September

Table 7 (Continued)

Estimated Worldwide Military Aerospace Digital MOS Memory Shipments
(Millions of Dollars)

	1986	1987	1988	1988 Share
SGS-Thomson/Thomson TMS	11	14	21	5.6%
Harris Semiconductor	40	34	20	5.4%
Cypress	11	15	18	4.8%
Inmos	14	15	17	4.6%
Electronic Designs	3	7	15	4.0%
Honeywell	0	5	14	3.8%
AMD/MMI	13	15	14	3.8%
National Semiconductor	14	14	13	3.5%
Atmel	2	7	11	2.9%
Motorola	4	6	10	2.7%
Texas Instruments	6	8	10	2.7%
Micron Technology	2	4	9	2.4%
Fujitsu	7	9	9	2.4%
Performance Semiconductor	1	3	8	2.1%
Matra-Harris	2	4	6	1.6%
Microchip Technology	3	4	6	1.6%
Other	28	39	42	11.3%

Source: Dataquest
September 1989

Table 8

Estimated Worldwide Military Aerospace Digital MOS Logic Shipments
(Millions of Dollars)

	1986	1987	1988	1988 Share
Total	$296	$361	$418	
LSI Logic	$ 37	$ 56	$ 81	19.4%
Harris Semiconductor	70	69	60	14.4%
Plessey/Ferranti/Interdes.	17	21	22	5.3%
Motorola	17	19	21	5.0%
National Semiconductor	17	18	20	4.8%

(Continued)

© 1989 Dataquest Incorporated September

Table 8 (Continued)

Estimated Worldwide Military Aerospace Digital MOS Logic Shipments
(Millions of Dollars)

	1986	1987	1988	1988 Share
SGS-Thomson/Thomson TMS	11	14	17	4.1%
Honeywell	13	17	17	4.1%
Marconi Electronic Devices	11	14	16	3.8%
GM Hughes	16	17	14	3.3%
VLSI Technology	4	7	13	3.1%
IDT	3	5	11	2.6%
Texas Instruments	5	9	11	2.6%
Matra-Harris	3	6	10	2.4%
Gould Semiconductor	10	10	8	1.9%
Cypress	2	4	8	1.9%
Rockwell	6	7	8	1.9%
Other	55	68	81	19.4%

Source: Dataquest
September 1989

Table 9

Estimated Worldwide Military Aerospace Digital MOS Microcomponent Shipments
(Millions of Dollars)

	1986	1987	1988	1988 Share
Total	$162	$196	$246	
Intel	$ 31	$ 34	$ 42	17.1%
Motorola	21	24	28	11.4%
SGS-Thomson/Thomson TMS	14	18	20	8.1%
Harris Semiconductor	15	16	19	7.7%
Zilog	11	13	15	6.1%
UTMC	4	5	8	3.3%
AMD/MMI	6	7	8	3.3%
National Semiconductor	4	5	6	2.4%
Performance Semiconductor	1	3	5	2.0%
Analog Devices	0	1	5	2.0%
Other	55	70	93	37.8%

Source: Dataquest
September 1989

© 1989 Dataquest Incorporated September

Table 12

Estimated Worldwide Military Aerospace Optoelectronic Shipments (Millions of Dollars)

	1986	1987	1988	1988 Share
Total	$86	$98	$101	
Hewlett-Packard	$15	$16	$ 18	17.8%
SGS-Thomson/Thomson TMS	10	13	15	14.9%
Texas Instruments	12	13	14	13.9%
Siemens	5	7	8	7.9%
Honeywell	7	7	7	6.9%
Philips-Signetics	3	4	4	4.0%
Motorola	4	4	3	3.0%
Telefunken Electronics	0	0	1	1.0%
Harris Semiconductor	1	1	1	1.0%
Other	29	33	30	29.7%

Source: Dataquest
September 1989

Table 13

Estimated North America Military Aerospace Semiconductor Shipments (Millions of Dollars)

	1986	1987	1988	1988 Share
Total Semiconductor	$1,890	$1,932	$1,975	
Harris (GE/RCA)	$ 267	$ 270	$ 234	11.8%
Texas Instruments	199	176	155	7.8%
National Semiconductor	238	194	151	7.6%
Motorola	151	145	141	7.1%
AMD	128	127	116	5.9%
LSI Logic	36	53	76	3.8%
Honeywell	40	51	58	2.9%
Intel	48	54	57	2.9%
Analog Devices	41	45	51	2.6%
IDT	30	38	46	2.3%
Unitrode	42	18	40	2.0%

(Continued)

© 1989 Dataquest Incorporated September

Table 13 (Continued)

Estimated North America Military Aerospace Semiconductor Shipments (Millions of Dollars)

	1986	1987	1988	1988 Share
Raytheon	38	37	38	1.9%
Philips-Signetics	58	46	38	1.9%
SGS-Thomson/Thomson TMS	22	27	35	1.8%
Siliconix	22	26	28	1.4%
Precision Monolithics	27	28	27	1.4%
GM Hughes	26	31	25	1.3%
Cypress	12	17	25	1.3%
International Rectifier	17	19	24	1.2%
Xicor	15	21	24	1.2%
M/A COMM	21	21	23	1.2%
SEEQ Technology	14	17	21	1.1%
Microsemi	23	21	21	1.1%
Hewlett-Packard	18	19	20	1.0%
Rockwell	11	14	19	1.0%
ITT	14	16	17	0.9%
General Instrument (Disc)	12	13	16	0.8%
Electronic Designs	3	7	15	0.8%
Sprague	21	20	15	0.8%
UTMC	6	8	14	0.7%
Avantek	7	11	14	0.7%
Silicon General	12	13	14	0.7%
Alpha Industries	7	9	14	0.7%
Zilog	10	12	13	0.7%
Solitron Devices	11	12	13	0.7%
Performance Semiconductor	2	6	13	0.7%
VLSI Technology	4	7	13	0.7%
Linear Technology	10	11	13	0.7%
Inmos	9	10	12	0.6%
TRW	29	27	12	0.6%
AMCC	12	12	12	0.6%
Adams Russel	8	10	12	0.6%
Atmel	2	8	12	0.6%
Fujitsu	12	12	11	0.6%
Burr-Brown	8	9	10	0.5%
Other	147	184	217	11.0%

Source: Dataquest
September 1989

© 1989 Dataquest Incorporated September

Table 14

Estimated European Military Aerospace Semiconductor Shipments (Millions of Dollars)

	1986	1987	1988	1988 Share
Total	$478	$582	$636	
Philips-Signetics	$ 51	$ 59	$ 62	9.7%
Motorola	47	53	57	9.0%
SGS-Thomson/Thomson TMS	39	50	56	8.8%
Plessey/Ferranti/Interdes.	41	48	52	8.2%
National Semiconductor	38	42	40	6.3%
Texas Instruments	38	40	40	6.3%
AMD/MMI	25	30	32	5.0%
Analog Devices	25	30	32	5.0%
Matra-Harris	8	14	20	3.1%
Siemens	11	14	16	2.5%
Marconi Electronic Devices	11	15	16	2.5%
IDT	7	10	14	2.2%
Intel	9	11	12	1.9%
ASEA/Brown Boveri	9	10	11	1.7%
Harris Semiconductor	8	10	11	1.7%
Siliconix	8	10	10	1.6%
Hewlett-Packard	4	5	6	0.9%
Inmos	5	5	6	0.9%
Burr-Brown	4	5	6	0.9%
International Rectifier	3	5	6	0.9%
LSI Logic	1	3	6	0.9%
Other	86	113	125	19.7%

Source: Dataquest
September 1989

© 1989 Dataquest Incorporated September

(Page intentionally left blank)

© 1989 Dataquest Incorporated September

Semiconductor Suppliers--Competitive Analysis

OVERVIEW

This section profiles competitive activity in the supply of semiconductors for military and civil aerospace applications. In general, very few "pure-play" suppliers serve this market, but the companies that make the investments in dedicated marketing, facilities, and research and development are and will continue to be the strongest participants.

The key environmental factor affecting 1987 shipments was the general slowdown of business caused by flattening government outlays. This slowdown, coupled with an oversupply, overinventory situation, drove most prices down, especially in the commodity categories. We predict that many of the suppliers that jumped in or began focusing on this market during 1985 and 1986 will retreat, as it exhibits relatively fewer opportunities than the commercial markets.

Worldwide market share estimates are presented in Tables 1 through 12. Some of the highlights of competitive events in 1987 are as follows:

- National Semiconductor's acquisition of Fairchild created the largest supplier with almost 10 percent of the market.
- Star performers in 1987 included LSI Logic and IDT, which grew at 35 and 36 percent, respectively.
- Companies positioned in such areas as CMOS SRAMs, CMOS gate arrays, and microcomponents, in general, witnessed above average growth.
- Companies heavily positioned in the commodity bipolar logic and standard linear segments saw growth elude them in the face of collapsed prices.
- Firms operating or selling in Europe experienced "currency translation growth" in U.S. dollars on the order of 15 percent.
- The top 10 companies accounted for 52 percent of the shipments.
- In the fast-growth MOS categories, the market remains dispersed among dozens of suppliers, as it remains relatively immature.

© 1988 Dataquest Incorporated August

Table 1

Estimated Worldwide Military/Aerospace Semiconductor Shipments (Millions of Dollars)

	1986	1987	1987 Share
National/Fairchild	$ 255	$ 250	9.7%
Texas Instruments	202	201	7.8
AMD/MMI	176	180	7.0
Harris Semiconductor	146	152	5.9
Motorola	140	148	5.8
GE Solid State	111	115	4.5
Philips-Signetics	80	83	3.2
Intel	64	70	2.7
SGS-Thomson	62	70	2.7
Plessey/Ferranti/Interdesign	51	58	2.3
Honeywell	51	55	2.1
LSI Logic	40	54	2.1
IDT	38	52	2.0
Analog Devices	41	45	1.8
Raytheon	42	42	1.6
GM Hughes	27	33	1.3
Siliconix	30	33	1.3
Hewlett-Packard	30	31	1.2
Precision Monolithics	29	31	1.2
TRW	31	31	1.2
Cypress	20	29	1.1
Thomson Military	23	27	1.1
Siemens	23	27	1.1
Inmos	23	26	1.0
Fujitsu	22	26	1.0
International Rectifier	21	22	0.9
Telefunken Electronics	17	21	0.8
Sprague	19	20	0.8
Burr-Brown	17	19	0.7
Marconi Electronic Devices	14	19	0.7
ITT	15	19	0.7
General Instrument (Disc)	16	18	0.7
Matra Harris	13	16	0.6
Solitron Devices	12	14	0.5
Unitrode	30	14	0.5

(Continued)

 © 1988 Dataquest Incorporated August

Table 1 (Continued)

Estimated Worldwide Military/Aerospace
Semiconductor Shipments
(Millions of Dollars)

	1986	1987	1987 Share
Teledyne	11	13	0.5
Rockwell	10	13	0.5
ASEA/Brown Boveri	11	13	0.5
AMCC	13	13	0.5
Zilog	11	13	0.5
Linear Technology	11	13	0.5
Others	367	433	16.9
Total Semiconductor	$2,368	$2,566	100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 2

Estimated Worldwide Military/Aerospace IC Shipments
(Millions of Dollars)

	1986	1987	1987 Share
National/Fairchild	$ 235	$ 229	10.9%
AMD/MMI	176	180	8.6
Texas Instruments	169	167	8.0
Harris Semiconductor	146	152	7.3
Motorola	94	199	4.8
GE Solid State	96	100	4.8
Intel	64	70	3.3
Philips-Signetics	61	61	2.9
LSI Logic	40	54	2.6
SGS-Thomson	48	54	2.6
IDT	38	52	2.5
Plessey/Ferranti/Interdesign	45	51	2.4
Honeywell	44	48	2.3
Analog Devices	41	45	2.1
Raytheon	38	38	1.8
Precision Monolithics	28	30	1.4
Cypress	20	29	1.4
Siliconix	24	27	1.3
Inmos	23	26	1.2
Fujitsu	20	24	1.1
Thomson Military	19	22	1.1
GM Hughes	18	21	1.0
Burr-Brown	17	19	0.9
Marconi Electronic Devices	14	19	0.9
Matra Harris	13	16	0.8
Sprague	15	16	0.8
Siemens	12	14	0.7
Linear Technology	11	13	0.6
AMCC	13	13	0.6
Rockwell	10	13	0.6
Zilog	11	13	0.6
Others	318	374	17.9
Total	$1,924	$2,094	100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 3

Estimated Worldwide Military/Aerospace Bipolar Digital Shipments (Millions of Dollars)

	1986	1987	1987 Share
AMD/MMI	$147	$147	21.9%
Texas Instruments	125	116	17.3
National/Fairchild	118	112	16.7
Philips-Signetics	52	50	7.4
Motorola	51	50	7.4
Honeywell	34	37	5.5
Raytheon	26	25	3.7
Harris Semiconductor	25	23	3.4
Plessey/Ferranti/Interdesign	18	20	3.0
AMCC	13	13	1.9
Others	74	79	11.8
Total	$683	$672	100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 4

Estimated Worldwide Military/Aerospace Bipolar Digital Memory Shipments (Millions of Dollars)

	1986	1987	1987 Share
AMD/MMI	$ 56	$ 53	43.4%
National/Fairchild	28	26	21.3
Philips-Signetics	15	14	11.5
Harris Semiconductor	11	9	7.4
Fujitsu	7	8	6.6
Raytheon	4	4	3.3
Texas Instruments	5	3	2.5
Motorola	2	2	1.6
Siemens	2	2	1.6
Others	1	1	0.8
Total	$132	$122	100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 5

Estimated Worldwide Military/Aerospace Digital Bipolar Logic Shipments (Millions of Dollars)

	1986	1987	1987 Share
Texas Instruments	$120	$113	20.5%
AMD/MMI	91	94	17.1
National Semiconductor	90	86	15.6
Motorola	49	48	8.7
Honeywell	34	37	6.7
Philips-Signetics	37	36	6.5
Raytheon	22	21	3.8
Plessey/Ferranti/Interdesign	18	20	3.6
Harris Semiconductor	14	14	2.5
AMCC	13	13	2.4
Others	63	68	12.4
Total	$551	$550	100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 6

Estimated Worldwide Military/Aerospace Digital MOS Shipments (Millions of Dollars)

	1986	1987	1988	1987 Share
GE Solid State HARRIS	$ 81	$ 86	160	9.4%
Intel	64	70	77	7.7
Harris Semiconductor	64	70		7.7
LSI Logic	40	54	79	5.9
IDT	38	52	72	5.7
National Semiconductor	40	43	46	4.7
SGS-Thomson	32+23	37+26	63	4.1
AMD/MMI	29	33	36	3.6
Motorola	26	32	35	3.5
Cypress	20	25 29	30	3.2
Texas Instruments	22	28	35	3.1
~~Inmos~~	~~23~~	26		2.9
Plessey/Ferranti/Interdesign	17	21		2.3
Marconi Electronic Devices	14	19		2.1
GM Hughes	17	18		2.0
Thomson Military	15	17		1.9
Matra Harris	13	16		1.8
Zilog	11	13		1.4
Xicor	7	11		1.2
Fujitsu	8	11		1.2
Gould Semiconductor	11	11		1.2
Others	165	210		23.1
Total	$760	$911		100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 7

Estimated Worldwide Military/Aerospace
Digital MOS Memory Shipments
(Millions of Dollars)

	1986	1987	1987 Share
IDT	$ 34	$ 44	14.5%
Intel	33	35	11.6
Inmos	22	25	8.3
Cypress	19	24	7.9
Harris Semiconductor	20	~~21~~ >34 37	6.9
SGS-Thomson	18	19	6.3
AMD/MMI	14	15	5.0
National/Fairchild	14	14	4.6
GE Solid State	13	13	4.3
Xicor	7	11	3.6
Others	65	82	3.3
Total	$259	$303	100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 8

Estimated Worldwide Military/Aerospace
Digital MOS Logic Shipments
(Millions of Dollars)

	1986	1987	1987 Share
GE Solid State	$ 62	$ 66	17.2%
LSI Logic	40	53	13.8
Harris Semiconductor	41	45	11.7
National/Fairchild	20	22	5.7
Plessey/Ferranti/Interdesign	17	21	5.5
GM Hughes	16	17	4.4
Texas Instruments	12	15	3.9
Marconi Electronic Devices	11	15	3.9
Gould Semiconductor	10	10	2.6
Sprague	8	9	2.3
Others	79	110	28.7
Total	$316	$383	100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 9

Estimated Worldwide Military/Aerospace Digital MOS Microcomponent Shipments (Millions of Dollars)

	1986	1987	1987 Share
Intel	$ 31	$ 34	15.2%
Motorola	16	19	8.5
Zilog	11	13	5.8
AMD/MMI	8	10	4.5
SGS-Thomson	8	10	4.5
Thomson Military	8	9	4.0
National/Fairchild	6	7	3.1
GE Solid State	6	7	3.1
Matra Harris	4	5	2.2
Rockwell	4	5	2.2
Others	81	104	46.6
Total	$183	$223	100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 10

Estimated Worldwide Military/Aerospace Analog Shipments
(Millions of Dollars)

	1986	1987	1987 Share
National/Fairchild	$ 77	$ 74	14.5%
Harris Semiconductor	57	59	11.5
Analog Devices	41	45	8.8
Precision Monolithics	28	30	5.9
Siliconix	23	25	4.9
Texas Instruments	22	23	4.5
Burr-Brown	17	19	3.7
Motorola	17	18	3.5
GE Solid State	15	14	2.7
TRW	13	13	2.5
Raytheon	12	13	2.5
Linear Technology	11	13	2.5
Silicon General	12	12	2.3
Teledyne	10	12	2.3
SGS-Thomson	9	11	2.2
Others	117	130	25.4
Total	$481	$511	100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 11

Estimated Worldwide Military/Aerospace Discrete Shipments (Millions of Dollars)

	1986	1987	1987 Share
Motorola	$ 41	$ 43	11.3%
International Rectifier	21	22	5.8
National/Fairchild	20	21	5.5
Texas Instruments	20	21	5.5
Philips-Signetics	16	18	4.7
General Instrument (Disc)	16	18	4.7
SGS-Thomson	14	16	4.2
Solitron Devices	12	14	3.7
Hewlett-Packard	13	14	3.7
TRW	13	13	3.4
Others	172	180	47.4
Total	$358	$380	100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

 © 1988 Dataquest Incorporated August

Table 12

Estimated Worldwide Military/Aerospace
Optoelectronics Shipments
(Millions of Dollars)

	1986	1987	1987 Share
Hewlett-Packard	$17	$17	18.5%
Texas Instruments	13	13	14.1
Honeywell	7	7	7.6
Siemens	5	6	6.5
TRW	5	5	5.4
Others	39	44	47.8
Total	$86	$92	100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1988

© 1988 Dataquest Incorporated August

Table 12

[illegible] Worldwide Military/Aerospace
Optoelectronics Shipments
(Millions of Dollars)

	[illegible]	[illegible]	[illegible]
Hewlett-Packard	[illegible]		[illegible]
Texas Instruments	[illegible]	[illegible]	[illegible]
Honeywell	[illegible]	[illegible]	[illegible]
Siemens	[illegible]		[illegible]
TRW	[illegible]		
Others	[illegible]	[illegible]	[illegible]
Total	[illegible]		[illegible]

Note: Columns [illegible]

[illegible]

. Demographics

U.S. Demographics

Dataquest

a company of
The Dun & Bradstreet Corporation

Published by Dataquest Incorporated

The content of this report represents our interpretation and analysis of information generally available to the public or released by responsible individuals in the subject companies, but is not guaranteed as to accuracy or completeness. It does not contain material provided to us in confidence by our clients.

Printed in the United States of America. All rights reserved. No part of this publication may be reproduced, stored in retrieval systems, or transmitted, in any form or by any means—mechanical, electronic, photocopying, duplicating, microfilming, videotape, or otherwise—without the prior written permission of the publisher.

© 1990 Dataquest Incorporated
May 1990

Table of Contents

List of Tables

(Continued)

List of Tables (Continued)

List of Figures

Demographic Terms

CAGR (compound annual growth rate). Calculated using the formula:

$$\text{CAGR} = \left(\frac{\text{Value in year } 1+n}{\text{Value in year } 1}\right)^{\left(\frac{1}{n}\right)} -1$$

civilian population. Resident population of the United States that does not include resident or overseas armed forces, merchant marines, or citizens living outside the United States.

corporation. A self-perpetuating body set up as a business entity separate from its owners. This means that ownership is separate from management and incurs limited liability.

desktop. Defined in Dataquest's desktop analyses as a potential location for a desktop information device.

elementary grades. Elementary grades are classified through the school district. If the district covers kindergarten through eighth grade, then up through eighth grade is considered elementary. If the district covers only through sixth grade, then only through sixth grade is considered elementary.

enterprise. An aggregation of establishments that have common ownership. This definition includes a parent company plus all of its subsidiaries and branches, as well as single establishments that have no financial links with other establishments.

establishment. A single physical location where business activity is conducted, whether or not there are any financial links to other units. Establishments include independently owned and operated businesses as well as the headquarters, subsidiaries, and branches of larger firms.

family. A group of two or more persons residing together who are related by birth, marriage, or adoption.

household. A housing unit intended as separate living quarters. A household includes all persons, either related or unrelated, living in the unit.

householder. The person in whose name the housing unit is owned or rented. The term is never applied to either husbands or wives in married-couple families, but relates only to persons in families maintained by either men or women without a spouse.

information worker. An individual who is or will be a user of an automated desktop information device.

median income. Indicates the value that divides the income distribution into two equal parts, one part having values above the median and the other having values below the median.

nonfamily. A group of two or more persons residing together who are unrelated.

occupational tenure. The cumulative number of years a person works in his or her current occupation, regardless of the number of employers, interruptions in employment, or times spent in other occupations.

other four-year colleges. A school that places its primary emphasis on undergraduate education. A four-year college can offer doctorate and professional degrees, but its graduate programs will not be as extensive as those of a university.

participation rates. Represents the proportion of the population that is in the labor force.

partnership. An association of two or more persons to carry on as co-owners of a business. Partners may be individuals, corporations, estates, trusts, or other partnerships and may be actively or passively involved in business operations.

secondary grades. Secondary grades are classified like elementary grades, by district. If the district covers eighth through twelfth grades, then grades eight through twelve are considered secondary. Likewise, if the district covers grades nine through twelve, then only nine through twelve are considered secondary.

sole proprietorship. A business that is fully owned and managed by a single individual.

total population. Includes all citizens, armed forces personnel, and merchant marines of the United States living at home or abroad.

two-year colleges. A school that offers an associate degree, but not a baccalaureate degree. Two-year colleges are also called junior colleges.

university. A school that places its primary emphasis on graduate and professional education. Universities offer doctoral studies in numerous fields and support at least two professional programs.

vocational school. A school that offers a certification in a specialized profession but does not offer classes applicable toward an associate or baccalaureate degree.

Education and Government Environments

The evolution of demographic changes in the United States has profoundly affected American society. One significant factor that has caused major shifts in school enrollment is the alteration in the fertility rate of women.

- The continuing effects of the baby boom (1946-1964) have caused enrollment at the elementary and secondary levels to:
  - Increase—1950s and 1960s
  - Decrease—1970s and early 1980s
  - Increase—Mid-1980s to late 1980s
- Higher education (postsecondary) enrollment has also been affected. Enrollment has:
  - Increased—Mid-1960s and 1970s
  - Peaked—Mid-1980s
  - Increased—Late 1980s
- Changes in the enrollment of elementary and secondary schools reflect shifts in school-age population. As women started having more children in the early 1980s, the school-age population began to increase.
- Enrollment in grades kindergarten through 8 will continue to increase well into the 1990s. However, enrollment in grades 9 through 12 is expected to decline through 1990, then begin to increase through 1997.
- Although enrollment in elementary and secondary schools was decreasing in the 1970s, the number of teachers in public elementary and secondary schools increased. Part of the increase can be attributed to a greater number of teachers required to implement special and bilingual education programs and smaller class-size policies. The number of teachers declined in the late 1970s and early 1980s. After 1983, the number of classroom teachers reached an all-time high of 2.3 million in 1987. This number is expected to reach 2.6 million by 1997.
- Although school-age population contributes to the enrollment of higher education institutions, the younger population is no longer the sole source of enrollment.
- The traditional college-age population is between 18 and 24 years old. This group declined from 30.4 million in 1981, to 27.4 million in 1987. This decline is expected to continue throughout most of the 1990s, reaching 24.0 million in 1997.
- There are several factors influencing changes in enrollment. Some of these factors are:
  - Economic conditions
  - Political and administrative decisions
  - Perceived value of a degree
  - Intrinsic value of higher education
  - College costs
- Although the traditional college-age population is declining, higher education enrollment will be supplemented by the increasing entrance of women, part-time, and older students.
- Preparing students for their post-education work experience is critical. As the required skill level to perform basic job tasks escalates, the demand on the education system to provide a solid foundatior to meet these requirements is heightened.
- The 1990s will be a time for the education system and the workplace to join together and take action to keep the skill level of the work force in step with the rapid changes in technology and skill requirements.

In This Section

Tables E-1 through E-9 and G-1, and Figure 1 provide a general overview of education and government statistics. Areas covered in this section are number of schools, enrollment, expenditures, and government employment.

Table E-1. Number of U.S. Schools, Student Enrollment, and Instructional Staff

	Schools	Percent	Student Enrollment (Thousands)	Percent	Instructional Staff (Thousands)	Percent
Elementary						
Public	59,311	52.8	28,818	49.1	1,336	38.8
Private	15,303	13.6	4,097	7.0	256	7.4
Secondary						
Public	20,758	18.5	11,505	19.6	1,003	29.1
Private	2,438	2.2	1,175	2.0	96	2.8
K-12						
Public	2,179	NA	NA	NA	NA	NA
Private	4,949	NA	NA	NA	NA	NA
Other						
Public	1,000	NA	NA	NA	NA	NA
Private	2,926	NA	NA	NA	NA	NA
Subtotal	108,864	96.9	45,595	77.7	2,691	78.1
Higher Education						
Public	1,549	1.4	10,188	17.4	534	15.5
Private	1,908	1.7	2,899	4.9	221	6.4
Subtotal	3,457	3.1	13,087	22.3	755	21.9
Total	112,321	100.0	58,682	100.0	3,446	100.0

Note: Instructional staff for elementary and secondary education represents teachers exclusively.
Others includes special schools, vocational schools, and adult education schools.
Columns may not add to totals shown because of rounding.

NA = Not available

Source: Market Data Retrieval
U.S. Department of Education,
National Center for Education Statistics

Table E-2. Public School Systems and Student Enrollment by Enrollment-Size Class, 1988-1989

Enrollment Size (Students)	Number of Systems	Percent	Enrollment (Thousands)	Percent
0	195	1.3	NA	0
1 to 299	3,984	25.9	526	1.3
300 to 599	2,266	14.7	1,010	2.5
600 to 999	1,813	11.8	1,454	3.6
1,000 to 2,499	3,529	23.0	5,860	14.5
2,500 to 4,999	1,907	12.4	6,748	16.7
5,000 to 9,999	924	6.0	6,546	16.2
10,000 to 24,999	473	3.1	7,112	17.6
25,000 or more	177	1.2	11,233	27.7
Size Not Reported	108	0.7	NA	0
Total	15,376	100.0	40,489	100.0

Note: Enrollments and numbers of schools should be regarded as approximations only.
These totals differ from those in other tables because this table represents data reported by school districts rather than by states.
Columns may not add to totals shown because of rounding.
NA = Not available

Source: U.S. Department of Education, National Center for Education Statistics

Table E-3. Student Enrollment at U.S. Colleges and Universities, 1985-1995

	Total Enrollment	Four-Year Institutions	Two-Year Institutions	Percent Change
Actual				
1985	12,247	7,716	4,531	0
Estimated				
1986	12,397	7,753	4,644	1.2
1987	12,544	7,816	4,728	1.2
Projected				
1988	12,557	7,878	4,679	0.1
1989	12,570	7,857	4,713	0.1
1990	12,585	7,862	4,723	0.1
1991	12,529	7,831	4,698	(0.2)
1992	12,408	7,756	4,652	(1.3)
1993	12,300	7,679	4,621	(2.3)
1994	12,201	7,605	4,596	(2.6)
1995	12,151	7,563	4,588	(2.1)

Source: U.S. Department of Education, National Center for Education Statistics

Table E-4. Student Enrollment in Grades Kindergarten through 8 and 9 through 12 in Public and Private Elementary and Secondary Schools, 1985-1995 (Thousands of Students)

	Total Public and Private			Public			Private		
Year	K-12	K-8	9-12	K-12	K-8	9-12	K-12	K-8	9-12
Actual									
1987	45,547	32,101	13,446	40,200	27,983	12,217	5,347	4,118	1,229
Projected									
1988	45,522	32,475	13,047	40,280	28,439	11,841	5,242	4,036	1,206
1989	45,609	32,904	12,705	40,337	28,807	11,530	5,272	4,097	1,175
1990	46,092	33,542	12,550	40,752	29,366	11,386	5,340	4,176	1,164
1991	46,718	34,031	12,687	41,306	29,794	11,512	5,412	4,237	1,175
1992	47,366	34,470	12,896	41,879	30,178	11,701	5,487	4,292	1,195
1993	48,000	34,792	13,208	42,444	30,460	11,984	5,556	4,332	1,224
1994	48,635	34,980	13,655	43,014	30,624	12,390	5,621	4,356	1,265
1995	49,112	35,110	14,002	43,442	30,738	12,704	5,670	4,372	1,298

Source: U.S. Department of Education, National Center for Education Statistics

Table E-5. Institutions of Higher Education by Control and Student Enrollment, 1987

Student Enrollment	All Institutions Number	All Institutions Enrollment (Thousands)	Universities Number	Universities Enrollment (Thousands)	Other Four-Year Colleges Number	Other Four-Year Colleges Enrollment (Thousands)	Two-Year Colleges Number	Two-Year Colleges Enrollment (Thousands)
Public Institutions								
Less than 200	7	1	0	0	1	0	6	1
200 to 499	40	15	0	0	11	4	29	11
500 to 999	131	100	0	0	29	23	102	76
1,000 to 2,499	415	713	0	0	107	189	308	524
2,500 to 4,999	319	1,137	1	5	103	376	215	756
5,000 to 9,999	316	2,208	7	59	134	930	175	1,220
10,000 to 19,999	220	2,998	30	452	91	1,222	99	1,325
20,000 to 29,999	73	1,741	34	832	18	430	21	479
30,000 or More	28	1,063	22	841	2	71	4	150
Subtotal	1,549	9,976	94	2,189	496	3,245	959	4,542
Private Institutions								
Less than 200	400	41	0	0	283	29	117	12
200 to 499	395	133	0	0	235	79	160	54
500 to 999	393	284	0	0	307	224	86	60
1,000 to 2,499	463	716	0	0	423	654	40	62
2,500 to 4,999	148	509	6	25	139	473	3	11
5,000 to 9,999	68	465	24	183	43	275	1	7
10,000 to 19,999	33	424	24	313	7	82	2	29
20,000 to 29,999	5	125	5	125	0	0	0	0
30,000 or More	3	95	3	95	0	0	0	0
Subtotal	1,908	2,792	62	741	1,437	1,816	409	235
Public and Private Institutions								
Less than 200	407	42	0	0	284	29	123	13
200 to 499	435	148	0	0	246	83	189	65
500 to 999	524	384	0	0	336	248	188	137
1,000 to 2,499	878	1,429	0	0	530	843	348	586
2,500 to 4,999	467	1,646	7	30	242	849	218	766
5,000 to 9,999	384	2,673	31	242	177	1,204	176	1,227
10,000 to 19,999	253	3,422	54	764	98	1,304	101	1,354
20,000 to 29,999	78	1,866	39	957	18	430	21	479
30,000 or More	31	1,158	25	937	2	71	4	150
Total	3,457	12,768	156	2,930	1,933	5,061	1,368	4,777

Source: U.S. Department of Education, National Center for Education Statistics

Table E-6. Expenditures of U.S. Schools, 1986 (Millions of Dollars)

Type of School	Expenditures	Percent
Public Elementary and Secondary		
Instruction	89,559	61.1
Support Services	51,905	35.4
Noninstruction	5,125	3.5
Total, Elementary and Secondary	146,589	100.0
Higher Education		
Public Institutions		
Instruction	21,881	34.6
Research	5,705	9.0
Public Service	2,516	4.0
Academic Support	4,694	7.4
Student Services	2,922	4.6
Institutional Support	5,667	9.0
Operation and Maintenance	5,177	8.2
Scholarships and Fellowships	1,576	2.5
Others	13,057	20.7
Subtotal	63,195	100.0
Private Institutions		
Instruction	9,151	26.6
Research	2,732	8.0
Public Service	604	1.8
Academic Support	1,974	5.7
Student Services	1,641	4.8
Institutional Support	3,684	10.7
Operation and Maintenance	2,428	7.1
Scholarships and Fellowships	2,584	7.5
Others	9,543	27.8
Subtotal	34,341	100.0
Total, Higher Education	97,536	
Total	244,125	

Source: U.S. Department of Education, National Center for Education Statistics

Table E-7. Ratio of Students to Microcomputers in Public Schools

	School Year				
Grade Level	1985-86*	1986-87*	1987-88	1988-89	1989-90
Elementary	55.3	43.7	36.8	32.4	28.0
Junior High	41.6	32.9	27.6	23.8	22.0
Senior High	37.9	31.1	26.3	22.8	20.5
Total	45.5	36.5	30.8	26.9	24.1

Note: Total represents all public schools including K-12, but excluding schools of special education. Data are preliminary.

Source: Market Data Retrieval

*Data collection was limited to those schools with a microcomputer.

Table E-8. Installed Base of Microcomputers in Public Elementary and Secondary Schools by Manufacturer and School Year

	School Year				
Manufacturer	**1985-86**	**1986-87**	**1987-88**	**1988-89**	**1989-90**
Apple	460,900	632,900	783,400	930,600	1,072,000
Tandy-Radio Shack	139,000	155,800	171,900	178,200	183,000
Commodore	116,300	130,900	140,400	141,600	138,000
IBM	42,100	68,200	108,900	147,700	189,000
Others	84,300	94,100	107,600	124,900	125,000
Total	842,600	1,081,900	1,312,200	1,523,000	1,707,000

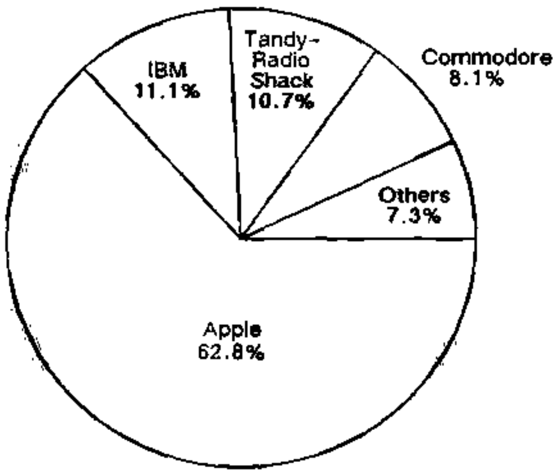
Source: Market Data Retrieval

Table E-9. Microcomputers for Student Instruction in Elementary and Secondary Schools, 1986-1988

	Number of Schools				Percent with Microcomputers			
Year	All	Elementary	Junior High	Senior High	All	Elementary	Junior High	Senior High
1986	80.5	50.7	9.7	15.1	95.6	94.9	98.5	98.7
1987	80.6	50.9	9.7	15.0	96.4	96.0	98.6	99.0
1988	80.8	51.0	9.8	15.0	97.1	96.8	98.8	99.1

Source: Market Data Retrieval

Figure 1. Installed Base of Microcomputers in School for School Year, 1989-1990



0006893-1

Source: Market Data Retrieval
Dataquest
June 1990

Table G-1. Federal, State, and Local Government Employment by Industry Sector, 1988

SIC Category	Employees
Construction	188,500
Manufacturing	126,039
Transportation and Public Utilities	480,541
Retail Trade	80,655
Services	8,503,458
Hospitals	1,253,829
Social Services	285,018
Amusement and Recreation	138,445
Educational	5,525,277
Elementary and Secondary	5,087,240
Colleges and Universities	1,250,769
Public Administration	6,098,305
U.S. Postal Service	834,673
Total	16,312,171

Source: U.S. Department of Labor,
Bureau of Labor Statistics

Households and Population

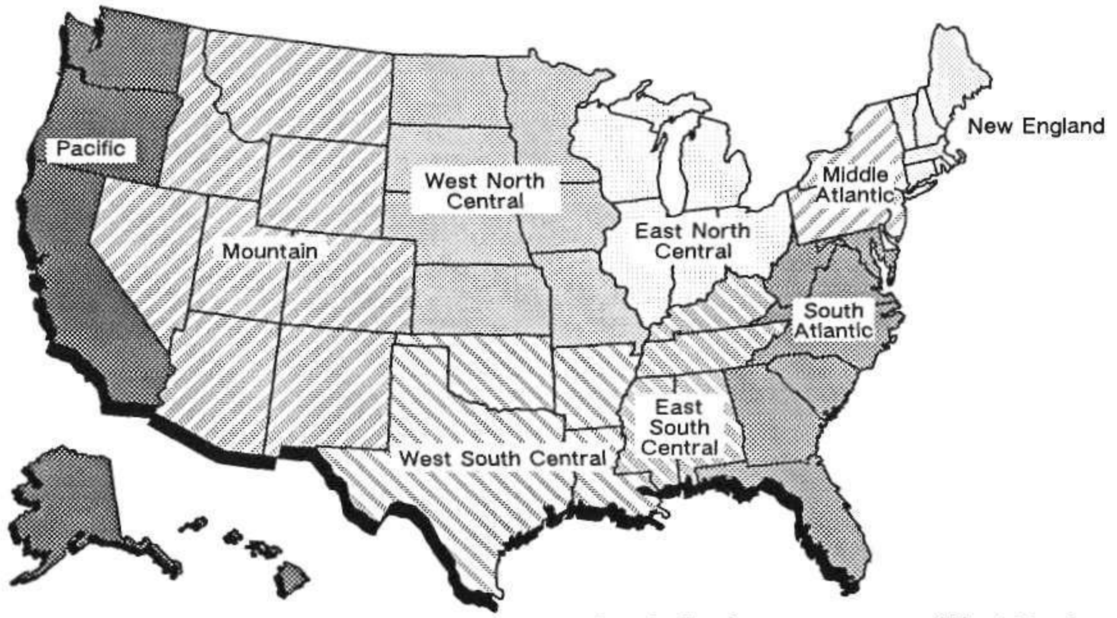
The phrase "traditional nuclear family" is rapidly becoming a sociological term describing the past in American society. As the new decade begins, the movement away from the two-parent, one-income family with children shall continue. This transition time will give rise to an increase in nonfamily, single-parent households, and dual-income marriages without children.

- The percentage of households composed of a married couple with children in the home is 26 percent, down from 31 percent in 1980.
- The fastest growing household classification is people living with nonrelatives. Although the number of households of this type has increased, it accounts for only 5 percent of total households.
- The overall number of households has grown steadily for decades. In 1910, there were 20.3 million households, increasing in number to 92.8 million in 1989.
- In 1989, 16.5 percent of all family households were maintained by women without a husband present, compared with 9.2 percent in 1950. Two contributing factors to this increase are:
  - A greater number of women participating in the work force
  - A higher incidence of divorce than ever before
- The median age for first marriages is getting older. In the late 1980s, the median age for women getting married for the first time was 23.6 and 26.0 for men. These ages compare with the 1950s, when the median age for first marriages was 20.1 and 22.5 for women and men, respectively. The rise in median age for first marriages will have implications on initial and lifetime fertility rates and marriage dissolution. Those couples who are older at the time of their first marriage have fewer children born and a lower incidence of divorce.
- Almost one-fourth of family households with children are maintained by a single parent.
- Nearly 9 out of 11 children living with a single parent are with their mothers. Unfortunately, many women in this circumstance have lower than average incomes. Subsequently, children raised in poverty are at higher risk of low educational attainment, more frequent crime involvement, and out-of-wedlock childbearing.
- The current social patterns in childbearing point to the continuation of small family units as the norm for the nineties.
- Five states have grown by at least 10 percent since 1985. These increases are significantly higher than the national rate of 4 percent. The five states are:
  - Nevada—18 percent
  - Arizona—12 percent
  - Florida and New Hampshire—11 percent
  - California—10 percent (Overall growth in California—2.7 million—accounted for more than one-fourth of the entire nation's growth since 1985.)
- Rebounding from a slight decline in the early 1980s, the East North Central States (such as Michigan and Ohio) experienced population increases in the second half of the decade.
- West Virginia, Kentucky, Mississippi, and the District of Columbia all experienced either slow growth or population declines in the mid-1980s to late 1980s.

In This Section

Figures 2, 3, and 4, and Tables H-1 through H-4 and P-1 through P-8 provide a detailed overview of the U.S. population and household demographics.

Figure 2. U.S. Census Regions and Divisions



Northeast Region

New England Division

- Maine
- New Hampshire
- Vermont
- Massachusetts
- Rhode Island
- Connecticut

Middle Atlantic Division

- New York
- New Jersey
- Pennsylvania

Midwest Region

East North Central Division

- Ohio
- Indiana
- Illinois
- Michigan
- Wisconsin

West North Central Division

- Minnesota
- Iowa
- Missouri
- North Dakota
- South Dakota
- Nebraska
- Kansas

South Region

South Atlantic Division

- Delaware
- Maryland
- District of Columbia
- Virginia
- West Virginia
- North Carolina
- South Carolina
- Georgia
- Florida

East South Central Division

- Kentucky
- Tennessee
- Alabama
- Mississippi

West South Central Division

- Arkansas
- Louisiana
- Oklahoma
- Texas

West Region

Mountain Division

- Montana
- Idaho
- Wyoming
- Colorado
- New Mexico
- Arizona
- Utah
- Nevada

Pacific Division

- Washington
- Oregon
- California
- Alaska
- Hawaii

0006893-2

Source: U.S. Department of Commerce
Bureau of the Census
Dataquest
June 1990

Table H-1. Number of U.S. Households and Average Household Size

Year	1985	1986	1987	1988	1989	1990	Estimated 1995	Estimated 2000
Households (Millions)	86.8	88.4	89.5	91.1	92.8	94.2	100.3	105.9
CAGR (%)	1.6	1.8	1.2	1.8	1.9	1.7	1.3	1.2
Persons per Household	2.69	2.67	2.66	2.64	2.62	2.60	NA	2.48

NA = Not available

Source: U.S. Department of Commerce, Bureau of the Census

Table H-2. Income Distribution of U.S. Households, 1988

Income	Households (Thousands)	Percent
Less than $5,000	5,737	6.2
$5,000 to $9,999	10,006	10.8
$10,000 to $14,999	9,516	10.3
$15,000 to $19,999	9,126	9.8
$20,000 to $24,999	8,184	8.8
$25,000 to $29,999	7,891	8.5
$30,000 to $34,999	6,984	7.5
$35,000 to $39,999	6,414	6.9
$40,000 to $49,999	9,638	10.4
$50,000 to $74,999	12,455	13.4
$75,000 or More	6,877	7.4
Total	92,828	100.0
Median Income	$27,225	
Mean Income	$34,017	

Source: U.S. Department of Commerce, Bureau of the Census

Table H-3. Average U.S. Household Size

Type of Household	Persons per Household 1986	1987	1988	1989
All Households	2.67	2.66	2.64	2.62
Family Households[1]	3.28	3.22	3.21	3.16
Married Couple Households	3.32	3.27	3.25	3.23
Male Householder, No Wife	2.94	2.88	2.92	2.75
Female Householder, No Husband	3.11	3.09	3.08	2.95
Nonfamily Households[2]	1.21	1.22	1.22	NA
Male Householder	1.33	1.34	1.33	NA
Female Householder	1.13	1.13	1.13	NA

[1] Family households consist of people related to the householder by birth, marriage, or adoption.
[2] Nonfamily households consist of a person living alone or a householder living with people unrelated by birth, marriage, or adoption.
NA = Not available

Source: U.S. Department of Commerce, Bureau of the Census

Table H-4. U.S. Households by Region (Thousands of Households)

Region	1988 Households	Percent	1989 Households	Percent	CAGR
Northeast	19,137	21.0	19,158	20.6	0.11
Midwest	22,402	24.6	22,719	24.5	1.42
South	31,048	34.1	31,962	34.4	2.94
West	18,480	20.3	19,078	20.5	3.24
Total	91,067	100.0	92,917	100.0	2.03

Note: Columns may not add to totals shown because of rounding.

Source: U.S. Department of Commerce, Bureau of the Census

Table P-1. Population of the United States, 1987-2000 (Thousands of People)

	Actual			Estimated			
	1987	1988	1989	1991	1994	1997	2000
Population	244,425	246,048	248,241	252,502	258,338	263,543	268,266
CAGR (%)	1.39	0.66	0.89	0.85	0.76	0.67	0.59

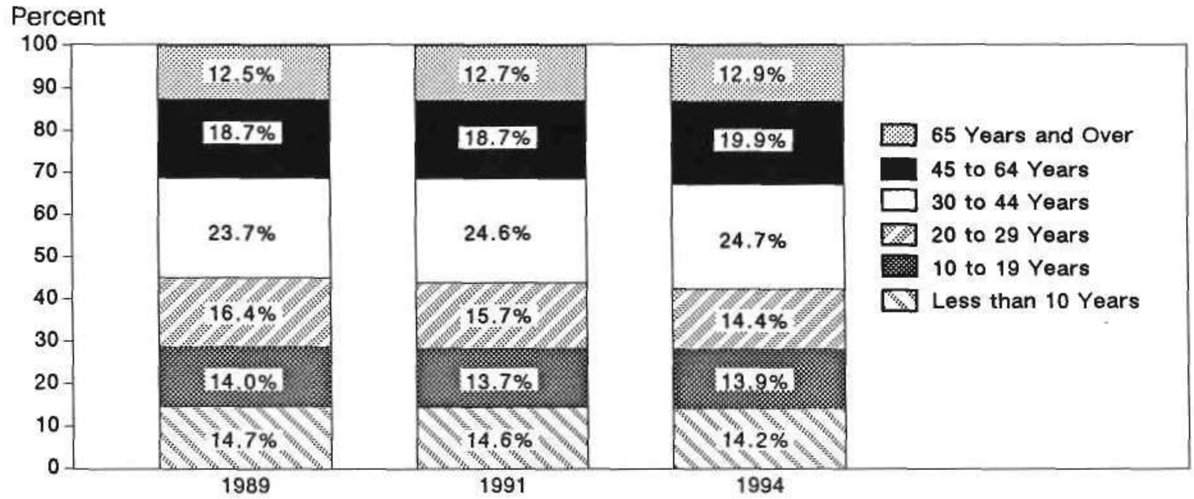
Source: U.S. Department of Commerce,
Bureau of the Census
Dataquest
June 1990

Table P-2. Distribution of U.S. Population by Age (Percent)

	Actual		Estimated		
Age	1989	1991	1994	1997	2000
Less than 10 Years	14.7	14.6	14.2	13.7	13.0
10-19 Years	14.0	13.7	13.9	14.2	14.3
20-29 Years	16.4	15.7	14.4	13.5	13.2
30-44 Years	23.7	24.6	24.7	24.4	23.6
45-64 Years	18.7	18.7	19.9	21.2	22.9
65 Years and Over	12.5	12.7	12.9	13.0	13.0
	100.0	100.0	100.0	100.0	100.0

Source: U.S. Department of Commerce, Bureau of the Census

Figure 3. Actual and Estimated Distribution of U.S. Population by Age



0006893-3

Source: U.S. Department of Commerce
Bureau of the Census
Dataquest
June 1990

Table P-3. Top 50 Metropolitan Statistical Areas, 1988

Rank	Name	Population (Thousands)
1	New York - Northern New Jersey - Long Island, NY - NJ - CT	18,120,200
2	Los Angeles - Anaheim - Riverside, CA	13,769,700
3	Chicago - Gary - Lake County, IL - IN - WI	8,180,900
4	San Francisco - Oakland - San Jose, CA	6,041,800
5	Philadelphia - Wilmington - Trenton, PA - NJ - DE - MD	5,963,300
6	Detroit - Ann Arbor, MI	4,620,200
7	Boston - Lawrence - Salem, MA - NH	4,109,900
8	Dallas - Fort Worth, TX	3,766,100
9	Washington, DC - MD - VA	3,734,200
10	Houston - Galveston - Brazoria, TX	3,641,500
11	Miami - Fort Lauderdale, FL	3,000,500
12	Cleveland - Akron - Lorain, OH	2,769,000
13	Atlanta, GA	2,736,600
14	St. Louis, Mo - IL	2,466,700
15	Seattle - Tacoma, WA	2,420,800
16	Minneapolis - St. Paul, MN - WI	2,387,500
17	San Diego, CA	2,370,400
18	Baltimore, MD	2,342,500
19	Pittsburgh - Beaver Valley, PA	2,284,100
20	Phoenix, AZ	2,029,500
21	Tampa - St. Petersburg - Clearwater, FL	1,995,100
22	Denver - Boulder, CO	1,858,000
23	Cincinnati - Hamilton, OH - KY - IN	1,728,500
24	Kansas City, MO - KS	1,575,400
25	Milwaukee - Racine, WI	1,571,700
26	Portland - Vancouver, OR - WA	1,414,200
27	Sacramento, CA	1,385,200
28	Norfolk - Virginia Beach - Newport News, VA	1,380,200
29	Columbus, OH	1,344,300
30	San Antonio, TX	1,323,200
31	New Orleans, LA	1,306,900
32	Indianapolis, IN	1,236,600
33	Buffalo - Niagara Falls, NY	1,175,600
34	Providence - Pawtucket - Fall River, RI - MA	1,125,400
35	Charlotte - Gastonia - Rock Hill, NC	1,112,000
36	Hartford - New Britain - Middletown, CT	1,067,600
37	Salt Lake City - Ogden, UT	1,065,000
38	Rochester, NY	980,100
39	Memphis, TN - AR - MS	979,300
40	Nashville, TN	971,800
41	Orlando, FL	971,200
42	Louisville, KY	967,000
43	Oklahoma City, OK	963,800
44	Dayton - Springfield, OH	948,000
45	Greensboro - Winston-Salem - High Point, NC	924,700
46	Birmingham, AL	923,400
47	Jacksonville, FL	898,100
48	Albany - Schenectady - Troy, NY	850,800
49	Richmond - Petersburg, VA	844,300
50	Honolulu, HI	838,500

Source: U.S. Department of Commerce, Bureau of the Census

Table P-4. 100 Largest U.S. Cities, 1988

Rank	City	Population (Thousands)
1	New York, NY	7,353
2	Los Angeles, CA	3,353
3	Chicago, IL	2,978
4	Houston, TX	1,698
5	Philadelphia, PA	1,647
6	San Diego, CA	1,070
7	Detroit, MI	1,036
8	Dallas, TX	987
9	San Antonio, TX	941
10	Phoenix, AZ	924
11	Baltimore, MD	751
12	San Jose, CA	738
13	San Francisco, CA	732
14	Indianapolis, IN	727
15	Memphis, TN	645
16	Jacksonville, FL	635
17	Washington, D.C.	617
18	Milwaukee, WI	599
19	Boston, MA	578
20	Columbus, OH	570
21	New Orleans, LA	532
22	Cleveland, OH	521
23	El Paso, TX	511
24	Seattle, WA	502
25	Denver, CO	492
26	Nashville-Davidson, TN	481
27	Austin, TX	465
28	Kansas City, MO	439
29	Oklahoma City, OK	434
30	Fort Worth, TX	427
31	Atlanta, GA	420
32	Portland, OR	418
33	Long Beach, CA	415
34	St. Louis, MO	404
35	Tucson, AZ	386
36	Albuquerque, NM	378
37	Honolulu, HI	376
38	Pittsburgh, PA	375
39	Miami, FL	371
40	Cincinnati, OH	370
41	Tulsa, OK	368
42	Charlotte, NC	368
43	Virginia Beach, VA	365
44	Oakland, CA	357
45	Omaha, NE	353
46	Minneapolis, MN	345
47	Toledo, OH	341
48	Sacramento, CA	338
49	Newark, NJ	314
50	Buffalo, NY	314
51	Fresno, CA	307

(Continued)

Table P-4 (Continued). 100 Largest U.S. Cities, 1988

Rank	City	Population (Thousands)
52	Wichita, KS	295
53	Norfolk, VA	286
54	Colorado Springs, CO	283
55	Louisville, KY	282
56	Tampa, FL	282
57	Mesa, AZ	280
58	Birmingham, AL	277
59	Corpus Christi, TX	261
60	St. Paul, MN	259
61	Arlington, TX	257
62	Anaheim, CA	245
63	Santa Ana, CA	240
64	St. Petersburg, FL	235
65	Baton Rouge, LA	235
66	Rochester, NY	230
67	Lexington-Fayette, KY	226
68	Akron, OH	222
69	Aurora, CO	219
70	Anchorage, AK	218
71	Shreveport, LA	218
72	Jersey City, NJ	218
73	Richmond, VA	213
74	Riverside, CA	211
75	Las Vegas, NV	211
76	Mobile, AL	209
77	Jackson, MS	201
78	Montgomery, AL	194
79	Des Moines, IA	193
80	Stockton, CA	191
81	Lubbock, TX	188
82	Lincoln, NE	188
83	Huntington Beach, CA	187
84	Raleigh, NC	187
85	Grand Rapids, MI	185
86	Yonkers, NY	183
87	Greensboro, NC	182
88	Garland, TX	180
89	Little Rock, AR	180
90	Fort Wayne, IN	180
91	Madison, WI	178
92	Dayton, OH	178
93	Columbus, GA	178
94	Knoxville, TN	172
95	Spokane, WA	171
96	Fremont, CA	166
97	Amarillo, TX	166
98	Tacoma, WA	164
99	Chattanooga, TN	163
100	Hialeah, FL	162

Source: U.S. Department of Commerce, Bureau of the Census

Table P-5. Summary of U.S. Civilian Population By Labor Force Status, 1989

	Population (Thousands)
Civilian Noninstitutional Population Under 16 Years	57,038
Civilian Noninstitutional Population 16 Years and Over	
Civilian Labor Force	
Employed	
Nonagricultural Industries	
Wage and Salary Workers	
Private Household Workers	1,112
Government	17,637
Others	87,568
Self-Employed Workers	8,692
Unpaid Family Workers	282
Subtotal	115,291
Agricultural	
Wage and Salary Workers	1,682
Self-Employed Workers	1,417
Unpaid Family Workers	132
Subtotal	3,231
Total	118,523
Unemployed	6,594
Total	125,117
Not in Labor Force	
Keeping House	27,252
Going to School	7,454
Unable to Work	3,487
Other Reasons	24,966
Subtotal	63,158
Total	188,275
Institutionalized Population	2,928
Civilian Population	248,241

Note: Civilian population figure does not include armed forces or institutionalized population under 16 years. Noninstitutional population under 16 years as of July 1, 1988.

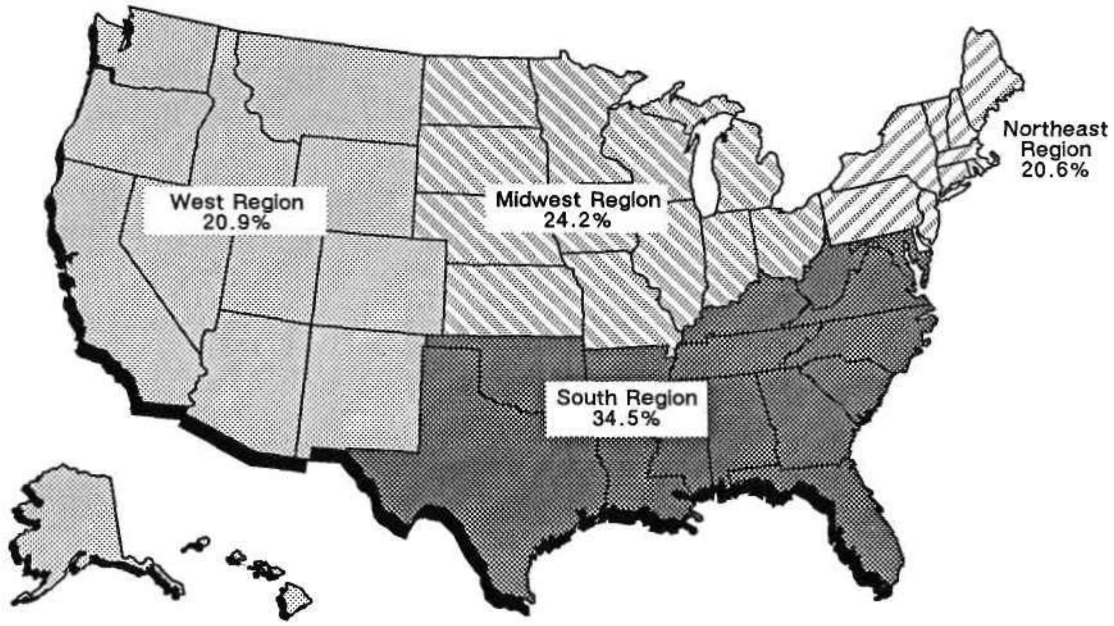
Source: U.S. Department of Labor, Bureau of Labor Statistics

Table P-6. U.S. Census Regions and Divisions

Northeast Region	Midwest Region	South Region	West Region
New England Division	East North Central Division	South Atlantic Division	Mountain Division
Maine	Ohio	Delaware	Montana
New Hampshire	Indiana	Maryland	Idaho
Vermont	Illinois	District of Columbia	Wyoming
Massachusetts	Michigan	Virginia	Colorado
Rhode Island	Wisconsin	West Virginia	New Mexico
Connecticut		North Carolina	Arizona
		Maryland	Utah
		Georgia	Nevada
		Florida	
Middle Atlantic Division	West North Central Division	East South Central Division	Pacific Division
New York	Minnesota	Kentucky	Washington
New Jersey	Iowa	Tennessee	Oregon
Pennsylvania	Missouri	Alabama	California
	North Dakota	Mississippi	Alaska
	South Dakota		Hawaii
	Nebraska	West South Central Division	
	Kansas	Arkansas	
		Louisiana	
		Oklahoma	
		Texas	

Source: U.S. Department of Commerce, Bureau of the Census

Figure 4. Distribution of U.S. Population by Census Divisions



Source: U.S. Department of Commerce
Bureau of the Census
Dataquest
June 1990

Table P-7. U.S. Population by Region and Division (Thousands)

	1989	Percent	1990	Percent
Northeast Region				
New England Division	13,047	5.3	12,733	5.1
Middle Atlantic Division	37,726	15.2	35,690	14.3
Subtotal	50,773	20.5	48,423	19.4
Midwest Region				
East North Central Division	42,298	17.0	42,372	17.0
West North Central Division	17,851	7.2	17,894	7.2
Subtotal	60,149	24.2	60,266	24.2
South Region				
South Atlantic Division	43,115	17.4	43,144	17.3
East South Central Division	15,406	6.2	16,121	6.5
West South Central Division	27,002	10.9	28,328	11.4
Subtotal	85,523	34.5	87,593	35.1
West Region				
Mountain Division	13,513	5.4	15,404	6.2
Pacific Division	38,283	15.4	37,516	15.1
Subtotal	51,796	20.9	52,920	21.2
Total	248,241	100.0	249,202	100.0

Note: Columns may not add to totals shown because of rounding.

Source: U.S. Department of Commerce,
Bureau of the Census
Dataquest
June 1990

Table P-8. U.S. Population by Census Regions, Divisions, and States

Region	Population (Thousands)	Percent
Northeast Region		
New England Division		
Maine	1,222	0.5
New Hampshire	1,107	0.4
Vermont	567	0.2
Massachusetts	5,913	2.4
Rhode Island	998	0.4
Connecticut	3,239	1.3
Subtotal	13,046	5.3
Middle Atlantic Division		
New York	17,950	7.2
New Jersey	7,736	3.1
Pennsylvania	12,040	4.9
Subtotal	37,726	15.2
Midwest Region		
East North Central Division		
Ohio	10,907	4.4
Indiana	5,593	2.3
Illinois	11,658	4.7
Michigan	9,273	3.7
Wisconsin	4,867	2.0
Subtotal	42,298	17.0
West North Central Division		
Minnesota	4,353	1.8
Iowa	2,840	1.1
Missouri	5,159	2.1
North Dakota	660	0.3
South Dakota	715	0.3
Nebraska	1,611	0.6
Kansas	2,513	1.0
Subtotal	17,851	7.2

(Continued)

Table P-8 (Continued). U.S. Population by Census Regions, Divisions, and States

Region	Population (Thousands)	Percent
South Region		
South Atlantic Division		
Delaware	673	0.3
Maryland	4,694	1.9
District of Columbia	604	0.2
Virginia	6,098	2.5
West Virginia	1,857	0.7
North Carolina	6,571	2.6
South Carolina	3,512	1.4
Georgia	6,436	2.6
Florida	12,671	5.1
Subtotal	43,116	17.4
East South Central Division		
Kentucky	3,727	1.5
Tennessee	4,940	2.0
Alabama	4,118	1.7
Mississippi	2,621	1.1
Subtotal	15,406	6.2
West South Central Division		
Arkansas	2,406	1.0
Louisiana	4,382	1.8
Oklahoma	3,224	1.3
Texas	16,991	6.8
Subtotal	27,003	10.9
West Region		
Mountain Division		
Montana	806	0.3
Idaho	1,014	0.4
Wyoming	475	0.2
Colorado	3,317	1.3
New Mexico	1,528	0.6
Arizona	3,556	1.4
Utah	1,707	0.7
Nevada	1,111	0.4
Subtotal	13,514	5.4

(Continued)

Table P-8 (Continued). U.S. Population by Census Regions, Divisions, and States

Region	Population (Thousands)	Percent
West Region (Continued)		
Pacific Division		
Washington	4,761	1.9
Oregon	2,820	1.1
California	29,063	11.7
Alaska	527	0.2
Hawaii	1,112	0.4
Subtotal	38,283	15.4
Total	248,241	100.0

Note: Includes armed forces residing in each state. Columns may not add to totals shown because of rounding.

Source: U.S. Department of Commerce, Bureau of the Census
Dataquest
June 1990

Business

The business sector of the U.S. economy is faced with responding to a multitude of high-impact trends occurring simultaneously in our society. The production orientation of American business is transforming into a service-providing framework. As the structure of business is rebuilt, a new set of challenges await businesses in the nineties.

- Over the next decade, service-producing industries are projected to reach 79.0 percent of all nonfarm wage and salary jobs, compared with 75.9 percent in 1988.
- Employment within the services segment of service-producing industries will account for nearly one-half of all new jobs added over the next 10 years.
- In health and business services alone, employment is expected to reach 18 million by the year 2000. The fastest growing business service industry will be computer services. The business starts of computer-related services have been increasing at an accelerating level.
- The installation of automatic processing equipment in industries such as food production and automotive has raised productivity levels while reducing employment.
- Increased demand for printed material has augmented growth in both employment in this field and the establishment of new small firms. Printing and publishing is one of the few manufacturing sectors where growth has increased to accommodate these new opportunities.
- Strong migration to western states such as Nevada, Arizona, and California has spawned opportunities. The market for opening new businesses in response to this population movement is widening.
- The results of The Dun & Bradstreet Corporation's Dun's 5000 Survey show that 40.9 percent of the companies surveyed expect to increase capital spending in 1990 over their 1989 level. This is a positive economic development in light of rising interest rates.
- Capital equipment expenditures, within the information industry sector, are less dependent on interest rates because of the pace of technological change. The average life-cycle of a computer is shorter than that of a turbine, tractor, or desk.
- There is a strong correlation between the size of the company and plans to increase capital spending. Over half of the companies with greater than 10,000 employees plan to increase capital equipment expenditures. Only 31.7 percent of the companies with less than 20 employees plan to spend more.
- The implementation of technologically advanced equipment in the workplace will foster a continued need for businesses to train and retrain existing employees.

In This Section

Tables B-1 through B-5 and Figures 5 through 7 provide a detailed overview of the overall composition of U.S. business.

Table B-1. Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

Industry Sector	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
	Number of Establishments by Employment-Size Class								
Agriculture, Forestry, Fisheries									
Agricultural Production	206,669	7,775	4,473	1,154	743	52	19	220,885	2.5
Agricultural Services	85,386	6,648	2,965	704	360	19	5	96,087	1.1
Forestry	3,213	274	159	47	48	10	1	3,752	0
Fishing, Hunting, and Trapping	2,315	174	103	29	6	0	0	2,627	0
Subtotal	297,583	14,871	7,700	1,934	1,157	81	25	323,351	3.7
Percent	92.0	4.6	2.4	0.6	0.4	0	0	100.0	
Mining									
Oil and Gas Extraction	29,653	4,176	2,852	876	587	58	45	38,247	0.4
Other Mining	8,180	1997	1756	579	675	91	47	13,325	0.2
Subtotal	37,833	6,173	4,608	1,455	1,262	149	92	51,572	0.6
Percent	73.4	12.0	8.9	2.8	2.4	0.3	0.2	100.0	
Contract Construction									
General Contractors and Builders	271,208	20,894	11,356	2,900	1,458	58	27	307,901	3.5
Heavy Construction Contractors	30,870	6,306	5,114	1,946	1,197	60	39	45,532	0.5
Special Trade Contractors	432,107	42,268	24,537	6,060	2,563	54	16	507,605	5.8
Subtotal	734,185	69,468	41,007	10,906	5,218	172	82	861,038	9.9
Percent	85.3	8.1	4.8	1.3	0.6	0	0	100.0	
Manufacturing									
Food and Kindred Products	15,565	4,852	5,142	2,888	3,704	488	238	32,877	0.4
Tobacco Manufactures	97	29	28	32	63	10	16	275	0
Textile Mill Products	5,805	1,612	1,894	1,127	1,743	309	112	12,602	0.1
Apparel and Other Textile Products	16,668	4,061	4,438	2,613	3,028	261	52	31,121	0.4
Lumber and Wood Products	30,805	5,713	4,693	1,946	1,527	84	30	44,798	0.5

(Continued)

Table B-1 (Continued). Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

	Number of Establishments by Employment-Size Class								
Industry Sector	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
Manufacturing (Continued)									
Furniture and Fixtures	11,041	2,599	2,353	1,179	1,239	129	41	18,581	0.2
Paper and Allied Products	2,708	1,326	1,958	1,327	1,891	169	112	9,491	0.1
Printing and Publishing	76,496	12,146	8,673	3,463	2,791	260	167	103,996	1.2
Chemicals and Allied Products	10,881	3,780	3,810	1,916	2,086	335	258	23,066	0.3
Petroleum and Coal Products	2,167	621	611	265	343	60	58	4,125	0
Rubber and Miscellaneous Plastics Products	7,861	2,812	3,555	2,238	2,283	160	74	18,983	0.2
Leather and Leather Products	2,336	455	469	278	377	39	12	3,966	0
Stone, Clay, and Glass Products	14,065	3,781	3,411	1,353	1,262	145	54	24,071	0.3
Primary Metal Industries	4,497	1,834	2,158	1,226	1,586	215	137	11,653	0.1
Fabricated Metal Products	24,325	8,292	8,718	4,086	3,361	219	141	49,142	0.6
Machinery, except Electrical	52,140	13,206	10,872	4,311	3,829	466	319	85,143	1.0
Electric and Electronic Equipment	14,118	4,269	4,754	2,647	3,677	612	430	30,507	0.3
Transportation Equipment	10,623	2,461	2,414	1,321	1,976	349	439	19,583	0.2
Instruments and Related Products	10,972	2,943	2,794	1,418	1,683	255	209	20,274	0.2
Miscellaneous Manufacturing Industries	27,242	4,079	3,187	1,276	966	80	29	36,859	0.4
Subtotal	340,412	80,871	75,932	36,910	39,415	4,645	2,928	581,113	6.7
Percent	58.6	13.9	13.1	6.4	6.8	0.8	0.5	100.0	
Transportation, Communications, Utilities									
Railroad Transportation	1,653	409	415	208	364	73	69	3,191	
Local and Interurban Passenger Transportation	13,677	3,902	3,991	1,530	905	72	36	24,113	0.3
Trucking and Warehousing	111,081	17,206	13,570	4,542	2,737	199	89	149,424	1.7
Water Transportation	8,778	1,177	940	300	265	20	12	11,492	0.1
Transportation by Air	10,293	1,864	1,803	808	642	78	88	15,576	0.2
Pipe Lines, except Natural Gas	497	182	163	58	41	3	0	944	0
Transportation Services	39,418	5,854	2,794	741	495	42	20	49,364	0.6

(Continued)

Table B-1 (Continued). Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

Industry Sector	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
	Number of Establishments by Employment-Size Class								
Transportation, Communications, Utilities (Continued)									
Communication									
Telephone	5,644	2,139	1,837	880	951	168	209	11,828	0.1
Telegraph	857	134	57	19	31	1	4	1,103	0
Broadcasting	4,347	3,608	3,049	835	521	16	15	12,391	0.1
Others	6,416	1,416	1,229	425	475	39	18	10,018	0.1
Electric, Gas, and Sanitary Services	19,632	4,557	4,386	2,189	1,799	259	175	32,997	0.4
Subtotal	222,293	42,448	34,234	12,535	9,226	970	735	322,441	3.7
Percent	68.9	13.2	10.6	3.9	2.9	0.3	0.2	100.0	
Wholesale Trade									
Durable Goods	333,253	56,051	31,782	7,364	3,438	169	110	432,167	5.0
Nondurable Goods	188,211	29,225	18,292	5,480	3,282	209	75	244,774	2.8
Subtotal	521,464	85,276	50,074	12,844	6,720	378	185	676,941	7.8
Percent	77.0	12.6	7.4	1.9	1.0	0.1	0	100.0	
Retail Trade									
Building Materials and Garden Supplies	99,721	11,764	5,653	1,440	526	11	4	119,119	1.4
General Merchandise Stores									
Department Stores	3,453	1,644	2,769	3,458	7,784	285	90	19,483	0.2
Others	29,702	3,505	1,813	873	592	41	9	36,535	0.4
Food Stores									
Grocery Stores	136,435	17,557	15,628	9,472	5,823	86	42	185,043	2.1
Others	57,540	6,348	2,603	377	126	9	0	67,003	0.8
Automotive Dealers and Service Stations									
New and Used Car Dealers	13,516	8,129	13,818	6,547	1,711	0	3	43,724	0.5

(Continued)

Table B-1 (Continued). Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

Industry Sector	Number of Establishments by Employment-Size Class								
	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
Retail Trade (Continued)									
Used Car Dealers	31,583	858	204	25	5	0	0	32,675	0.4
Auto and Home Supply	52,347	5,677	1,445	137	68	3	3	59,680	0.7
Gasoline Service Stations	96,454	7,443	1,505	409	207	1	1	106,020	1.2
Others	22,572	2,287	720	103	24	0	0	25,706	0.3
Apparel and Accessory Stores	172,455	15,417	4,406	879	545	42	24	193,768	2.2
Furniture and Home Furnishings Stores									
Household Appliances Stores	20,657	1,484	690	96	38	0	1	22,966	0.3
Radio, TV, and Music Stores	29,380	1,570	522	125	71	7	0	31,675	0.4
Others	124,489	11,150	3,891	582	264	13	6	140,395	1.6
Eating and Drinking Places	260,440	76,014	74,413	22,087	3,798	109	46	436,907	5.0
Miscellaneous Retail									
Drug Stores	36,831	11,931	5,743	652	189	13	8	55,367	0.6
Liquor Stores	38,043	2,040	411	39	7	1	1	40,542	0.5
Used Merchandise Stores	46,388	720	409	77	32	0	1	47,627	0.5
Miscellaneous Shopping Goods	310,257	14,202	4,400	1,006	351	24	17	330,257	3.8
Nonstore Retailers	64,950	3,812	2,170	731	474	41	34	72,212	0.8
Others	180,890	5,172	2,009	365	137	11	2	188,586	2.2
Subtotal	1,828,103	208,724	145,222	49,480	22,772	697	292	2,255,290	25.9
Percent	81.1	9.3	6.4	2.2	1.0	0	0	100.0	
Finance, Insurance, Real Estate									
Banking	45,860	27,441	16,259	4,626	2,831	316	326	97,659	1.1
Credit Agencies, Except Banks	29,997	4,379	2,706	825	655	73	36	38,671	0.4
Securities, Commodities Brokers, and Services	23,305	4,075	3,485	1,229	814	80	90	33,078	0.4
Insurance Carriers	12,423	4,555	5,142	2,280	2,537	411	406	27,754	0.3
Insurance Agents, Brokers and Services	120,529	9,292	5,658	1,668	991	95	35	138,268	1.6

(Continued)

Table B-1 (Continued). Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

Industry Sector	Number of Establishments by Employment-Size Class 0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
Finance, Insurance, Real Estate (Continued)									
Real Estate	313,425	27,955	16,421	3,814	1,771	72	29	363,487	4.2
Holding and Other Investment Offices	28,915	2,197	1,359	531	381	60	36	33,479	0.4
Subtotal	574,454	79,894	51,030	14,973	9,980	1,107	958	732,396	8.4
Percent	78.4	10.9	7.0	2.0	1.4	0.2	0.1	100.0	
Services									
Hotels and Other Lodging Places	55,361	7,981	7,430	3,729	3,802	306	136	78,745	0.9
Personal Services									
Laundry, Cleaning, Garment Services	70,370	4,942	2,337	824	476	6	2	78,957	0.9
Photographic Studios	18,947	472	139	38	28	5	1	19,630	0.2
Beauty and Barber Shops	152,746	6,405	1,220	102	16	0	0	160,489	1.8
Shoe Repair, Hat Cleaning	8,280	40	6	1	0	0	0	8,327	0.1
Funeral Services	19,532	1,245	315	38	16	0	0	21,146	0.2
Miscellaneous Personal Services	34,981	1,175	542	154	107	9	4	36,972	0.4
Business Services									
Advertising	26,517	3,210	1,634	498	307	30	15	32,211	0.4
Credit Collection and Reporting	5,414	1,361	994	266	130	6	6	8,177	0.1
Mailing, Reproduction, Stenography	15,728	1,682	1,155	363	268	9	1	19,206	0.2
Services to Buildings	40,825	6,710	4,303	1,513	1,529	143	82	55,105	0.6
News Syndicates	586	122	114	35	30	5	0	892	0
Personnel Supply Services	17,721	3,148	1,651	679	939	110	73	24,321	0.3
Computer and Data Processing Services	41,041	6,224	4,405	1,678	1,471	153	114	55,086	0.6
Miscellaneous Business Services	195,790	14,234	8,529	2,873	2,461	210	82	224,179	2.6
Auto Repair, Services, Garages									
Auto Rental, without Drivers	18,372	2,267	1,396	419	227	9	7	22,697	0.3
Auto Parking	2,258	378	319	103	74	4	1	3,137	0

(Continued)

Table B-1 (Continued). Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

Industry Sector	Number of Establishments by Employment-Size Class 0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
Services (Continued)									
Auto Repair Shops	193,843	8,757	2,181	218	85	6	3	205,093	2.4
Auto Services, except Repair	23,053	1,926	1,055	104	28	2	2	26,170	0.3
Miscellaneous Repair Services	170,398	5,903	2,670	602	311	13	8	179,905	2.1
Motion Pictures	34,961	3,145	1,387	334	219	16	9	40,071	0.5
Amusement and Recreation Services	71,427	10,648	8,263	2,663	1,231	57	63	94,352	1.1
Health Services									
Offices of Physicians	169,628	15,109	6,702	1,329	685	51	41	193,545	2.2
Offices of Dentists	89,783	5,023	943	93	16	0	0	95,858	1.1
Offices of Osteopathic Physicians	5,849	309	87	5	1	1	0	6,252	0.1
Offices of Other Health Practitioners	50,951	1,585	468	107	76	2	0	53,189	0.6
Nursing and Personal Care Facilities	2,649	1,283	3,870	6,416	5,817	97	40	20,172	0.2
Hospitals	1,075	613	1,087	1,555	4,384	1,588	1,899	12,201	0.1
Medical and Dental Laboratories	14,340	1,694	1,024	321	230	17	13	17,639	0.2
Outpatient Care Facilities	3,801	1,728	1,645	627	322	13	18	8,154	0.1
Other Health and Allied Services	4,457	1,831	1,838	844	807	52	17	9,846	0.1
Legal Services	112,716	10,193	6,039	1,722	1,038	91	10	131,809	1.5
Educational Services									
Elementary and Secondary Schools	14,700	12,431	38,378	23,086	9,175	592	296	98,658	1.1
Colleges and Universities	570	346	563	360	1,034	249	335	3,457	0
Libraries and Information Centers	16,467	1,104	914	310	162	18	6	18,981	0.2
Correspondence and Vocational Schools	3,049	791	849	388	238	15	7	5,337	0.1
Other Schools and Educational Services	10,741	1,885	1,757	793	1,030	167	72	16,445	0.2
Social Services	89,954	16,785	10,750	3,333	2,133	115	41	123,111	1.4
Museums, Botanical, Zoological Gardens	3,998	573	550	200	145	9	4	5,479	0.1

(Continued)

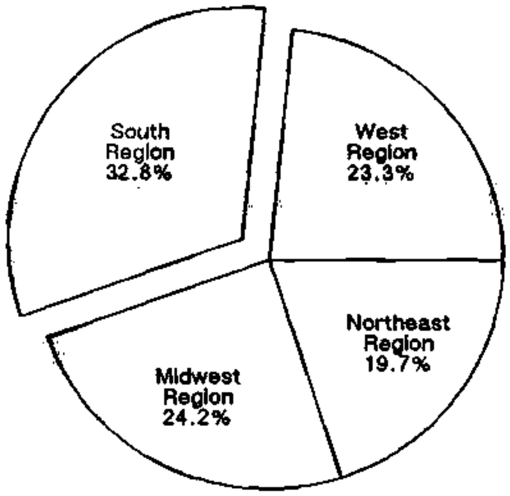
Table B-1 (Continued). Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

	Number of Establishments by Employment-Size Class								
Industry Sector	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
Services (Continued)									
Membership Organizations	186,483	16,667	11,025	3,420	1,720	130	52	219,497	2.5
Miscellaneous Services	212,405	26,299	16,960	5,466	4,375	470	395	266,370	3.1
Subtotal	2,211,767	208,224	157,494	67,609	47,143	4,776	3,855	2,700,868	31.0
Percent	81.9	7.7	5.8	2.5	1.7	0.2	0.1	100.0	
Total	6,768,094	795,949	567,301	208,646	142,893	12,975	9,152	8,505,010	97.6
Percent	79.6	9.4	6.7	2.5	1.7	0.2	0.1	100.0	
Other Government									
Federal								42,047	0.5
Military								13,462	0.2
State								52,656	0.6
Local								99,893	1.1
Subtotal								208,058	2.4
Percent								100.0	
Total								8,713,068	100.0
Percent								100.0	

Note: Columns may not add to totals shown due to rounding.

Source: Dun's Marketing Services
Dataquest
June 1990

Figure 5. Percent Distribution of Business Establishments by Industry Sector



0006893-7

Source: Dun's Marketing Services
Dataquest
June 1990

Table B-2. Distribution of U.S. Establishments by State and Employment-Size Class

	Number of Establishments by Employment-Size Class							
Census Regions and Divisions	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total
Northeast Region								
New England Division								
Maine	34,147	4,115	2,835	1,016	637	64	43	42,857
New Hampshire	31,334	4,130	2,981	1,031	740	79	36	40,331
Vermont	20,046	2,335	1,619	543	299	16	12	24,870
Massachusetts	147,121	21,047	15,540	5,834	4,569	482	354	194,947
Rhode Island	24,794	3,514	2,431	920	616	79	42	32,396
Connecticut	111,443	13,918	9,887	3,336	2,376	233	175	141,368
Subtotal	368,885	49,059	35,293	12,680	9,237	953	662	476,769
Middle Atlantic Division								
New York	460,645	57,846	40,904	14,966	10,801	1,086	855	587,103
New Jersey	192,813	27,712	20,645	7,480	5,795	543	417	255,405
Pennsylvania	278,179	35,217	25,121	10,075	7,414	796	469	357,271
Subtotal	931,637	120,775	86,670	32,521	24,010	2,425	1,741	1,199,779
Midwest Region								
East North Central Division								
Ohio	238,075	31,741	24,151	9,245	6,662	603	451	310,927
Indiana	120,415	15,789	11,526	4,431	3,278	287	197	155,923
Illinois	335,450	38,554	29,319	11,037	8,050	770	507	423,687
Michigan	208,395	27,432	19,871	7,220	4,882	373	342	268,515
Wisconsin	125,275	15,196	11,153	4,198	3,026	272	191	159,311
Subtotal	1,027,610	128,712	96,020	36,131	25,898	2,305	1,688	1,318,363

(Continued)

Table B-2 (Continued). Distribution of U.S. Establishments by State and Employment-Size Class

	Number of Establishments by Employment-Size Class							
Census Regions and Divisions	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total
West North Central Division								
Minnesota	139,330	14,598	10,223	4,180	2,955	253	175	171,714
Iowa	141,791	9,503	6,878	2,463	1,589	140	101	162,465
Missouri	130,109	15,178	11,181	4,078	2,917	284	192	163,939
North Dakota	25,450	2,363	1,472	527	289	20	13	30,134
South Dakota	30,675	2,527	1,739	630	368	18	17	35,974
Nebraska	57,557	5,429	3,927	1,388	873	91	45	69,310
Kansas	87,412	8,536	5,761	2,054	1,322	110	76	105,271
Subtotal	612,324	58,134	41,181	15,320	10,313	916	619	738,807
South Region								
South Atlantic Division								
Delaware	15,310	2,161	1,520	568	431	58	44	20,092
Maryland	100,460	15,460	10,773	3,996	2,728	243	177	133,837
District of Columbia	20,578	3,331	2,541	962	717	108	125	28,362
Virginia	147,099	18,422	12,724	4,832	3,486	361	277	187,201
West Virginia	39,585	4,444	3,362	1,104	732	81	53	49,361
North Carolina	153,380	18,936	13,583	5,318	4,007	411	255	195,890
South Carolina	74,752	8,982	6,272	2,522	1,936	232	132	94,828
Georgia	143,907	19,688	13,461	5,438	3,800	383	247	186,924
Florida	308,145	39,942	26,388	10,067	6,581	530	354	392,007
Subtotal	1,003,216	131,366	90,624	34,807	24,418	2,407	1,664	1,288,502
East South Central Division								
Kentucky	84,731	9,245	6,955	2,692	1,702	174	104	105,603
Tennessee	108,148	14,103	9,859	3,681	2,738	298	179	139,006
Alabama	81,663	10,225	7,559	2,915	2,148	254	128	104,892
Mississippi	60,539	6,396	4,445	1,827	1,287	162	61	74,717
Subtotal	335,081	39,969	28,818	11,115	7,875	888	472	424,218

(Continued)

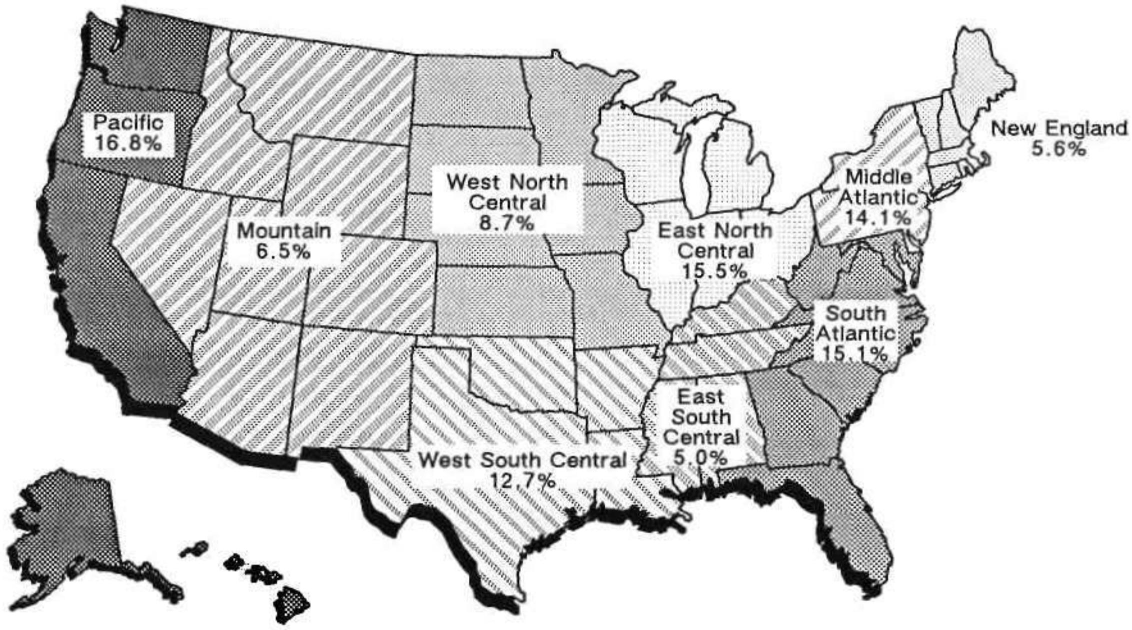
Table B-2 (Continued). Distribution of U.S. Establishments by State and Employment-Size Class

Census Regions and Divisions	Number of Establishments by Employment-Size Class							
	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total
West South Central Division								
Arkansas	65,053	6,094	4,227	1,625	1,189	125	74	78,387
Louisiana	94,255	11,336	8,370	3,023	1,890	178	116	119,168
Oklahoma	97,605	9,446	6,585	2,368	1,408	114	78	117,604
Texas	652,001	53,912	36,213	13,395	9,214	796	648	766,179
Subtotal	908,914	80,788	55,395	20,411	13,701	1,213	916	1,081,338
West Region								
Mountain Division								
Montana	36,726	3,098	2,103	585	319	25	11	42,867
Idaho	37,383	3,427	2,261	723	386	52	31	44,263
Wyoming	22,284	1,865	1,348	443	250	12	8	26,210
Colorado	127,495	12,601	9,018	3,119	1,941	160	138	154,472
New Mexico	43,628	4,712	3,241	1,078	660	59	29	53,407
Arizona	115,191	12,474	8,473	2,986	1,935	166	108	141,333
Utah	42,021	4,890	3,322	1,296	858	69	63	52,519
Nevada	29,232	3,624	2,460	834	602	65	86	36,903
Subtotal	453,960	46,691	32,226	11,064	6,951	608	474	551,974
Pacific Division								
Washington	144,554	15,348	10,572	3,765	2,202	172	143	176,756
Oregon	98,859	9,954	7,092	2,328	1,439	140	71	119,883
California	877,279	94,360	66,445	24,198	15,722	1,309	1,063	1,080,376
Alaska	15,674	1,566	998	323	253	21	13	18,848
Hawaii	22,419	3,225	2,272	813	583	52	33	29,397
Subtotal	1,158,785	124,453	87,379	31,427	20,199	1,694	1,323	1,425,260
Total	6,800,419	779,946	553,605	205,475	142,601	13,408	9,557	8,505,010

Note: Columns may not add to totals shown because of rounding.

Source: Dun's Marketing Services
Dataquest
June 1990

Figure 6. Distribution of Business Establishments by Census Divisions



0006893-6

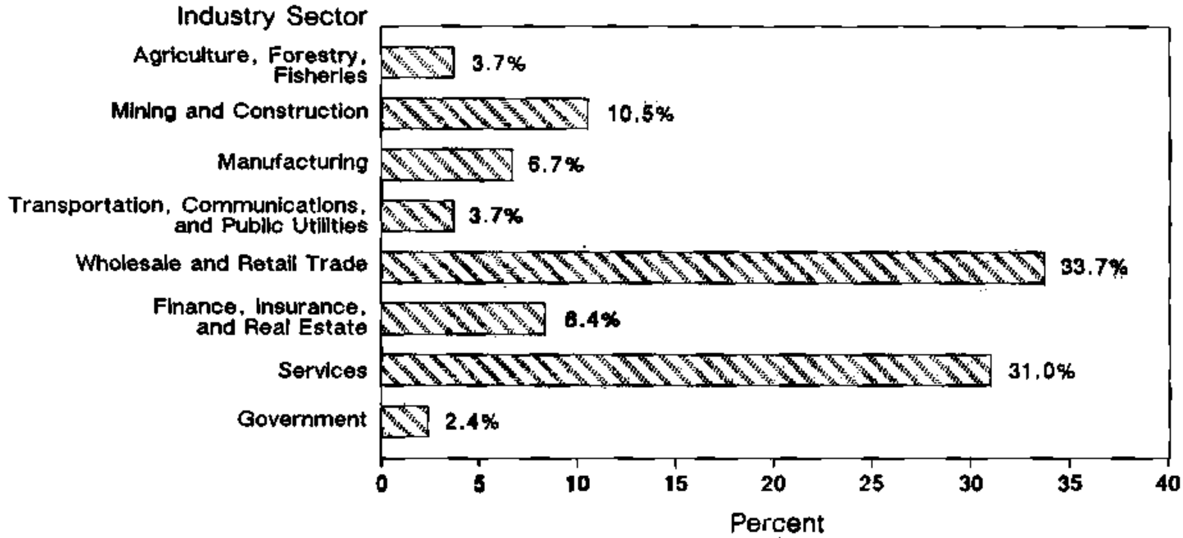
Source: U.S. Department of Commerce
Bureau of the Census
Dataquest
June 1990

Table B-3. Establishment Data by Census Region, 1990

Census Regions and Divisions	Total	Percent of Total
Northeast Region		
New England Division	476,769	5.6
Middle Atlantic Division	1,199,779	14.1
Midwest Region		
East North Central Division	1,318,363	15.5
West North Central Division	738,807	8.7
South Region		
South Atlantic Division	1,288,502	15.1
East South Central Division	424,218	5.0
West South Central Division	1,081,338	12.7
West Region		
Mountain Division	551,974	6.5
Pacific Division	1,425,260	16.8
Total	8,505,010	100.0

Source: Dun's Marketing Services
Dataquest
June 1990

Figure 7. Distribution of Establishments by Census Region



0006693-5

Source: Dun's Marketing Services
Dataquest
June 1990

Table B-4. Distribution of Establishments by Sales Volume and Industry Sector

Industry	Number of Establishments by Sales Volume							
	0-99.9m	100-499.9m	500-999.9m	1-4.9mm	5-9.9mm	10-49.9mm	50mm+	Total
Agriculture, Forestry, and Fisheries	90,637	196,803	17,744	13,071	1,382	1,036	184	320,857
Percent of Subtotal	28.2	61.3	5.5	4.1	0.4	0.3	0.1	100.0
Mining	8,099	24,356	7,252	8,039	1,268	1,439	721	51,175
Percent of Subtotal	15.8	47.6	14.2	15.7	2.5	2.8	1.4	100.0
Construction	224,862	416,314	88,551	100,809	13,219	9,247	1,382	854,385
Percent of Subtotal	26.3	48.7	10.4	11.8	1.5	1.1	0.2	100.0
Manufacturing	94,813	225,669	73,437	119,700	26,078	27,327	9,598	576,622
Percent of Subtotal	16.4	39.1	12.7	20.8	4.5	4.7	1.7	100.0
Transportation, Public Utilities, and Communication	67,962	129,025	47,825	55,656	8,818	7,679	2,982	319,947
Percent of Subtotal	21.2	40.3	14.9	17.4	2.8	2.4	0.9	100.0
Wholesale Trade	49,593	280,769	111,150	165,290	32,468	27,291	5,151	671,712
Percent of Subtotal	7.4	41.8	16.5	24.6	4.8	4.1	0.8	100.0
Retail Trade	519,621	1,272,072	221,955	176,104	21,962	22,532	3,620	2,237,865
Percent of Subtotal	23.2	56.8	9.9	7.9	1.0	1.0	0.2	100.0
Banking	4,780	15,596	11,157	36,922	11,435	12,095	4,920	96,904
Percent of Subtotal	4.9	16.1	11.5	38.1	11.8	12.5	5.1	100.0
Finance, Insurance, and Real Estate	139,113	330,992	68,650	63,482	10,711	12,126	4,760	629,833
Percent of Subtotal	22.1	52.6	10.9	10.1	1.7	1.9	0.8	100.0
Services	1,083,624	1,240,714	186,449	187,216	22,137	19,822	5,749	2,745,711
Percent of Subtotal	39.5	45.2	6.8	6.8	0.8	0.7	0.2	100.0
Total	2,283,103	4,132,309	834,170	926,289	149,478	140,593	39,067	8,505,010
Percent of Total	26.8	48.6	9.8	10.9	1.8	1.7	0.5	100.0

Note: Columns may not add to totals shown because of rounding.
m = Thousands
mm = Millions

Source: Dun's Marketing Services
Dataquest
June 1990

Table B-5. Primary Mainframe Installation Sites of IBM/PCM* by Vertical Market

Vertical Market	Total	IBM	Amdahl	Others
Natural Resources/Construction	223	207	14	2
Process Manufacturing	1,073	1,034	15	24
Discrete Manufacturing	1,467	1,404	26	37
Transportation	203	185	9	9
Communications	119	111	7	1
Utilities	223	212	9	2
Wholesale Trade	572	546	11	15
Retail Trade	444	419	7	18
Finance	821	788	21	12
Insurance	727	694	16	17
Real Estate	68	63	1	4
Health Care	407	397	7	3
Hotels and Lodging	18	17	0	1
Business Services	1,339	1,219	68	52
Other Services	484	459	12	13
Education	707	677	11	19
Government	783	677	67	39
Others	61	59	1	1
Total	9,739	9,168	302	269

*Plug-compatible mainframe

Source: Dataquest
June 1990

Work Force

Labor force opportunities in the 1990s will be challenged by industry employment trends, technological change, worker displacement, and education and training needs for workers. Technology and changes in business practices are two factors, in particular, that will play a key role in the ability to achieve and maintain job stability in this new decade.

- Three of the nine major occupational groups are expected to grow more rapidly than the average for total employment over the next 10 years—executive, administrative, and managerial; professional specialty; and technicians and related support. In addition to being the fastest growing groups, these fields also require the highest level of educational attainment to fulfill job requirements.
- An exception to the growth pattern of the top three occupational categories lies in the service workers. Although this category is projected to grow faster than average, it has relatively few workers with college degrees and a rather high incidence of workers with less than a high-school education.
- Occupations within the professional specialty category growing most in this growth segment are:
  - Engineers
  - Computer specialists
  - Lawyers
  - Health-diagnosing and treatment occupations
  - Teachers (except college and university)
- Technological changes and advancements have been key in furthering the demand for several occupations, including engineers and computer specialists.
- The service occupations group will add more than 4 million jobs by the year 2000, an increase of 23 percent. This category will add more new jobs than any other major occupational group.
- Technological innovation and use of office automation will encourage a slowing trend in the growth in the administrative support occupations. However, this technological movement will affect certain occupations positively, such as computer operators.
- Very low employment growth is expected in agriculture, forestry, and fishing. An increase of less than 100,000 jobs is projected through the year 2000.
- A negative result of declining industries is worker displacement. Some of these workers may be reemployed in their same occupation in a growing industry or retrained for a similar position in the declining industry. However, those workers displaced because of technological change, regardless of whether they are in growing or declining industries, will have a more difficult time finding reemployment.

In This Section

Tables W-1 through W-7 and Figures 8 through 11 highlight the work force by job classification, white-collar segmentation, and employment growth by industry.

Table W-1. Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Managerial and Professional Specialty	29,190	25.39	30,398	25.91	4.1
Executive, Administrative, and Managerial	14,216	12.37	14,848	12.65	4.4
Officials and Administrators, Public Administration	472	0.41	519	0.44	10.0
Financial Managers	502	0.44	472	0.40	(6.0)
Personnel and Labor Relations Managers	130	0.11	128	0.11	(1.5)
Purchasing Managers	99	0.09	110	0.09	11.1
Managers, Marketing, Advertising, and PR	482	0.42	514	0.44	6.6
Administrators, Education and Related Fields	562	0.49	585	0.50	4.1
Managers, Medicine and Health	163	0.14	188	0.16	15.3
Managers, Properties and Real Estate	433	0.38	451	0.38	4.2
Management-Related Occupations	3,772	3.28	3,908	3.33	3.6
Accountants and Auditors	1,329	1.16	1,416	1.21	6.5
Underwriters and Other Financial Officers	741	0.64	103	0.09	(86.1)
Management Analysts	199	0.17	183	0.16	(8.0)
Personnel, Training, Labor Relations	390	0.34	426	0.36	9.2
Buyers, Wholesale and Retail Except Farm Production	233	0.20	214	0.18	(8.2)
Construction Inspectors	60	0.05	61	0.05	1.7
Inspectors and Compliance Officers, Except Construction	194	0.17	196	0.17	1.0
Others (Includes Other Financial Officers)	626	0.54	1309	1.12	109.1
Executive, Administrative, and Managerial NEC	7601	6.61	7973	6.79	4.9
Professional Specialty	14,974	13.02	15,550	13.25	3.8
Architects	143	0.12	157	0.13	9.8
Engineers	1,805	1.57	1,823	1.55	1.0
Aerospace	115	0.10	112	0.10	(2.6)
Chemical	65	0.06	67	0.06	3.1
Civil	218	0.19	249	0.21	14.2
Electrical and Electronic	573	0.50	571	0.49	(0.3)

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Industrial	221	0.19	199	0.17	(10.0)
Mechanical	297	0.26	310	0.26	4.4
Engineers NEC	316	0.27	315	0.27	(0.3)
Mathematical and Computer Scientists	732	0.64	853	0.73	16.5
Computer Systems Analysts and Scientists	479	0.42	566	0.48	18.2
Operations and Systems Researchers and Analyst	210	0.18	239	0.20	13.8
Mathematical and Computer Scientists NEC	43	0.04	48	0.04	11.6
Natural Scientists	395	0.34	413	0.35	4.6
Chemists, except Biochemists	125	0.11	122	0.10	(2.4)
Biological and Life Scientists	75	0.07	77	0.07	2.7
Natural Scientists NEC	195	0.17	214	0.18	9.7
Health Diagnosing Occupations	818	0.71	854	0.73	4.4
Physicians	541	0.47	548	0.47	1.3
Dentists	152	0.13	170	0.14	11.8
Health Diagnosing Occupations NEC	125	0.11	136	0.12	8.8
Health Assessment and Treating Occupations	2,154	1.87	2,242	1.91	4.1
Registered nurses	1,559	1.36	1,599	1.36	2.6
Pharmacists	168	0.15	174	0.15	3.6
Dietitians	74	0.06	83	0.07	12.2
Therapists	298	0.26	324	0.28	8.7
Inhalation	65	0.06	63	0.05	(3.1)
Physical	82	0.07	90	0.08	9.8
Speech	66	0.06	63	0.05	(4.5)
Others	85	0.07	108	0.09	27.1
Health Assessment and Treating Occupations NEC	140	0.12	62	0.05	(55.7)
Teachers, College and University	700	0.61	709	0.60	1.3
Teachers, except College and University	3,773	3.28	3,936	3.35	4.3
Prekindergarten and Kindergarten	393	0.34	431	0.37	9.7

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

	1988		1989		
Occupational Category	Number of Workers	Percent of Total	Number of Workers	Percent of Total	1988-1989 Percent Change
Elementary School	1,424	1.24	1,489	1.27	4.6
Secondary School	1,187	1.03	1,220	1.04	2.8
Special Education	246	0.21	257	0.22	4.5
Teachers, NEC	524	0.46	539	0.46	2.9
Counselors, Educational and Vocational	206	0.18	214	0.18	3.9
Librarians, Archivists and Curators	219	0.19	212	0.18	(3.2)
Librarians	196	0.17	188	0.16	(4.1)
Librarians, Archivists and Curators NEC	23	0.02	24	0.02	4.3
Social Scientists and Urban Planners	343	0.30	374	0.32	9.0
Economists	116	0.10	122	0.10	5.2
Psychologists	196	0.17	210	0.18	7.1
Social Scientists and Urban Planners NEC	31	0.03	42	0.04	35.5
Social, Recreation, and Religious Workers	1,052	0.92	1,043	0.89	(0.9)
Social Workers	537	0.47	527	0.45	(1.9)
Recreation Workers	92	0.08	101	0.09	9.8
Clergy	348	0.30	336	0.29	(3.4)
Religious Workers NEC	75	0.07	79	0.07	5.3
Lawyers and Judges	757	0.66	774	0.66	2.2
Lawyers	724	0.63	741	0.63	2.3
Lawyers and Judges NEC	33	0.03	33	0.03	0
Writers, Artists, Entertainers, Athletes	1,855	1.61	1,921	1.64	3.6
Authors	82	0.07	82	0.07	0
Technical Writers	58	0.05	65	0.06	12.1
Designers	510	0.44	534	0.46	4.7
Musicians and Composers	151	0.13	170	0.14	12.6
Actors and Directors	100	0.09	96	0.08	(4.0)
Painters, Sculptors, Craft Artists and Artist Printmakers	215	0.19	229	0.20	6.5
Photographers	117	0.10	112	0.10	(4.3)

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Editors and Reporters	260	0.23	253	0.22	(2.7)
Public Relations Specialists	151	0.13	159	0.14	5.3
Announcers	52	0.05	51	0.04	(1.9)
Athletes	73	0.06	74	0.06	1.4
Writers, Artists, Entertainers, Athletes NEC	86	0.07	96	0.08	11.6
Other Professional Specialty	22	0.02	25	0.02	13.6
Technical, Sales, and Administrative Support	35,532	30.91	36,127	30.79	1.7
Technicians and Related Support	3,521	3.06	3,645	3.11	3.5
Health Technologists and Technicians	1,226	1.07	1,276	1.09	4.1
Clinical Laboratory Technologists and Technicians	272	0.24	308	0.26	13.2
Dental Hygienists	78	0.07	80	0.07	2.6
Radiologic Technicians	133	0.12	124	0.11	(6.8)
Licensed Practical Nurses	423	0.37	414	0.35	(2.1)
Health Technicians and Related Support NEC	320	0.28	350	0.30	9.4
Engineering and Related Technologists and Technicians	930	0.81	937	0.80	0.8
Electrical and Electronic Technicians	322	0.28	326	0.28	1.2
Drafting Occupations	290	0.25	296	0.25	2.1
Surveying and Mapping Technicians	78	0.07	70	0.06	(10.3)
Engineering and Related Technologists and Technicians NEC	240	0.21	245	0.21	2.1
Science Technicians	216	0.19	217	0.18	0.5
Biological Technicians	55	0.05	59	0.05	7.3
Chemical Technicians	81	0.07	74	0.06	(8.6)
Science Technicians NEC	80	0.07	84	0.07	5.0
Technicians, except Health, Engineering, and Science	1,149	1.00	1,216	1.04	5.8
Airplane Pilots and Navigators	88	0.08	109	0.09	23.9
Computer Programmers	570	0.50	561	0.48	(1.6)
Legal Assistants	203	0.18	210	0.18	3.4
Technicians, except Health, Engineering, and Science	288	0.25	336	0.29	16.7

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

	1988		1989		
Occupational Category	Number of Workers	Percent of Total	Number of Workers	Percent of Total	1988-1989 Percent Change
Sales Occupations	13,747	11.96	14,065	11.99	2.3
Supervisors and Proprietors	3,658	3.18	3,828	3.26	4.6
Sales Representatives, Finance and Business Service	2,410	2.10	2,371	2.02	(1.6)
Insurance Sales	545	0.47	535	0.46	(1.8)
Real Estate Sales	792	0.69	772	0.66	(2.5)
Securities and Financial Services Sales	319	0.28	302	0.26	(5.3)
Advertising and Related Sales	168	0.15	156	0.13	(7.1)
Sales Occupations, Other Business Services	585	0.51	607	0.52	3.8
Sales Representatives, Commodities, except Retail	1,551	1.35	1,612	1.37	3.9
Sales Workers, Retail and Personal Services	6,068	5.28	6,186	5.27	1.9
Sales Workers, Motor Vehicles and Boats	294	0.26	300	0.26	2.0
Sales Workers, Apparel	462	0.40	449	0.38	(2.8)
Sales Workers, Shoes	112	0.10	107	0.09	(4.5)
Sales Workers, Furniture and Home Furnishings	166	0.14	152	0.13	(8.4)
Sales Workers, Radio, Television, Hi-Fi, and Appliances	180	0.16	203	0.17	12.8
Sales Workers, Hardware, and Building Supplies	198	0.17	206	0.18	4.0
Sales Workers, Parts	169	0.15	160	0.14	(5.3)
Sales Workers, Other Commodities	1,537	1.34	1,522	1.30	(1.0)
Sales Counter Clerks	189	0.16	190	0.16	0.5
Cashiers	2,337	2.03	2,473	2.11	5.8
Street and Door-to-Door Sales Workers	318	0.28	323	0.28	1.6
News Vendors	108	0.09	101	0.09	(6.5)
Sales-Related Occupations	59	0.05	68	0.06	15.3
Administrative Support, Including Clerical	18,264	15.89	18,416	15.69	0.8
Supervisors	764	0.66	736	0.63	(3.7)
General Office	458	0.40	446	0.38	(2.6)
Financial Records Processing	91	0.08	82	0.07	(9.9)

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Supervisors, Distributing, Scheduling, and Adjusting	165	0.14	169	0.14	2.4
Supervisors NEC	50	0.04	39	0.03	(22.0)
Computer Equipment Operators	869	0.76	876	0.75	0.8
Computer Operators	865	0.75	870	0.74	0.6
Computer Equipment Operators NEC	4	0	6	0.01	50.0
Secretaries, Stenographers, and Typists	4,876	4.24	4,788	4.08	(1.8)
Secretaries	4,030	3.51	4,010	3.42	(0.5)
Stenographers	48	0.04	47	0.04	(2.1)
Typists	798	0.69	731	0.62	(8.4)
Information Clerks	1,479	1.29	1,451	1.24	(1.9)
Interviewers	163	0.14	183	0.16	12.3
Hotel Clerks	103	0.09	89	0.08	(13.6)
Transportation Ticket and Reservation Agents	114	0.10	112	0.10	(1.8)
Receptionists	848	0.74	815	0.69	(3.9)
Information Clerks NEC	251	0.22	252	0.21	0.4
Records Processing Occupations, Except Financial	827	0.72	851	0.73	2.9
Order Clerks	197	0.17	199	0.17	1.0
Personnel Clerks, except Payroll and Timekeeping	65	0.06	77	0.07	18.5
Library Clerks	143	0.12	144	0.12	0.7
File Clerks	271	0.24	284	0.24	4.8
Records Clerks	132	0.11	116	0.10	(12.1)
Records Processing Occupations, except Financial	19	0.02	31	0.03	63.2
Financial Records Processing	2,414	2.10	2,394	2.04	(0.8)
Bookkeepers, Accounting, and Auditing Clerks	1,970	1.71	1,926	1.64	(2.2)
Payroll and Timekeeping Clerks	173	0.15	177	0.15	2.3
Billing Clerks	157	0.14	159	0.14	1.3
Cost and Rate Clerks	75	0.07	83	0.07	10.7
Financial Records Processing NEC	39	0.03	49	0.04	25.6

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Duplicating, Mail, and Other Office Machine Operators	68	0.06	65	0.06	(4.4)
Communications Equipment Operators	218	0.19	210	0.18	(3.7)
Telephone Operators	210	0.18	201	0.17	(4.3)
Communications Equipment Operators NEC	8	0.01	9	0.01	12.5
Mail and Message Distributing Occupations	936	0.81	952	0.81	1.7
Postal Clerks, except Mail Carriers	313	0.27	313	0.27	0
Mail Carriers, Postal Service	320	0.28	327	0.28	2.2
Mail Clerks, except Postal Service	163	0.14	179	0.15	9.8
Messengers	141	0.12	133	0.11	(5.7)
Material Recording, Scheduling, and Distributing	1,681	1.46	1,745	1.49	3.8
Dispatchers	171	0.15	189	0.16	10.5
Production Coordinators	192	0.17	196	0.17	2.1
Traffic, Shipping and Receiving Clerks	521	0.45	550	0.47	5.6
Stock and Inventory Clerks	559	0.49	561	0.48	0.4
Weighers, Measurers, and Checkers	72	0.06	76	0.06	5.6
Expediters	95	0.08	96	0.08	1.1
Material Clerks NEC	71	0.06	77	0.07	8.5
Adjusters and Investigators	949	0.83	1,079	0.92	13.7
Insurance Adjusters, Examiners, and Investigators	287	0.25	325	0.28	13.2
Investigators and Adjusters, except Insurance	466	0.41	546	0.47	17.2
Eligibility Clerks, Social Welfare	65	0.06	72	0.06	10.8
Bill and Account Collectors	130	0.11	136	0.12	4.6
Miscellaneous Administrative Support	3,183	2.77	3,269	2.79	2.7
General Office Clerks	833	0.72	810	0.69	(2.8)
Bank Tellers	478	0.42	503	0.43	5.2
Data Entry Keyers	362	0.31	414	0.35	14.4
Statistical Clerks	85	0.07	86	0.07	1.2

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Teachers' Aides	423	0.37	440	0.37	4.0
Miscellaneous Administrative Support NEC	1002	0.87	1,016	0.87	1.4
Service Occupations	15,332	13.34	15,556	13.26	1.5
Private Household	909	0.79	872	0.74	(4.1)
Child Care Workers	378	0.33	358	0.31	(5.3)
Cleaners and Servants	476	0.41	464	0.40	(2.5)
Private Household NEC	55	0.05	50	0.04	(9.1)
Protective Service	1,944	1.69	1,960	1.67	0.8
Supervisors, Protective Services	174	0.15	169	0.14	(2.9)
Supervisors, Police and Detectives	93	0.08	83	0.07	(10.8)
Supervisors, Protective Services NEC	81	0.07	86	0.07	6.2
Firefighting and Fire Prevention	218	0.19	208	0.18	(4.6)
Firefighting Occupations	195	0.17	188	0.16	(3.6)
Firefighting and Fire Prevention NEC	23	0.02	20	0.02	(13.0)
Police and Detectives	755	0.66	803	0.68	6.4
Police and Detectives, Public Service	427	0.37	461	0.39	8.0
Sheriffs, Bailiffs, and Other Law Enforcement Officers	111	0.10	112	0.10	0.9
Correctional Institution Officers	217	0.19	230	0.20	6.0
Guards	796	0.69	781	0.67	(1.9)
Guards and Police, except Public Service	675	0.59	658	0.56	(2.5)
Guards, NEC	121	0.11	123	0.10	1.7
Service Occupations, except Private Household, Protective Service	12,479	10.85	12,724	10.84	2.0
Food Preparation and Service Occupations	5,182	4.51	5,351	4.56	3.3
Supervisors	325	0.28	356	0.30	9.5
Bartenders	324	0.28	322	0.27	(0.6)
Waiters and Waitresses	1,363	1.19	1,389	1.18	1.9
Cooks, except Short Order	1,634	1.42	1,713	1.46	4.8

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Short-Order Cooks	95	0.08	91	0.08	(4.2)
Food Counter, Fountain, and Related Occupations	325	0.28	354	0.30	8.9
Kitchen Workers, Food Preparation	132	0.11	126	0.11	(4.5)
Waiters' and Waitresses' Assistants	339	0.29	352	0.30	3.8
Miscellaneous Food Preparation	645	0.56	648	0.55	0.5
Health Service Occupations	1,977	1.72	2,042	1.74	3.3
Dental Assistants	165	0.14	187	0.16	13.3
Health Aides, except Nursing	407	0.35	416	0.35	2.2
Nursing Aides, Orderlies, and Attendants	1,404	1.22	1,439	1.23	2.5
Cleaning and Building Service Occupations	2,994	2.60	2,997	2.55	0.1
Supervisors	159	0.14	154	0.13	(3.1)
Maids and Housemen	644	0.56	646	0.55	0.3
Janitors and Cleaners	2,133	1.86	2,148	1.83	0.7
Cleaning and Building Service Occupations, NEC	58	0.05	49	0.04	(15.5)
Personal Service Occupations	2,327	2.02	2,333	1.99	0.3
Barbers	94	0.08	81	0.07	(13.8)
Hairdressers and Cosmetologists	769	0.67	736	0.63	(4.3)
Attendants, Amusement and Recreation Facilities	130	0.11	133	0.11	2.3
Public Transportation Attendants	77	0.07	86	0.07	11.7
Welfare Service Aides	92	0.08	95	0.08	3.3
Child Care Workers	853	0.74	861	0.73	0.9
Personal Service Occupations, NEC	312	0.27	341	0.29	9.3
Precision Production, Craft and Repair	13,664	11.88	13,818	11.78	1.1
Mechanics and Repairers	4,454	3.87	4,550	3.88	2.2
Supervisors	256	0.22	285	0.24	11.3
Mechanics and Repairers, except Supervisors	4,198	3.65	4,265	3.63	1.6

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Vehicle and Mobile Equipment Mechanics and Repairers	1,811	1.58	1,793	1.53	(1.0)
Automobile Mechanics	879	0.76	880	0.75	0.1
Bus, Truck, and Stationery Engine Mechanics	325	0.28	320	0.27	(1.5)
Aircraft Engine Mechanics	131	0.11	122	0.10	(6.9)
Small-Engine Repairers	70	0.06	65	0.06	(7.1)
Automobile Body and Related Repairers	194	0.17	191	0.16	(1.5)
Heavy Equipment Mechanics	159	0.14	160	0.14	0.6
Vehicle and Mobile Equipment	53	0.05	55	0.05	3.8
Industrial Machinery Repairers	547	0.48	539	0.46	(1.5)
Electrical and Electronic Equipment Repairers	677	0.59	680	0.58	0.4
Electronic Repairers, Communications and Industrial Equipment	165	0.14	165	0.14	0
Data Processing Equipment Repairers	140	0.12	152	0.13	8.6
Telephone Line Installers and Repairers	61	0.05	54	0.05	(11.5)
Telephone Installers and Repairers	202	0.18	193	0.16	(4.5)
Electronic and Electronic Equipment NEC	109	0.09	116	0.10	6.4
Heating, Air Conditioning, and Refrigeration Mechanics	262	0.23	279	0.24	6.5
Miscellaneous Mechanics and Repairers	874	0.76	948	0.81	8.5
Office Machine Repairers	60	0.05	67	0.06	11.7
Millwrights	96	0.08	101	0.09	5.2
Miscellaneous Mechanics NEC	718	0.62	780	0.66	8.6
Mechanics and Repairers, NEC	27	0.02	26	0.02	(3.7)
Construction Trades	5,098	4.43	5,142	4.38	0.9
Supervisors	617	0.54	662	0.56	7.3
Construction Trades, except Supervisors	4,481	3.90	4,479	3.82	0
Brickmasons and Stonemasons	202	0.18	219	0.19	8.4
Carpet Installers	108	0.09	109	0.09	0.9
Carpenters	1,427	1.24	1,369	1.17	(4.1)

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Drywall Installers	149	0.13	155	0.13	4.0
Electricians	701	0.61	702	0.60	0.1
Electrical Power Installers and Repairers	101	0.09	104	0.09	3.0
Painters, Construction, and Maintenance	525	0.46	543	0.46	3.4
Plumbers, Pipefitters, and Steamfitters	494	0.43	456	0.39	(7.7)
Concrete and Terrazzo Finishers	85	0.07	77	0.07	(9.4)
Insulation Workers	54	0.05	64	0.05	18.5
Roofers	156	0.14	178	0.15	14.1
Structural Metal Workers	48	0.04	63	0.05	31.3
Construction Trade NEC	431	0.37	440	0.37	2.1
Extractive Occupations	144	0.13	138	0.12	(4.2)
Precision Production Occupations	3,968	3.45	3,988	3.40	0.5
Supervisors	1,361	1.18	1,353	1.15	(0.6)
Precision Metalworking	896	0.78	911	0.78	1.7
Tool and Die Makers	145	0.13	148	0.13	2.1
Machinists	497	0.43	479	0.41	(3.6)
Sheet-Metal Workers	126	0.11	141	0.12	11.9
Precision Metalworking, NEC	128	0.11	143	0.12	11.7
Precision Woodworking Occupations	106	0.09	95	0.08	(10.4)
Cabinet Makers and Bench Carpenters	66	0.06	56	0.05	(15.2)
Precision Woodworking, NEC	40	0.03	39	0.03	(2.5)
Precision Textile, Apparel, Furnishings Machine Workers	296	0.26	277	0.24	(6.4)
Dressmakers	126	0.11	117	0.10	(7.1)
Upholsterers	84	0.07	71	0.06	(15.5)
Precision Textile, NEC	86	0.07	89	0.08	3.5
Precision Workers, Assorted Materials	529	0.46	565	0.48	6.8
Optical Goods Workers	60	0.05	80	0.07	33.3

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Dental Laboratory and Medical Appliance Technicians	49	0.04	51	0.04	4.1
Electrical and Electronic Equipment Assemblers	305	0.27	316	0.27	3.6
Precision Workers Assorted NEC	115	0.10	118	0.10	2.6
Precision Food Production Occupations	418	0.36	414	0.35	(1.0)
Butchers and Meat Cutters	258	0.22	266	0.23	3.1
Bakers	126	0.11	113	0.10	(10.3)
Precision Food Production NEC	34	0.03	35	0.03	2.9
Precision Inspectors, Testers, and Related Workers	126	0.11	125	0.11	(0.8)
Inspectors, Testers and Graders	113	0.10	113	0.10	0
Precision Inspectors, NEC	13	0.01	12	0.01	(7.7)
Plant and System Operators	236	0.21	249	0.21	5.5
Stationary Engineers	103	0.09	109	0.09	5.8
Plant and System Operators NEC	133	0.12	140	0.12	5.3
Operators, Fabricators, and Laborers	17,814	15.49	18,022	15.36	1.2
Machine Operators, Assemblers, and Inspectors	8,117	7.06	8,248	7.03	1.6
Machine Operators and Tenders, except Precision	5,362	4.66	5,381	4.59	0.4
Metalworking and Plastic Working Machine Operators	465	0.40	470	0.40	1.1
Lathe and Turning Machine Operators	63	0.05	55	0.05	(12.7)
Punching and Stamping Press Machine Operators	123	0.11	120	0.10	(2.4)
Grinding, Abrading, Buffing, and Polishing Machine Operators	141	0.12	143	0.12	1.4
Metalworking and Plastic Operators NEC	138	0.12	152	0.13	10.1
Metal and Plastic Processing Machine Operators	170	0.15	160	0.14	(5.9)
Molding and Casing Machine Operators	102	0.09	97	0.08	(4.9)
Metal and Plastic Processing, NEC	68	0.06	63	0.05	(7.4)
Woodworking Machine Operators	159	0.14	165	0.14	3.8
Sawing Machine Operators	105	0.09	96	0.08	(8.6)
Other Woodworking, NEC	54	0.05	69	0.06	27.8

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Printing Machine Operators	505	0.44	474	0.40	(6.1)
Printing Machine Operators	339	0.29	324	0.28	(4.4)
Typesetters and Compositors	67	0.06	66	0.06	(1.5)
Printing Machine Operators, NEC	99	0.09	84	0.07	(15.2)
Textile, Apparel, and Furnishings Machine Operators	1,355	1.18	1,356	1.16	0.1
Winding and Twisting Machine Operators	76	0.07	77	0.07	1.3
Textile Sewing Machine Operators	749	0.65	757	0.65	1.1
Pressing Machine Operators	146	0.13	134	0.11	(8.2)
Laundering and Dry Cleaning Machine Operator	222	0.19	220	0.19	(0.9)
Textile, Apparel, and Furnishings, NEC	162	0.14	168	0.14	3.7
Machine Operators, Assorted Materials	2,680	2.33	2,736	2.33	2.1
Packaging and Filling Machine Operators	414	0.36	442	0.38	6.8
Mixing and Blending Machine Operators	102	0.09	110	0.09	7.8
Separating, Filtering, and Clarifying Machine Operators	56	0.05	62	0.05	10.7
Painting and Paint Spraying Machine Operator	200	0.17	186	0.16	(7.0)
Furnace, Kiln, and Oven Operators, except Food	102	0.09	96	0.08	(5.9)
Slicing and Cutting Machine Operators	215	0.19	219	0.19	1.9
Photographic Process Machine Operators	98	0.09	91	0.08	(7.1)
Machine Operators, Assorted Materials, NEC	1493	1.30	1530	1.30	2.5
Other Machine Operators and Tenders	28	0.02	20	0.02	(28.6)
Fabricators, Assemblers, and Hand-Working Occupations	1,906	1.66	2,011	1.71	5.5
Welders and Cutters	555	0.48	612	0.52	10.3
Assemblers	1,141	0.99	1,177	1.00	3.2
Fabricators, Assemblers, NEC	210	0.18	222	0.19	5.7
Production Inspectors, Testers, Samplers, and Weighers	849	0.74	856	0.73	0.8
Production Inspectors, Checkers, and Examiners	683	0.59	688	0.59	0.7
Production Testers	63	0.05	60	0.05	(4.8)

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Graders and Sorters, except Agricultural	96	0.08	102	0.09	6.3
Production Inspectors, NEC	7	0.01	6	0.01	(14.3)
Transportation and Material-Moving Occupations	4,831	4.20	4,886	4.16	1.1
Motor Vehicle Operators	3,592	3.12	3,602	3.07	0.3
Truck Drivers, Heavy	1,826	1.59	1,850	1.58	1.3
Truck Drivers, Light	782	0.68	766	0.65	(2.0)
Drivers-Sales Workers	201	0.17	192	0.16	(4.5)
Bus Drivers	450	0.39	440	0.37	(2.2)
Taxi-Cab Drivers and Chauffeurs	218	0.19	220	0.19	0.9
Motor Vehicle Operators, NEC	115	0.10	134	0.11	16.5
Transportation Occupations, except Motor Vehicle	195	0.17	177	0.15	(9.2)
Rail Transportation Occupations	137	0.12	129	0.11	(5.8)
Locomotive Operating Occupations	51	0.04	0	0	(100.0)
Rail NEC	86	0.07	129	0.11	50.0
Water Transportation Occupations	58	0.05	0	0	(100.0)
Material Moving Equipment Operators	1,043	0.91	1,107	0.94	6.1
Operating Engineers	210	0.18	220	0.19	4.8
Crane and Tower Operators	88	0.08	99	0.08	12.5
Excavating and Loading Machine Operators	108	0.09	128	0.11	18.5
Grader, Dozer, and Scraper Operators	92	0.08	98	0.08	6.5
Industrial Truck and Tractor Equipment Operators	431	0.37	452	0.39	4.9
Material Moving, NEC	114	0.10	110	0.09	(3.5)
Handlers, Equipment Cleaners, Helpers and Laborers	4,866	4.23	4,888	4.17	0.5
Helpers, Construction and Extractive Occupations	156	0.14	133	0.11	(14.7)
Helpers, Construction Trades	141	0.12	123	0.10	(12.8)
Helpers, NEC	15	0.01	10	0.01	(33.3)
Construction Laborers	799	0.69	755	0.64	(5.5)
Production Helpers	64	0.06	82	0.07	28.1

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

	1988		1989		
Occupational Category	Number of Workers	Percent of Total	Number of Workers	Percent of Total	1988-1989 Percent Change
Freight, Stock, and Material Handlers	1,756	1.53	1,743	1.49	(0.7)
Stock Handlers and Baggers	891	0.77	900	0.77	1.0
Machine Feeders and Offbearers	110	0.10	91	0.08	(17.3)
Freight, Stock, Material, NEC	755	0.66	752	0.64	(0.4)
Garage and Service Station Related Occupations	246	0.21	230	0.20	(6.5)
Vehicle Washers and Equipment Cleaners	253	0.22	281	0.24	11.1
Hand Packers and Packagers	298	0.26	327	0.28	9.7
Laborers, except Construction	1,248	1.09	1,288	1.10	3.2
Handlers, Equipment Cleaners, Helpers, and Laborers	46	0.04	49	0.04	6.5
Farming, Forestry, and Fishing	3,437	2.99	3,421	2.92	(0.5)
Farm Operators and Managers	1,286	1.12	1,269	1.08	(1.3)
Farmers	1,154	1.00	1,118	0.95	(3.1)
Farm Managers	133	0.12	150	0.13	12.8
Other Agricultural and Related Occupations	1,978	1.72	1,976	1.68	(0.1)
Farm Occupations, except Managerial	1,020	0.89	964	0.82	(5.5)
Farm Workers	949	0.83	893	0.76	(5.9)
Farm Occupations, NEC	71	0.06	71	0.06	0
Related Agricultural Occupations	958	0.83	1,012	0.86	5.6
Supervisors	76	0.07	73	0.06	(3.9)
Groundskeepers and Gardeners, except Farmers	765	0.67	816	0.70	6.7
Animal Caretakers, except Farmers	101	0.09	104	0.09	3.0
Related Agriculture Occupations, NEC	16	0.01	19	0.02	18.8
Forestry and Logging Occupations	117	0.10	118	0.10	0.9
Timber Cutting and Logging	84	0.07	82	0.07	(2.4)
Forestry and Logging, NEC	33	0.03	36	0.03	9.1
Fishers, Hunters, and Trappers	56	0.05	59	0.05	5.4
Total	114,969	100.00	117,342	100.00	2.1

Note: Columns may not add to totals shown because of rounding.
NEC = Not elsewhere classified

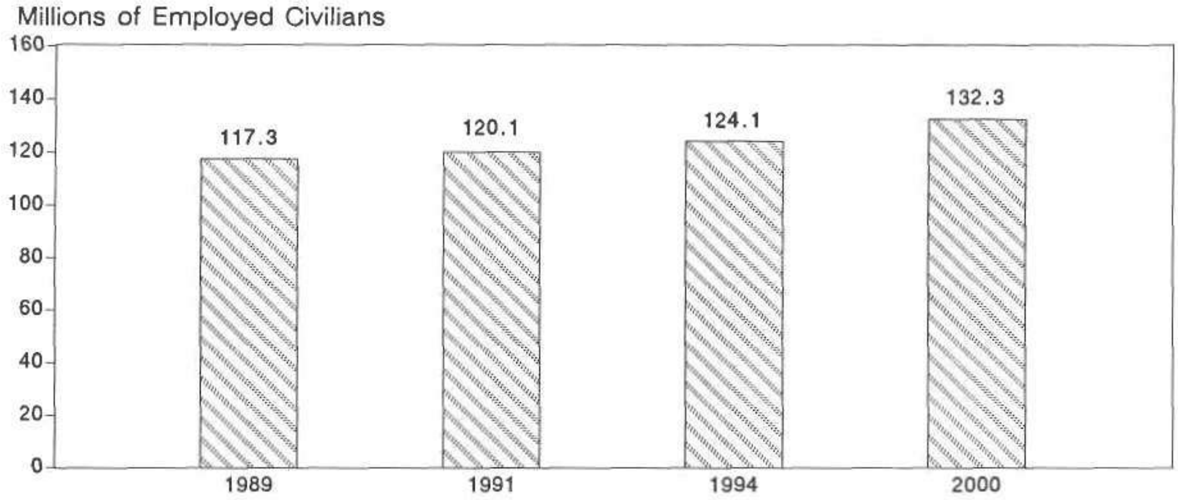
Source: U.S. Department of Labor, Bureau of Labor Statistics

Table W-2. Distribution of U.S. Work Force by Major Occupational Category (Thousands of Workers)

	Actual			Estimated		
Occupational Classification	1988	1989	1991	1994	1997	2000
Executive, Administrative, and Managerial	14,216	14,848	15,302	15,982	16,663	17,344
Professional Specialty	14,974	15,550	16,099	16,922	17,745	18,568
Technicians and Related Support	3,521	3,645	3,825	4,094	4,364	4,634
Sales Occupations	13,747	14,065	14,497	15,145	15,793	16,441
Administrative Support, Including Clerical	18,264	18,416	18,780	19,327	19,873	20,419
Private Household	909	872	871	868	866	864
Protective Service	1,944	1,960	2,037	2,152	2,268	2,383
Service, except Private Household and Protective	12,479	12,724	13,192	13,895	14,597	15,299
Precision Production, Craft, and Repair	13,664	13,818	14,036	14,363	14,690	15,017
Operators, Fabricators, and Laborers	17,814	18,022	18,026	18,033	18,039	18,046
Farming, Forestry, and Fishing	3,437	3,422	3,394	3,354	3,313	3,272
Total	114,969	117,342	120,059	124,135	128,211	132,287

Source: U.S. Department of Labor,
Bureau of Labor Statistics
Dataquest
June 1990

Figure 8. Actual and Estimated Number of Employed U.S. Civilian Workers



0006893-8

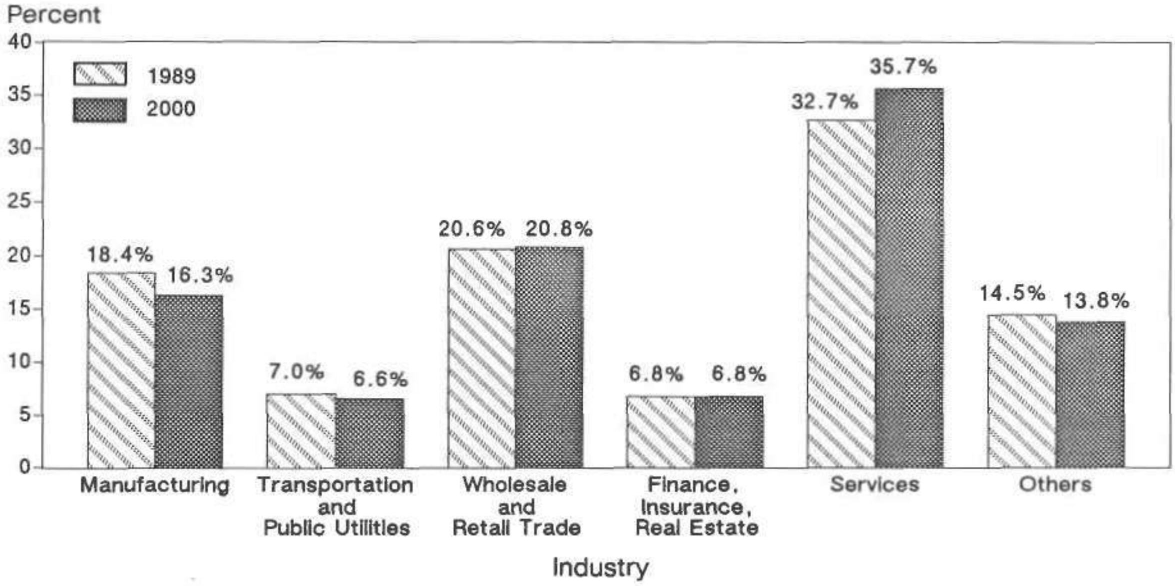
Source: Dataquest
June 1990

Table W-3. Employment Growth by Industry for 1988 and 1989 Annual Estimates through 2000 (Thousands of Workers)

	Actual		Estimated			
Industry	1988	1989	1991	1994	1997	2000
Agriculture	3,169	3,199	3,195	3,187	3,180	3,173
Mining	753	719	718	717	715	714
Construction	7,603	7,680	7,838	8,075	8,312	8,549
Manufacturing	21,320	21,652	21,626	21,590	21,555	21,523
Transportation and Public Utilities	8,064	8,094	8,203	8,367	8,531	8,695
Wholesale and Retail Trade	23,664	24,229	24,824	25,717	26,611	27,504
Finance	7,921	7,989	8,168	8,436	8,705	8,974
Services	37,043	38,227	39,871	42,334	44,794	47,251
Private Household	1,163	1,108	1,106	1,103	1,100	1,098
Public Administration	5,432	5,553	5,616	5,712	5,808	5,904
Total	114,969	117,342	120,059	124,135	128,211	132,287

Source: U.S. Department of Labor, Bureau of Labor Statistics
Dataquest
June 1990

Figure 9. Actual and Estimated Employment Growth by Industry, 1989-2000



0006893-9

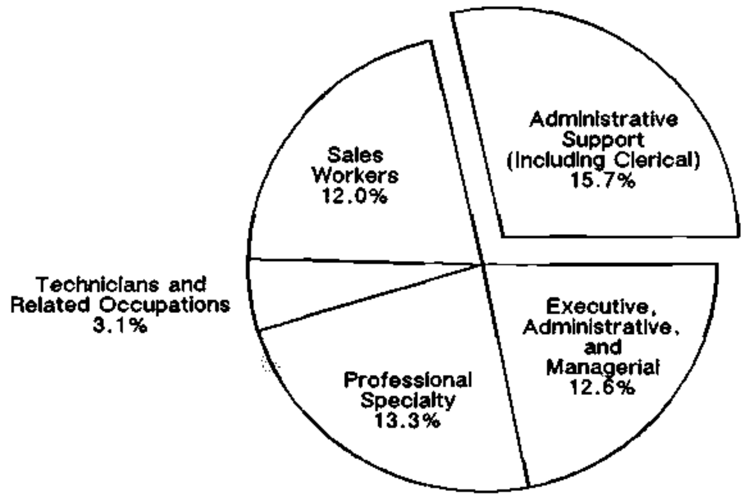
Source: US Department of Labor
Bureau of Labor Statistics
Dataquest
June 1990

Table W-4. Estimated U.S. White-Collar Workers by Job Classification

	1988		1989		1994	
Job Function	Total White-Collar Workers (Millions)	Percent Total Work Force	Total White-Collar Workers (Millions)	Percent Total Work Force	Total White-Collar Workers (Millions)	Percent Total Work Force
Executive, Administrative, and Managerial	14.2	12.4	14.8	12.6	16.0	12.9
Professional Specialty	15.0	13.0	15.6	13.3	16.9	13.6
Technicians and Related Occupations	3.5	3.0	3.6	3.1	4.1	3.3
Sales Workers	13.7	11.9	14.1	12.0	15.2	12.2
Administrative Support (Including Clerical)	18.3	15.9	18.4	15.7	19.3	15.5
Total White Collar	64.7	56.2	66.5	56.7	71.5	57.5
Total Work Force	114.9	100.0	117.3	100.0	124.2	100.0

Source: U.S. Department of Labor, Bureau of Labor Statistics
Dataquest
June 1990

Figure 10. 1989 White-Collar Workers by Job Classification as a Percentage of Total Work Force



0006893-10

Source: US Department of Labor
Bureau of Labor Statistics
Dataquest
June 1990

Table W-5. Estimated U.S. White-Collar Workers by Industry Sector

Industry Sector	1988 Total White-Collar Workers (Millions)	1988 Percent Total White Collar	1989 Total White-Collar Workers (Millions)	1989 Percent Total White Collar	1994 Total White-Collar Workers (Millions)	1994 Percent Total White Collar
Services	24.4	37.7	25.4	38.2	29.3	41.0
Wholesale and Retail Trade	14.8	22.9	15.1	22.7	16.0	22.4
Manufacturing	8.1	12.5	8.3	12.5	7.9	11.0
Finance, Insurance, and Real Estate	7.3	11.3	7.4	11.1	8.0	11.2
Transportation, Communication, and Utilities	4.1	6.3	4.2	6.3	4.2	5.9
Others*	6.0	9.3	6.1	9.2	6.1	8.5
Total White Collar	64.7	100.0	66.5	100.0	71.5	100.0

*Includes agriculture, mining, construction, and public administration.

Source: U.S. Department of Labor, Bureau of Labor Statistics
Dataquest
June 1990

Table W-6. Estimated U.S. White-Collar Workers as a Percent of Total Work Force by Industry Sector

Industry Sector	1988 Total Work Force (Millions)	1988 Percent White Collar	1989 Total Work Force (Millions)	1989 Percent White Collar	1994 Total Work Force (Millions)	1994 Percent White Collar
Services	37.0	65.6	38.2	66.6	42.3	69.1
Wholesale and Retail Trade	23.7	65.8	24.2	62.2	25.7	62.1
Manufacturing	21.3	38.0	21.6	38.2	21.6	36.6
Finance, Insurance, and Real Estate	7.9	92.9	8.0	93.2	8.4	94.7
Transportation, Communication, and Utilities	8.1	50.8	8.1	51.9	8.4	50.9
Others*	16.9	35.8	17.2	35.0	17.7	33.8
Total Work Force	114.9	56.3	117.3	56.7	124.1	57.6

*Includes agriculture, mining, construction, and public administration; average of all four industries.

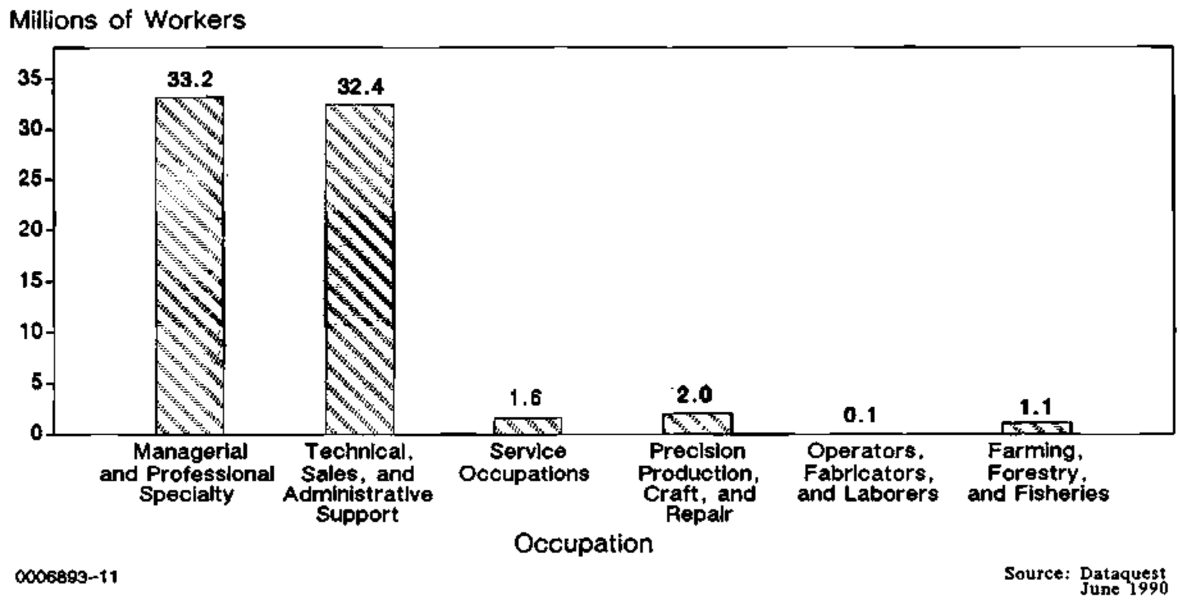
Source: U.S. Department of Labor, Bureau of Labor Statistics
Dataquest
June 1990

Table W-7. Number of Desktops by Job Classification (Thousands)

Occupational Classification	1989	1990	Estimated 1992	1994	1996
Managerial and Professional Specialty	33,179	33,747	34,885	36,022	37,160
Technical, Sales, and Administrative Support	32,394	32,827	33,694	34,561	35,428
Service Occupations	1,620	1,648	1,703	1,758	1,814
Precision Production, Craft, and Repair	2,044	2,058	2,085	2,113	2,141
Operators, Fabricators, and Laborers	114	117	123	130	136
Farming, Forestry, and Fishing	1,092	1,088	1,081	1,074	1,067
Total	70,443	71,485	73,571	75,658	77,746

Source: Dataquest
June 1990

Figure 11. Number of Desktops by Major Occupational Category, 1989



Source: Dataquest
June 1990

Dataquest

a company of
The Dun & Bradstreet Corporation

Dataquest Research and Sales Offices:

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
Phone: (408) 437-8000
Telex: 171973
Fax: (408) 437-0292

Technology Products Group
Phone: (800) 624-3280

Dataquest Incorporated
Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
Phone: (714) 957-0171
Telex: 5101002189 ICCDQ
Fax: (714) 957-0903

Dataquest Incorporated
Ledgeway Group
430 Bedford Street
Suite 340
Lexington, MA 02173
Phone: (617) 862-8500
Fax: (617) 862-8207

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: (02) 959 4544
Telex: 25468
Fax: (02) 929 0635

Dataquest Boston
1740 Massachusetts Ave.
Boxborough, MA 01719-2209
Phone: (508) 264-4373
Telex: 171973
Fax: (508) 635-0183

Dataquest Europe GmbH
Rosenkavalierplatz 17
D-8000 Munich 81
West Germany
Phone: (089) 91 1064
Telex: 5218070
Fax: (089) 91 2189

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
Phone: 0895-835050
Telex: 266195
Fax: 0895 835260/1/2

Dataquest Europe SA
Tour Gallieni 2
36, avenue Gallieni
93175 Bagnolet Cedex
France
Phone: (1) 48 97 31 00
Telex: 233 263
Fax: (1) 48 97 34 00

Dataquest Hong Kong
Rm. 401, Connaught Comm. Bldg.
185 Wanchai Rd.
Wanchai, Hong Kong
Phone: 8387336
Telex: 80587
Fax: 5722375

Dataquest Israel
59 Mishmar Ha'yarden Street
Tel Aviv, Israel 69865
or
P.O. Box 18198
Tel Aviv, Israel
Phone: 52 913937
Telex: 341118
Fax: 52 32865

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo 104 Japan
Phone: (03) 5566-0411
Fax: (03) 5566-0425

Dataquest Korea
Daeheung Bldg., Room 505
648-23 Yeoksam-dong
Kangnam-gu
Seoul, Korea 135
Phone: (02) 552-2332
Fax: (02) 552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 4597181
Telex: 38257
Fax: 4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sect. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: (02) 501-7960
Telex: 27459
Fax: (02) 505-4265

Dataquest West Germany
In der Schneithohl 17
6242 Kronberg 2
West Germany
Phone: 06173/61685
Telex: 418089
Fax: 06173/67901

GM Hughes Electronics Corporation

3044 West Grand Boulevard
Detroit, Michigan 48202
Telephone: (313) 556-3510
Fax: (313) 974-4487
Dun's Number: 00-535-6613

Date Founded: 1985

CORPORATE STRATEGIC DIRECTION

GM Hughes Electronics Corporation (GMHE) has been a consistent world leader in the areas of automotive, defense, and space electronics since its inception in 1985. The company was formed in 1985 when General Motors bought Hughes Aircraft Company for $2.7 billion*, changed the name to GM Hughes Electronics, and made GMHE a wholly owned subsidiary of General Motors. GMHE operates through two main subsidiaries—Hughes Aircraft Company and Delco Electronics Corporation.

Hughes Aircraft Company's main customer has traditionally been the U.S. government because the majority of Hughes' revenue comes from the defense electronics industry. Hughes' recent strategy has been to expand into commercial electronics markets, freeing the company from complete reliance on governmental defense spending. In 1990, commercial sales rose to 25 percent of total revenue, up from 20 percent in 1989. The company's goal is to reach a 60 percent defense and 40 percent commercial mix by the mid-1990s and a 50 percent/50 percent mix by the end of the decade.

Delco Electronics has been among the world leaders in the automotive electronics industry throughout the 1980s and early 1990s. The company produces electronic systems for automobiles with applications including the PASS-Key theft deterrent system, the control system for GM's Supplemental Inflatable Restraint air bag safety system, and the electronic controller for antilock braking systems. Although Delco's primary customer remains GM North America, an increasing amount of sales are to international and non-GM automotive companies. International and non-GM sales reached a record-high $382 million in 1990, accounting for 10.2 percent of total revenue.

In 1990, Delco Electronics and Hughes continued to increase the number of joint ventures between the two companies. Hughes is currently involved in over 150 technology transfer projects that bring Hughes' aerospace technologies to the automotive electronics markets. The joint ventures between Delco and Hughes include GM's IMPACT Electric Vehicle, for which Hughes is working on battery development and Delco is producing the electronic components and HE Microwave Corporation, which is developing transmit/receive radar modules that can be used as obstacle detection systems in both aircraft and automobiles.

GM-Hughes Electronics' total revenue increased 3.2 percent to $11.7 billion in fiscal 1990 from $11.4 billion in fiscal 1989. Net income decreased 8.7 percent to $577.2 million in fiscal 1990 from $632.4 million in fiscal 1989. GMHE employed 96,000 people worldwide at the end of fiscal 1990.

Research and development expenditure totaled $568 million in fiscal 1990, representing 4.8 percent of total revenue. Capital expenditure increased 36.2 percent to $884 million in 1990, accounting for 7.5 percent of total revenue.

More detailed information is available in Tables 1 and 2, which appear after Business Segment Strategic Direction and present corporate highlights and revenue by region. Tables 3 through 5 at the end of this backgrounder present comprehensive financial information.

*All dollar amounts are in U.S. dollars.

©1991 Dataquest Incorporated October—Reproduction Prohibited

BUSINESS SEGMENT STRATEGIC DIRECTION

Hughes Aircraft Company

In fiscal 1990, Hughes Aircraft revenue totaled $7.82 billion, up 5.1 percent from $7.44 billion in fiscal 1989. New orders totaled $7.4 billion, down 14.9 percent from $8.7 billion in 1989. Hughes Aircraft employed 67,000 people at the end of fiscal 1990, down from the 1986 peak of 82,000 employees.

In response to the continuing reductions in defense spending over the last five years, Hughes has begun to broaden its business base to nonmilitary areas while still serving the military market. This new strategy includes being more selective when bidding on development contracts that require front-end investment to ensure that the probable long-term financial return is adequate. It also includes increasing international business by upgrading existing systems and codeveloping or coproducing new systems with international partners and expanding Hughes' business in such commercial areas as telecommunications, simulation, and training.

The defense industry will remain an important part of Hughes' focus, and as a result of the favorable performance of high technology weapon systems in the Persian Gulf War, Hughes anticipates that future defense programs will rely increasingly on high-technology systems such as those that Hughes offers. More than 50 Hughes systems were used by coalition forces in the Persian Gulf, including tactical missiles, night vision equipment, command and control systems, airborne and artillery-locating radar, and sensing devices.

Hughes is organized into seven operating groups, six of which are engaged in prime contract businesses. These six groups are: Electro-Optical and Data Systems, Ground Systems, Missiles Systems, Radar Systems, Space and Communications, and Training and Support Systems. The seventh group, Industrial Electronics, supplies high-technology components to the company's systems group and also markets its products externally.

The Electro-Optical and Data Systems Group designs and manufactures electro-optical sensors, weapon control systems, and information-processing systems for space, aircraft, and surface applications. Major awards during 1990 included a contract to produce tube-launched, optically tracked, wire-guided, (TOW) weapon subsystems for the U.S. Army's Bradley Fighting Vehicle, a contract to develop and produce a lightweight thermal weapon sight for army use, and a contract to fabricate a sensor for the Strategic Defense Initiative.

The Ground Systems Group develops and produces systems for automated airspace management, shipboard command and control, electronic warfare, weapons control displays, air traffic control workstations, jam-resistant communications, sonar, underwater weapons, and land- and ship-based radar applications. In 1990, the group captured a major order for its TracView PC-based air traffic control system from Germany. The order involves the supply and installation of 36 systems, most of which are to be installed in former East German sites near Berlin. The group also received contracts totaling over $180 million to build air defense systems for Iceland and the Republic of China.

The Missile Systems Group designs, develops, and manufactures tactical guided missiles, guidance and control systems, and launchers and is a major contributor to strategic defense technology. Major 1990 contracts included a $202 million Phoenix air-to-air missile contract from the U.S. Navy and a $194 million Maverick air-to-surface missile contract providing missiles to the U.S. Air Force and Navy as well as to Spain, Denmark, New Zealand, Iceland, and Germany.

The Radar Systems Group designs and produces airborne radar systems for advanced tactical, strategic, and reconnaissance aircraft and airborne avionics systems; airborne electronic warfare systems; data links; displays and controls; and automotive displays. The group reached a milestone in 1990 with the production of the 1000th radar system for the F/A-18 Hornet strike fighter, currently used by the United States, Canada, Australia, and Spain.

The Space and Communications Group produces spacecraft for national defense, communications, weather observation, and scientific space exploration. It also provides large-scale information-processing systems and services, and operates and sells satellite communications services and terrestrial private business networks. Advances in 1990 included orders for

©1991 Dataquest Incorporated October—Reproduction Prohibited

15 new satellites from customers such as the U.S. Navy, the Societe Europeenne des Satellites of Luxemborg, the Astra broadcast service in Western Europe, the American Mobile Satellite consortium, and the Telesat Mobile Company of Canada. New products included InTELEconference, a video conferincing system using VSATs; the Personal Earth Station 6000, a state-of-the-art VSAT; and the new HS 601 space satellite system.

The Training and Support Systems Group designs and develops advanced simulation, visual, and display systems for a variety of commercial and military requirements. The organization also designs and fabricates various automatic test systems and provides integrated logistic support for aerospace products worldwide. The 1988 acquisition of Rediffusion Simulation Corp began to pay benefits in 1990 as Hughes launched its Concept 90 flight simulators into the civil aviation flight training market. The company estimates that the initial sales of the Concept 90 simulator captured approximately 75 percent of the worldwide market for the systems, with new customers including Delta Airlines.

The Industrial Electronics Group develops, produces, and markets high-technology components, subsystems, and equipment with a variety of industrial, defense, commercial, and scientific applications. 1990 achievments included the introduction of a large-screen projection system for high-definition television (HDTV) based on innovative video-rate liquid crystal light valve technology and the production of the first 50,000 of 350,000 solar cells for the primary power system of the U.S. space station Freedom.

In addition to Hughes' seven operating groups, the company has three major organizations that provide research and development innovations and the unique products and technology required by the major systems groups. The three laboratories are the Hughes Research Laboratories, the Santa Barbara Research Center, and the Hughes Microelectronics Center.

Delco Electronics Corporation

In fiscal 1990, Delco Electronics' total revenue was $4.0 billion, up from $3.9 billion in fiscal 1989. Delco Electronics consists of seven strategic business units: Audio Systems, Body and Chassis Electronics, Delco Systems Operations, IC Delco, Instrumentation and Air Controls, International, and Powertrain Electronics.

The Audio Systems business unit supplies the automotive industry with entertainment, communication and information products such as radios, speakers, antennas, steering wheel controls, and cellular phones. New releases in 1990 included a speed-compensated volume control for car stereos and a compact disc changer for the van upfitter market.

The Body and Chassis Electronics unit produces electronic controls for vehicle body and chassis systems, such as air bag, theft deterrent, antilock brake, suspension, and steering control modules.

Delco Systems Operations designs and manufactures internal navigation and guidance systems and computers, avionics systems, fire control electronics, and computer systems for both military and commercial customers. This unit is divided into six business segments: Commercial Avionics Systems, Armament Systems, Space Booster Systems, Military Avionics Systems, Tactical Missile Subsystems, and Automotive Programs.

The IC Delco unit is Delco Electronics' in-house custom IC designer and manufacturer and operates as an internal, standalone business. According to Delco, the company is the largest automotive consumer of integrated circuits, producing 170 million ICs annually.

The Instrumentation and Air Controls unit supplies automotive, heating, ventilation, and air conditioning controls and related products. This division produced a major technological innovation in 1990 with the release of a head-up display for automobiles. This system, which is a derivative of fighter aircraft systems, projects speed and other important information into the driver's forward field of vision, reducing the need for the driver to avert his attention from the road.

The International business unit markets Delco Electronics products outside traditional North American units. International sales have doubled in the 1985-1990 time period, with new customers including Fiat, Renault, Toyota, and Volga Automotive Works (VAZ). New overseas centers have recently been opened in Singapore, Germany, and France.

The Powertrain Electronics unit designs and manufactures pressure sensors, electronic modules for engine and transmission controls, and electronic controls for ignition and voltage regulators for passenger cars and trucks.

Further Information

For more information about the company's business segments, please contact the appropriate industry service. Dataquest tracks GM Hughes Electronics through its Military Aerospace Technology Market industry service group.

©1991 Dataquest Incorporated October—Reproduction Prohibited

Table 1
Five-Year Corporate Highlights (Millions of U.S. Dollars)

	1986	1987	1988	1989	1990
Five-Year Revenue	10,440.0	10,481.0	11,243.6	11,359.0	11,723.1
Percent Change	9.85	0.39	7.28	1.03	3.21
Capital Expenditure	700.6	469.4	533.0	648.5	884.3
Percent of Revenue	6.71	4.48	4.74	5.71	7.54
R&D Expenditure	408.1	416.0	550.9	592.0	567.6
Percent of Revenue	3.91	3.97	4.90	5.21	4.84
Number of Employees	102,000	100,000	100,000	94,000	96,000
Revenue (K)/Employee	102.35	104.81	112.44	120.84	122.12
Net Income	445.1	521.1	653.3	632.4	577.2
Percent Change	30.99	17.07	25.37	(3.20)	(8.73)

1990 Fiscal Year	Q1	Q2	Q3	Q4
Quarterly Revenue	2,859.4	2,992.1	2,934.5	2,937.1
Quarterly Profit	145.6	152.3	120.9	158.4

Source: GM Hughes
Annual Reports and Forms 10-K
Dataquest (October 1991)

Table 2
Revenue by Geographic Region (Percent)

Region	1986	1987	1988	1989	1990
North America	89.34	88.38	87.65	86.53	83.84
International	10.66	11.62	12.35	13.47	16.16

Source: GM Hughes
Annual Reports and Forms 10-K
Dataquest (October 1991)

©1991 Dataquest Incorporated October—Reproduction Prohibited

1990 SALES OFFICE LOCATIONS

Hughes Aircraft Company

North America—12
Europe—10
Japan—1
Asia/Pacific—4
ROW—2

Delco Electronics Corporation

North America—3
Europe—4
Japan—1
Asia/Pacific—4

MANUFACTURING LOCATIONS

Hughes Aircraft Company

Missiles Systems Group: Canoga Park, California; Tucson, Arizona; La Grange, Georgia

This group specializes in the development and production of advanced tactical guided missile systems. Associated fields of interest include missile guidance and propulsion systems, missile launch equipment, and ancillary subsystems and components; production of the Phoenix (AIM-54C) long air-to-air missile; and production of the TOW heavy antitank missile. The Missile Systems Group also has a contract to develop a wireless version. The group also produces the Maverick (AGM-65DF/F/G) air-to-ground missile for the air force and Marine Corps with Raytheon as the second source and the AMRAAM (AIM-120A) Advanced Medium-Range Air-to-Air Missile, which replaces the Sparrow (AIM-7) with Raytheon again as the second source. The AMRAAM program also includes defense systems, land combat systems, missile development, naval systems, and strike systems; production of the Angle Rate Bombing Set (ARBS) for improving day and night bombing accuracy for the A-4M Skyhawk and AV-8B Harrier; production of the IR guidance section for the air force's GBU-15 air-to-surface glide weapon; and validation/demonstration of the Advanced Anti-Tank Weapon System Medium (AAWSM).

Radar Systems Group: El Segundo, California

This group is engaged principally in the development and production of aerospace radars, radar-based avionics systems, synthetic aperture radars, airborne weapon control systems, aerospace displays and controls, aerovehicle dedicated data links, airborne electronic countermeasures/countermeasures equipment, and airborne computers. It also is involved in the production of aircraft and missile instrumentation and airborne and underwater telemetry equipment; the F-14 program, the F-15 program, the F/A-18 program, and product operations; production of the APG-65 radar used on the F/A-18 Hornet and selected for the upgrade on the German F-4F Phantom; production of the APG-70 radar, replacing the APG-63, which will be installed in the F-15s and dual-role F-15Es; production of the APG-71 radar for the F-144D Super Tomcat, whose predecessor was the AWG-9 System; development and production of the AXQ-14 Data Link, a two-way communications system providing an extended weapon control capability for the GBU-15 guided weapon; production of the Advanced Synthetic Aperture Radar System (ASAR-2) for the air force TR-1, which provides real-time, high-resolution ground maps; development and production of Head Up Display (HUD) for Sweden's JAS-39 Gripen fighter-attack-reconaissance aircraft; development of laser radar, teamed with General Dynamics, for the Cruise Missile Advanced Guidance Demonstration Program; development of the Airborne Shared Aperture Program to integrate radar, electronic countermeasures, and electronic support measures into one system; and modification of the AWG-9 weapons control system on the F-14.

Space and Communications Group: El Segundo, California

This group specializes in the development and production of earth satellites for telecommunications, earth observation, and meteorology; and payloads for space exploration. Additional responsibilities include deep-space communications equipment. Supporting capabilities include sophisticated antenna systems design; hydraulic, mechanical and thrust-generating components for space station keeping and altitude control; space-qualified microwave and electronics components; and space environmental test facilities. Other activities include development and production of commercial systems, defense information systems, government electronic systems, product operations, and systems applications; new work with INTELSAT; development of a space battery; preliminary design

©1991 Dataquest Incorporated October—Reproduction Prohibited

for the National Test Bed; and production of Ireland and Japan's first commercial communications satellite systems.

Ground Systems Group: Fullerton, California

This group develops and produces automated command-and-control and tactical air defense environment systems, civilian air traffic control systems, communications systems and equipment, radar systems, electronic warfare systems, sonar systems and sonar-guided torpedos, data processing and display systems, land mine warfare systems, command-and-control systems, quality systems, operations systems, software engineering, and training systems. It also is involved in the development and production of the UYQ-21 navy tactical display system, an automated air traffic control system for Korea, and air defense radars for Norway. It has a development contract for replacement of the U.S. air traffic control system and is involved in the production and development of weapon control display systems for the navy, the army's Enhanced Position Location Reporting System (EPLRS), a sonar based on low-frequency acoustic sensors, TPQ-36 radar, TPQ-37(V)4 radar, Surveillance Towed Assay Sonar Systems, electronics for a battlefield mine, and SLQ-17A Naval Electronic Warfare system.

Electro-Optical and Data Systems Group: El Segundo, California

This group is engaged principally in the development and production of electro-optical sensors and fire control systems for use in space, airborne, and surface applications; tactical and high-energy laser systems; and aerospace computers, signal and data processors, and software systems. Additional responsibilities include design and manufacturing of components, materials, and processes, advanced tactical programs, product operations, software engineering, space and strategic systems, tactical engineering, tactical programs, and technology support. Additional development and production include guidance electronic assemblies for the Trident II, thermal imaging and laser range finders for the M-1 tank, a thermal imaging system for the F/A-18 Hornet, a turret-mounted night vision system for U.S. customs, day-night vision sights for the TOW missile, a Marine Corps laser target-pinpointing device, an advanced carbon dioxide laser radar, a small-package advanced computer, the IMPRINT beyond visual range aircraft identification, laser range finders, the Sea Lite Beam Director (SLBD), a thermal imaging system for the army's Cobra helicopter, and the TOW weapon subsystem for the army's Bradley Fighting Vehicle.

Training and Support Systems: Long Beach, California

This group designs and fabricates test equipment and training and engineering simulators. It provides integrated logistic support of aerospace products, including field engineering, field installation and modification, repairs, provisions, and training and technical publications. It also performs range systems engineering, site activation and operation, field service and support, and support program development and develops test and training systems. Additional development and production includes the weapons tactics trainer for the F/A-18 Hornet, a simulator for the Advanced Tactical Fighter (ATF), the REALSCENE high-resolution, real-time visual and sensor system, Weapon Systems Test Sets for the Marine Corps, and TOW testing for the Bradley Fighting Vehicle.

Hughes Research Laboratories: Malibu, California

This group engages in long-range applied research, principally in physics and electronics. Major areas of research include solid-state microwave devices and circuits; submicron microelectronics, VLSI techniques, and gallium arsenide (GaAs) integrated circuits; ion beam technology, including ion propulsion systems; lasers and electro-optical components; fiber and integrated optics; materials for infrared sensors; pattern recognition and artificial intelligence systems; display devices; and new electronic materials. The group also is engaged in chemical physics, exploratory studies, ion physics, optical circuits, optical physics, plasma physics, and silicon integrated circuits.

Santa Barbara Research Center: Goleta, California

This group is engaged in advanced infrared technology, electro-optical technology, and fire sensing and suppression systems.

Industrial Electronics Group: Torrance, California

This group develops and produces advanced systems components and equipment used in a variety of

 ©1991 Dataquest Incorporated October—Reproduction Prohibited

scientific, industrial, military, and commercial applications. Broad areas of interest include microwave and millimeter-wave instruments, devices, components, and systems; image sensing; storage and display devices; industrial and commercial lasers; production and automation equipment, multiplex wire and secure voice communication systems; hybrid microcircuits; connectors and cable assemblies; solar cells; high-power, high-frequency traveling wave tubes; memory modules for high-speed computers; microwave integrated circuits for phase-array radars using GaAs; and high-power hybrid microcircuits.

Hughes Microelectronics Center: Carlsbad, California; Newport, California

This center develops and produces custom and semicustom monolithic integrated circuits, including gate arrays, very high-speed integrated circuit (VHSIC) class and other VLSI devices, and infrared focal plane components.

Other Industrial Electronics Group Facilities:

Irvine, California—This site has two facilities, one to develop and manufacture connecting devices and one to develop and manufacture microelectronic systems.

Carlsbad, California—This site develops and produces industrial products.

Newport Beach, California—This site develops and produces microelectronic circuits.

MANUFACTURING LOCATIONS

Delco Electronics Corporation

Kokomo, Indiana

The Delco Systems Operating Group (DSO) produces computers, guidance, navigation, and avionics systems for commercial and military air and space vehicles, as well as armament systems for armored vehicles.

SUBSIDIARIES

North America

Advanced Electronics Systems International (United States)
Delco Electronics Corporation (United States)
Delco Electronics Overseas Corp. (United States)
Delco Electronics Service Corp. (United States)
ESAL Company (United States)
Hughes Advanced Systems Company (United States)
Hughes-Aircraft Alabama (United States)
Hughes Aircraft Co. Inc. (United States)
Hughes Aircraft Company (United States)
Hughes Aircraft Holdings Canada Inc. (Canada)
Hughes Aircraft International Services Co. (United States)
Hughes Aircraft Mississippi Inc. (United States)
Hughes Aircraft South Carolina (United States)
Hughes Aircraft Systems Canada Ltd. (Canada)
Hughes Aircraft Systems International (United States)
Hughes Communications Inc. (United States)
Hughes Foreign Sales Corp. (U.S. Virgin Islands)
Hughes Georgia Inc. (United States)
Hughes International Inc. (United States)
Hughes International Sales Corp. (United States)
Hughes Investment Management Co. (United States)
Hughes Missiles Electronics (United States)
Hughes Nadge Corp. (United States)
Hughes Network Systems Inc. (United States)
Hughes Optical Products Inc. (United States)
Hughes Simulation Systems Inc. (United States)
Hughes Systems International (United States)
Hughes Technical Services Co. (United States)
Hughes Training Systems Inc. (United States)
International Electronics Systems (United States)
L-T Ranches Inc. (United States)
MDP Ltd. (United States)
Rediffusion Commercial Simulation Inc. (United States)
Rediffusion Simulation (Canada) Inc. (Canada)
Rediffusion Simulation Inc. (United States)
Santa Barbara Research Center (United States)
Spectrolab Inc. (United States)
Systems Building Corp. (United States)

Europe

Atlantic Satellites Ltd. (Ireland)
DCC Ltd. (United Kingdom)
Hughes Information Systems (Netherlands)
Hughes (U.K.) Ltd. (England)
Husint S.A. (Switzerland)

ROW

Delnos S.A. de S.V. (Mexico)
GM Singapore Pte. Ltd. (Singapore)

©1991 Dataquest Incorporated October—Reproduction Prohibited

ALLIANCES, JOINT VENTURES, AND LICENSING AGREEMENTS

1990

General Motors Corporation
General Motors and GM Hughes Electronic signed an agreement to sell and service cellular phones through GM dealers and sell cellular network equipment through Hughes Aircraft Co.

1989

Perkin-Elmer
Hughes Aircraft and the Perkin-Elmer Corporation signed an agreement whereby Hughes is to purchase Perkin-Elmer's Electro-Optics Technology Division (EOTD), a leading provider of electro-optical systems for specialized scientific and military applications.

1987

Tektronix
Delco Electronics Corporation and Tektronix's Liquid Crystal Shutter Strategic Program Unit (LCS SPU) entered into a joint technology development agreement. The technology partnership gives Delco Electronics the exclusive license to use Tektronix LCS SPU's liquid crystal shutter display technology in automotive instrument panels.

MERGERS AND ACQUISITIONS

1989

Sytek Inc.
Hughes Aircraft acquired Sytek from General Instrument Corporation.

Western Union Corporation
Hughes Aircraft acquired Western Union's Westar communications satellite system. The agreement was subject to approval of the Federal Communications Commission, which was granted in November 1989. Westar includes three satellites in orbit and one yet to be launched. Hughes already operates three satellites as the Galaxy system, which primarily services cable TV and radio.

1988

Honeywell
Hughes Aircraft acquired Honeywell's Training and Control Systems Division, one of the country's leading providers of electronic-simulation-based military training systems.

KEY OFFICERS

GM Hughes Electronics Corporation

Robert J. Schultz
Chairman, president, and chief executive officer

Donald J. Almquist
Executive vice president and director

Malcolm W. Currie
Executive vice president and director

Hughes Aircraft Company

Malcom R. Currie
Chairman and chief executive officer

D. Kenneth Richardson
President, chief operating officer, and director

James A. Abrahamson
Executive vice president and director

Michael T. Smith
Executive vice president, chief financial officer and director

Delco Electronics Corporation

Donald J. Almquist
Chairman, president, and chief executive officer

Harry G. Olsen
Vice president, chief financial officer, and director

©1991 Dataquest Incorporated October—Reproduction Prohibited

Table 3
Balance Sheet
Fiscal Year Ending in December
(Millions of U.S. Dollars)

Balance Sheet	1986	1987	1988	1989	1990
Cash	260.5	731.3	698.3	652.4	4,734.3
Receivables	779.4	908.2	903.6	937.7	452.9
Marketable Securities	-	-	7.5	3.6	966.0
Inventory	633.8	664.0	783.9	795.4	6.4
Other Current Assets	1,654.7	1,822.8	2,133.1	2,144.5	862.5
Total Current Assets	3,328.4	4,126.3	4,526.4	4,533.6	2,446.5
Net Property, Plants	2,767.2	2,750.6	2,805.0	2,991.8	3,353.7
Other Assets	4,286.3	4,249.7	4,476.4	4,674.7	4,639.5
Total Assets	10,381.9	11,126.6	11,807.8	12,200.1	12,727.5
Total Current Liabilities	2,946.2	3,427.3	3,424.3	3,197.3	3,360.4
Long-Term Debt	353.0	168.4	285.1	270.5	271.9
Other Liabilities	393.0	459.5	548.4	834.1	996.9
Total Liabilities	3,692.2	4,055.2	4,257.8	4,301.9	4,629.2
Total Shareholders' Equity	6,689.7	7,071.4	7,550.0	7,898.2	8,098.3
Converted Preferred Stock	-	-	-	-	-
Common Stock	6,365.9	6,365.9	6,365.9	6,365.9	6,365.9
Other Equity	-	3.3	3.6	7.4	(81.9)
Retained Earnings	323.8	702.2	1,180.5	1,524.9	1,814.3
Total Liabilities and Shareholders' Equity	10,381.9	11,126.6	11,807.8	12,200.1	12,727.5

Source: GM Hughes
Annual Reports and Forms 10-K
Dataquest (October 1991)

©1991 Dataquest Incorporated October—Reproduction Prohibited

Table 4
Consolidated Income Statement
Fiscal Year Ending in December
(Millions of U.S. Dollars, except Per Share Data)

Consolidated Income Statement	1986	1987	1988	1989	1990
Revenue	10,440.0	10,481.0	11,243.6	11,359.0	11,723.1
U.S. Revenue	9,327.2	9,263.3	9,855.4	9,828.6	9,828.5
Non-U.S. Revenue	1,112.8	1,217.7	1,388.2	1,530.4	1,894.6
Cost of Sales	8,154.8	8,035.5	8,446.1	8,521.3	8,791.1
R&D Expense	408.1	416.0	550.9	592.3	567.3
SG&A Expense	851.5	882.9	1,094.4	1,112.3	1,176.6
Capital Expense	700.6	469.4	533.0	648.5	884.3
Pretax Income	811.2	899.2	983.9	987.7	1,038.4
Pretax Margin (%)	7.77	8.58	8.75	8.70	8.86
Effective Tax Rate (%)	45.10	42.00	35.50	36.00	44.40
Net Income	445.1	521.1	653.3	632.4	577.2
Shares Outstanding, Millions	127.8	130.8	127.9	95.7	88.1
Per Share Data					
Earnings	1.48	1.67	2.01	1.94	1.82
Dividend	-	-	-	-	-
Book Value	52.35	54.06	59.03	82.53	91.92

Source: GM Hughes Corporation
Annual Reports and Forms 10-K
Dataquest (October 1991)

Table 5
Key Financial Ratios
Fiscal Year Ending in December

Key Financial Ratios	1986	1987	1988	1989	1990
Liquidity					
Current (Times)	1.13	1.20	1.32	1.42	1.41
Total Assets/Equity (%)	155.19	157.35	156.39	157.47	157.16
Current Liabilities/Equity (%)	44.04	48.47	45.35	40.48	41.50
Total Liabilities/Equity (%)	55.19	57.35	56.39	54.47	57.16
Profitability (%)					
Return on Assets	4.29	4.68	5.53	5.18	4.54
Return on Equity	6.65	7.37	8.65	8.01	7.13
Profit Margin	4.26	4.97	5.81	5.57	4.92
Other Key Ratios					
R&D Spending % of Revenue	3.91	3.97	4.90	5.21	4.84
Capital Spending % of Revenue	6.71	4.48	4.74	5.71	7.54
Employees	102,000	100,000	100,000	94,000	96,000
Revenue ($K)/Employee	102.35	104.81	112.44	120.84	122.12
Capital Spending % of Assets	6.75	4.22	4.51	5.32	6.95

Source: GM Hughes
Annual Reports and Forms 10-K
Dataquest (October 1991)

 ©1991 Dataquest Incorporated October—Reproduction Prohibited

Unisys Corporation

Post Office Box 500
Blue Bell, Pennsylvania 19424-0001
Telephone: (215) 542-4011
Fax: (215) 542-6850
Dun's Number: 00-535-8932

Date Merged: September 16, 1986

CORPORATE STRATEGIC DIRECTION

Unisys Corporation was formed in 1986 by the merger of Sperry and Burroughs. The company designs, manufactures, markets, and supports commercial, defense, and other information processing equipment and related software.

Unisys manufactures computers ranging from workstations (PCs) through mainframes and is also a supplier of defense electronics. The Information Systems and Related Services and Suppliers category constitutes the largest portion of Unisys' operations. The company's target market emphasis is on organizations such as airlines, banks, telephone companies, and government agencies that deliver a high volume of services in environments where transactions occur constantly at high speeds.

Revenue for both 1989 and 1990 was $10 billion.* Excluding favorable foreign currency effects, revenue in 1990 would have been down slightly. Revenue growth in defense was offset by a decline in commercial operations. The company had a net loss of $436.7 million for 1990, compared with a net loss of $639.3 million for 1989. The loss for 1990 is attributed to the weakened U.S. commercial computer market, conditions in the Middle East, and a special charge of $181 million taken in the third quarter of 1990 to cover reductions in the work force (the elimination of 5,000 jobs) and operational consolidations. As of December 31, 1990, Unisys had approximately 75,300 employees.

In July 1991, Unisys announced that it was taking a series of actions to accelerate a return to profitability. These actions were: streamline the product line in conformance with the Unisys architecture; reduce the number of market segments the company serves directly; sharply focus resources only where the company can add value and differentiation; and aggressively seek technology and marketing alliances to complement in-house strengths on the most cost-efficient basis.

As a result of these fundamental changes, and in light of the continued computer industry weakness, Unisys took special charges of $1.2 billion in the second quarter, which ended June 30, 1991. The charges included $925 million for restructuring to cover a planned work force reduction of approximately 10,000 employees, product and market segment pruning, and plant and excess facilities consolidation. The charges also include $275 million to cover a write-down of goodwill and a write-off of an investment in Memorex preferred stock. The company expects to reduce overall costs by $800 million on an annual basis by December 31, 1992.

In September 1991, Unisys sold its Timeplex Inc. networking subsidiary to a joint venture led by Ascom Holding AG of Switzerland for $207 million. Timeplex developed wide area networking and Enterprise Networking. It offered a full range of wide area and local area internetworking systems for the transmission of voice data and video. Timeplex and Unisys plan to maintain their joint marketing relationship.

In October 1991, Unisys announced that it intends to sell all of its interest in its Defense Systems business through an initial public offering to Paramax Inc., one of the leading U.S. defense electronics companies, headquartered in McLean, Virginia. A registration statement covering 20 million shares of common stock has been filed with the Securities and Exchange Commission. The anticipated price range for the common stock, as set forth in the registration statement, is $22 to $25 per share. In addition, Unisys will receive

*All dollar amounts are in U.S. dollars.

©1991 Dataquest Incorporated November—Reproduction Prohibited

$332 million in cash from Paramax Inc. The completion of the offering is subject to a number of conditions including regulatory approvals, financing, and market conditions.

Although there has been a multitude of changes that have occurred, there has been no fundamental change in the strategic direction. Unisys intends to specialize in providing mission-critical business solutions on open information networks and to focus resources on servicing and increasing revenue from its large established customer base. Unisys plans to pursue new business growth in four primary market segments: financial services, airlines, communications, and the public sector. The product lines being focused on are the 2200 and A Series Information Hub mainframes, Intel-based servers and workstations (PCs), and check and office imaging systems.

The R&D investment costs for fiscal year 1990 were $746.5 million, a decrease of 4 percent from 1989. R&D expenditure was 7.39 percent of revenue for fiscal 1990, compared with 7.74 percent of revenue for 1989.

Unisys sells its products and services worldwide, primarily through its direct sales force. Unisys also uses OEMs and value-added resellers (VARs) as well as distributors in some foreign countries. During fiscal 1990, Unisys had operations in approximately 100 countries. Revenue generated domestically was 487 percent and international was 52 percent. International sales are generated from the Asia/Pacific, Europe, and Central and South America markets.

After several years of collaboration, Unisys and five other computer companies from the United States and Europe formed a consortium to develop and promote an open system for exchanging electronic documents. The objective of the Open Document Architecture (ODA) consortium is to come up with a software tool kit that conforms to the ODA standard. The kit is expected to be available in 1993 and will be licensed to other computer companies and systems developers.

More detailed information is available in Tables 1 and 2, which appear after "Business Segment Strategic Direction" and present corporate highlights and revenue by geographic region. Information on revenue by distribution channel is not available. Tables 3 through 5 at the end of this backgrounder provide comprehensive financial information.

BUSINESS SEGMENT STRATEGIC DIRECTION

Unisys has two main business segments: Commercial Information Systems and Services and Defense Systems. Within these two business segments, Unisys classifies the majority of its products under the category called Information Systems and Related Services and Suppliers. This category represents more than 90 percent of consolidated revenue, operating profit, and identifiable assets during fiscal 1990.

The Information Systems and Related Services and Suppliers category has six specific product classes: Mainframes and Peripherals, Departmental Servers and Workstations (PCs), Software and Related Services, Equipment Maintenance, Custom Products and Services, and Other.

Information Systems and Related Services and Suppliers

Computer Systems

Mainframes and Peripherals comprise a complete line of small-to-large mainframes and related communications processors and peripheral products, such as printers, storage devices, and document-handling equipment. This class of products contributed more than $2.9 billion, or 29 percent of total revenue, for fiscal 1990. According to Dataquest, Unisys ranked seventh in the mainframe market with a 3.90 percent market share, compared with 5.26 percent for 1989. In the midframe market, Unisys ranked fourth with a 5.27 percent market share, compared with a 5.39 percent market share for 1989.

Departmental Servers and Workstations (PCs) accounted for 14 percent of total revenue or more than $1.4 billion for fiscal 1990. This class is made up of departmental servers and workstations including distributed systems, intelligent workstations (PCs), and UNIX OS-based equipment and terminals.

Software and Related Services consists of application and systems software with related professional services. This product class generated more than $2 billion, or 20 percent of total revenue, for fiscal 1990.

 ©1991 Dataquest Incorporated November—Reproduction Prohibited

Representing 20 percent of total 1990 revenue, Equipment Maintenance provides clients with preventive maintenance, spare parts, and other repair activities. This class constituted approximately $2 billion in revenue for fiscal 1990.

Custom Products and Services, which includes specialized information processing systems marketed mainly to governmental defense agencies, contributed 16 percent of total revenue, totaling approximately $1.6 billion in sales.

The Other class generated 1 percent of revenue, or approximately $185.3 million.

Unisys' Network Applications Platform (NAP) is a digital telephone switch that has been directly integrated with a mainframe system. The NAP runs on a full range of A Series models and enables telephone companies to offer customers advanced intelligent services that require mainframe storage capacity.

The A Series processors are descendants of the B5000 introduced in the early 1960s. The A Series product family is divided into four subfamilies of processors aimed at the needs of desktop, entry-level, midrange, and large-scale commercial data-processing customers. The Micro A, a multiuser desktop system, runs on the same operating system as the other members of the A Series. Housed in a Unisys PW personal computer, the Micro A runs the same software as other A series models and can be used to test and develop applications quickly for use on larger systems. The A10x models provide midrange performance with a larger selection of peripheral connectivity. The A12, A15x, A16, A17, and A19 field-upgradable models make up the large-scale systems.

The 1100/2200 Series is positioned as an information hub in a tiered integrated information environment. The goal is to support a new generation of computer applications using client/server technology to take advantage of the various attributes of information hubs and high-powered microprocessor-based workstations (PCs).

The 1100/2200 Series is broken into four subfamilies: the 2200/100 Series, which consists of entry-level systems; the 2200/400 Series, which consists of medium-scale systems; the 2200/600 Series, which consists of large-scale systems; and the 2200/900 Series, which consists of high-end systems. The 1100/2200 Series is primarily targeted at the airline, communications, and government markets.

InfoImage Image Item Processing System/Image Check Processing System (IIPS/ICPS) is based on Unisys' V Series mainframes and DP 1800 document processors. Through the elimination of many manual steps involved in processing checks, the system allows customers to cut labor expenses while doubling the number of checks they can process each hour.

InfoImage Engineering Document Management System (EDMS) runs on Unisys' UNIX-based systems and PW workstations. The system captures large documents, such as engineering drawings and facilities diagrams, which can be displayed, edited, and distributed electronically, reducing paperwork during design review cycles.

In April 1990, Unisys unveiled InfoImage Folder, an electronic file folder management system that automates and expedites the movement of paper-based information. Electronic files are handled in the same manner as paper files: Files are organized into folders that can hold many documents, each of which can have many pages. InfoImage Folder has menu-driven programs that enable the user to define form displays, map data to and from files on mainframes and other computers in the network, develop indexing routines, and automate document distribution.

Unisys BTOS/CTOS workstations are multitasking, allowing users to execute many tasks at the same time. They offer a modular architecture and built-in LAN capabilities so that users can build LANs of workstations quickly and without incurring costs for additional equipment. These LANs can be connected to users' central mainframes without sacrificing the processing power available to individual users. There are over 850,000 BTOS/CTOS systems installed.

UNIX

The Unisys U Series are business-oriented UNIX computers that run under an implementation of AT&T's UNIX System V. These systems act as "servers" in LANs, coordinating the flow of information between large-scale mainframe systems and smaller

©1991 Dataquest Incorporated November—Reproduction Prohibited

desktop systems. The U 5000 Series is based on the Motorola 68020 processor; the U 6000/30, 50, and 55 are Intel 80386-based systems manufactured by Network Computer Group, a wholly owned subsidiary.

Early in 1990, Unisys announced a series of broadband networking systems, which include the TX3/SuperHub and TIME/LAN family systems based on fiber-distributed data interface. Through fiber-optic technology, the TIME/LAN systems offer increases in working capacity that customers need to consolidate their LANs and to support high-speed, high-bandwidth applications such as imaging and videoconferencing. The TX3/SuperHub provides 28 times the capacity of T-1 systems and offers customers platforms to build super transport backbone networks.

Unisys also markets DCP and CP families of front-end network processors, concentrators, and gateways. These systems consolidate, format, and transmit data among workstations, departmental servers, and mainframes.

UNIX systems offer users a powerful platform to perform standalone tasks as well as connect into broader cooperative networks. More than 1,000 commercial UNIX applications run on Unisys' U Series systems.

Software

Unisys offers a wide range of software packages tailored for specific industries including banking, health care, manufacturing, and airlines. By supporting standard operating systems on its platforms and maintaining relationships with third-party software developers, the company also gives its customers access to off-the-shelf applications available on the general market.

Unisys' computer-aided software engineering (CASE)/fourth-generation language (4GL) tools—the Logic and Information Network Compiler (LINC), Maintaining, Preparing, Producing Executive Reports (MAPPER), and Ally systems—automate the software development process, decreasing development time and freeing organizations to concentrate on designing new systems that solve business problems. LINC and MAPPER are available on all major Unisys product platforms. Unisys has added "upper-CASE" system design capabilities to the LINC system as well, and extended the use of its software tools to outside developers whose upper-CASE technologies are widely used throughout the industry.

Defense Systems

Mil/Aero

The Defense Systems segment provides defense electronics through five major lines: shipboard and ground systems, systems development, communications systems, system support, and computer systems. However, as stated in the "Corporate Strategic Direction" section, Unisys is in the process of divesting itself from this line of business to focus on its Commercial Information Systems and Services.

Further Information

For further information about Unisys' business segments, please contact the appropriate Dataquest industry services.

©1991 Dataquest Incorporated November—Reproduction Prohibited

Table 1
Five-Year Corporate Highlights (Millions of U.S. Dollars)

	1986	1987	1988	1989	1990
Five-Year Revenue	7,432	9,713	9,902	10,097	10,111
Percent Change	67.79	30.69	1.95	1.97	0.14
Capital Expenditure	550	836	854	811	670
Percent of Revenue	7.40	8.61	8.62	8.03	6.63
R&D Expenditure	441	597	713	782	747
Percent of Revenue	5.93	6.15	7.20	7.74	7.39
Number of Employees (K)	98	93	93	82	75
Revenue ($K)/Employee	75.84	104.44	106.47	122.69	134.81
Net Income	(248)	578	681	(639)	(437)
Percent Change	(117.32)	1,444.19	17.82	(193.88)	(31.64)

1990 Fiscal Year	Q1	Q2	Q3	Q4
Quarterly Revenue	2,306	2,471	2,400	2,934
Quarterly Profit	(3.2)	11.8	(356.8)	(88.5)

Source: Unisys Corporation
Annual Reports and Forms 10-K
Dataquest (November 1991)

Table 2
Revenue by Geographic Region (Percent)

Region	1986	1987	1988	1989	1990
North America	57.10	56.40	54.20	50.90	48.20
International	42.90	43.60	45.80	49.10	51.80

Source: Unisys Corporation
Annual Reports and Forms 10-K
Dataquest (November 1991)

©1991 Dataquest Incorporated November—Reproduction Prohibited

1990 SALES OFFICE LOCATIONS

North America—200
Europe—1 (sales subsidiary only)
Asia/Pacific—7 (sales subsidiary only)
ROW—10 (sales subsidiary only)

MANUFACTURING LOCATIONS

North America

Camarillo, California
  Air traffic control systems, custom systems, development of Thailand's centralized air defense system
Eagan, Minnesota
  Standard militarized computer products and displays, information-processing systems, Submarine Standard Operating Systems
Flemington, New Jersey
  Personal computers
Great Neck, New York
  Electronic warfare, military systems, and support systems
Mission Viejo, California
  Low-end A Series
Plymouth, Michigan
  Imaging, check reader/sorters
Rancho Bernardo, California
  Low-end A Series
Roseville, Minnesota
  2200 Series systems, military computers
Salt Lake City, Utah
  UNIX

Europe

Barcelona, Spain
  AI equipment
Villers-Ecalles, France
  Financial terminals

Asia/Pacific

Jurong, Singapore
  Terminals
Milson's Point, Australia
  Software

ROW

Veleiros, Brazil
  Low-end A Series systems

SUBSIDIARIES

North America

Convergent Inc. (United States)
Unisys Canada Inc. (Canada)
Unisys Finance Corporation (United States)
Unisys International Company (United States)

Europe

Unisys Belgium (Belgium)
Unisys Deutschland GmbH (Germany)
Unisys Espana S.A. (Spain)
Unisys France (France)
Unisys Italia S.p.A. (Italy)
Unisys Limited (United Kingdom)
Unisys Netherland N.V. (Netherlands)
Unisys (Schweiz) A.G. (Switzerland)

Asia/Pacific

Unisys Australia Limited (Australia)

ROW

Unisys Eletronica Ltda. (Brazil)

ALLIANCES, JOINT VENTURES, AND LICENSING AGREEMENTS

1991

Timeplex Inc.
  Unisys sold Timeplex Inc. to Ascom Holding AG of Switzerland. However, the companies plan to maintain joint marketing relationship.

1990

  Unisys did not participate in any alliances, joint ventures, or licensing agreements during 1990.

 ©1991 Dataquest Incorporated November—Reproduction Prohibited

1989

FileNet
FileNet signed an agreement under which FileNet will provide Unisys with its Image Access Facility software and jukeboxes.

Touche Ross
Unisys and Touche Ross have agreed to a strategic alliance to provide large-scale commercial systems integration services.

Mercedes Information Technologies (Pty) Ltd.
Unisys sold its South African marketing and sales subsidiary to Mercedes Information Technologies.

Lodgistix Inc.
The two companies have a marketing alliance that makes Lodgistix a VAR of the Unisys PW2 line of products in conjunction with its MS-DOS-based property management system and sales and catering system.

Microamerica
Unisys signed a value-added distributor agreement with Microamerica. The agreement is expected to increase Unisys sales of UNIX-based multiuser systems and PCs through the third-party channel over the next five years significantly.

Tech Data Corp.
Unisys signed a value-added distribution arrangement with Tech Data. Under the agreement, Tech Data will resell Unisys' Intel 80386-based U 6000 Series of UNIX processors and the PW2 line to its customers.

SPSS Inc.
Unisys and SPSS agreed to a strategic alliance to provide statistical and graphics software solutions on Unisys hardware.

1988

Mitsui & Co.
The two companies entered into a joint venture to form Nihon Unisys Ltd.

MERGERS AND ACQUISITIONS

1990

Unisys made no mergers or acquisitions during 1990.

1989

Unisys made no mergers or acquisitions during 1989.

1988

Convergent Inc.
Convergent, acquired by Unisys, was a leader in distributed and networking solutions.

Timeplex Inc.
Timeplex was acquired by Unisys.

KEY OFFICERS

James A. Unruh
Chairman and chief executive officer

Reto Braun
President and chief operating officer

Hugh Lynch
President, Computer Systems & Products Group

PRINCIPAL INVESTORS

Information is not publicly available.

FOUNDERS

Information is not publicly available.

©1991 Dataquest Incorporated November—Reproduction Prohibited

Table 3
Balance Sheet
Fiscal Year Ending December 31
(Millions of U.S. Dollars)

Balance Sheet	1986	1987	1988	1989	1990
Cash	56	55	26	9	403
Receivables	1,807	2,915	2,785	2,698	2,366
Marketable Securities	0	0	0	0	0
Inventory	1,952	1,856	2,484	1,761	1,458
Other Current Assets	722	508	521	615	642
Total Current Assets	4,537	5,334	5,816	5,083	4,869
Net Property, Plants	2,192	1,858	2,003	1,855	1,709
Other Assets	2,680	3,399	3,716	3,813	3,711
Total Assets	9,409	10,591	11,535	10,751	10,289
Total Current Liabilities	3,342	3,666	3,432	3,537	4,210
Long-Term Debt	2,226	2,377	3,078	3,248	2,495
Other Liabilities	13	3	70	84	99
Total Liabilities	5,581	6,046	6,580	6,869	6,804
Converted Preferred Stock	1,432	1,426	1,429	1,429	1,578
Common Stock	231	747	797	797	810
Other Equity	486	355	294	126	196
Retained Earnings	1,679	2,017	2,435	1,530	901
Total Shareholders' Equity	3,828	4,545	4,955	3,882	3,485
Total Liabilities and Shareholders' Equity	9,409	10,591	11,535	10,751	10,289

Source: Unisys Corporation
Annual Reports and Forms 10-K
Dataquest (November 1991)

©1991 Dataquest Incorporated November—Reproduction Prohibited

Table 4
Consolidated Income Statement
Fiscal Year Ending December 31
(Millions of U.S. Dollars, except Per Share Data)

Consolidated Income Statement	1986	1987	1988	1989	1990
Revenue	7,432	9,713	9,902	10,097	10,111
U.S. Revenue	4,244	5,476	5,368	5,136	4,871
Non-U.S. Revenue	3,188	4,237	4,534	4,961	5,240
Cost of Sales	5,118	5,639	5,589	6,816	6,600
R&D Expense	441	597	713	782	747
SG&A Expense	1,905	2,378	2,527	2,710	2,720
Capital Expense	550	836	854	811	670
Pretax Income	(89)	951	959	(554)	(337)
Pretax Margin (%)	(1.20)	9.79	9.68	(5.49)	(3.33)
Effective Tax Rate (%)	NA	NA	NA	NA	NA
Net Income	(43)	578	681	(639)	(437)
Shares Outstanding, Millions	138	149	159	158	162
Per Share Data					
Earnings	(0.54)	2.93	3.27	(4.71)	(3.45)
Dividend	0.87	0.91	0.98	1.00	0.50
Book Value	27.74	30.50	31.16	24.57	21.51

NA = Not available

Source: Unisys Corporation
Annual Reports and Forms 10-K
Dataquest (November 1991)

Table 5
Key Financial Ratios
Fiscal Year Ending December 31

Key Financial Ratios	1986	1987	1988	1989	1990
Liquidity					
Current (Times)	1.36	1.45	1.69	1.44	1.16
Total Assets/Equity (%)	57.26	40.88	40.42	47.78	49.04
Current Liabilities/Equity (%)	87.30	80.66	69.26	91.11	120.80
Total Liabilities/Equity (%)	145.79	133.03	132.80	176.93	195.24
Profitability (%)					
Return on Assets	(0.46)	5.46	5.90	(5.95)	(4.25)
Return on Equity	(1.12)	12.72	13.74	(16.47)	(12.54)
Profit Margin	4.93	5.95	6.88	(6.33)	(4.32)
Other Key Ratios					
R&D Spending % of Revenue	5.66	6.15	7.20	7.74	7.39
Capital Spending % of Revenue	7.40	8.61	8.62	8.03	6.63
Employees (K)	98	93	93	82	75
Revenue ($K)/Employee	75.84	104.44	106.47	122.69	134.81
Capital Spending % of Assets	5.85	7.89	7.40	7.54	6.51

Source: Unisys Corporation
Annual Reports and Forms 10-K
Dataquest (November 1991)

©1991 Dataquest Incorporated November—Reproduction Prohibited

Westinghouse Electric Corporation

Westinghouse Building, Gateway Center
Pittsburgh, Pennsylvania 15222
Telephone: (412) 244-2000
Fax: (412) 642-3404
Dun's Number: 00-134-3955

Date Founded: 1886

CORPORATE STRATEGIC DIRECTION

Western Electric Corporation is a diversified, global, technology-based corporation operating in the principal business arenas of television and radio broadcasting, defense electronics, financial services, and the industrial, construction, and electrical utility markets. Westinghouse is a leading supplier of electronic systems to the U.S. government. The company has major operations in radio and television broadcasting, financial services, transport refrigeration, franchised beverage bottling and distribution, materials for electronic and electrical applications, land and community development, and waste-to-energy and environmental services. The company also operates several government-owned facilities under contracts with the Department of Energy and other federal government departments.

In February 1991, Westinghouse's management made a major decision regarding the Westinghouse Financial Services Inc. (WFSI) and Westinghouse Credit Corporation (WCC) subsidiaries. Action was taken to downsize or liquidate certain high-risk portfolios with the intention of reducing the company's liability caused by these uncertain ventures. Traditionally, Westinghouse has held underperforming assets for long periods of time in anticipation of their eventual value. Management has decided that, with the uncertain conditions of some markets, the company would be better served by the near-term liquidation of the high-risk assets that it has in these markets. A special provision for losses of $975 million* was recorded in the fourth quarter of fiscal 1990 to deal with the loss in value of these assets. Westinghouse hopes that the change in strategy will reduce future risk and improve the company's overall financial situation.

In January 1991, Westinghouse also undertook a major reorganization, realigning its business units into seven organizational groups: Broadcasting, Electronic Systems, Environmental Systems, Financial Services, Industries, The Knoll Group, and Power Systems.

The Broadcasting segment provides a variety of communications services dealing primarily in the areas of commercial radio and television broadcasting and program production and distribution. Electronic Systems is a leader in the research, development, production, and support of advanced electronic systems for U.S. government agencies such as NASA, the FAA, and the Department of Defense. The Environmental segment, a creation of the January 1991 repositioning, includes all of Westinghouse's ventures in the treatment and disposal of hazardous, radioactive, toxic, and municipal waste. Financial Services, under the official name of Westinghouse Financial Services Inc., deals with lending, leasing, and investing activities. The Industries segment consists of a wide range of businesses that supply products in areas such as electrical distribution, protection equipment, electrical components, and transport refrigeration equipment. The Knoll Group designs, manufactures, distributes, and markets office furniture to the global market. The Power Systems segment operates in the utilities market, offering nuclear and fossil-fueled power generation systems and services, and is a leading supplier of reload nuclear fuel.

Total revenue increased by 0.6 percent to $12.9 billion in fiscal 1990 from $12.8 billion in fiscal 1989. Net income decreased 70.9 percent to $268 million in fiscal 1990 from $922 million in fiscal 1989. This decrease was a result of the previously mentioned one-time charge of $975 million against the WFSI portfolio. Without this nonrecurring charge, net income had increased 8.6 percent to $1.0 billion in 1990. Westinghouse employs 116,000 people worldwide.

*All dollar amounts are in U.S. dollars.

 ©1991 Dataquest Incorporated October—Reproduction Prohibited

R&D expenditure totaled $1.0 billion in fiscal 1990, representing 7.9 percent of revenue. Capital spending totaled $405 million in fiscal 1990, representing 3.1 percent of revenue.

More detailed information is available in Tables 1 and 2, which appear after "Business Segment Strategic Direction" and present corporate highlights and revenue by region. Information on revenue by distribution channel is not available. Tables 3 through 5, at the end of this backgrounder, present comprehensive financial information.

BUSINESS SEGMENT STRATEGIC DIRECTION

Industries

The Industries group is composed of four business units: Thermo King Corporation, Distribution and Control (D&C), Westinghouse Electric Supply Company (WESCO), and Westinghouse Communities Inc.

Thermo King Corporation is a leader in the transport temperature control business and has recently expanded internationally into Ireland, the United Kingdom, and Spain. It is negotiating ventures in China and the Soviet Union. The D&C business supplies industrial, construction, and utility markets with a line of electrical distribution products, circuit protective devices, and control products. WESCO distributes electrical products made by Westinghouse and over 5,000 other suppliers. Westinghouse Communities is a land and community real estate development company active in the West and Southeast regions of the United States.

Westinghouse's Industries group remained the largest in terms of both operating revenue and net income, bringing in $3.4 billion in sales in 1990 and netting a $342 million profit. These figures represented a decrease of 4.3 percent and an increase of 30.5 percent, respectively, over the 1989 totals.

Electronic Systems

The Electronic Systems group is a premier supplier of advanced electronic systems to the Department of Defense and other government agencies. Products include surveillance and fire control radars, command and control systems, electronic countermeasures equipment, electro-optical and spaceborne sensors, missile launching and handling equipment, torpedoes, sonar, and communications equipment. Current Westinghouse contracts with the U.S. government include defense programs such as the F-16 radar, the Airborne Warning and Control System (AWACS), radar and infrared systems for the latest tactical aircraft, and the army's Longbow weapon control system for helicopters. Dataquest estimates that Westinghouse is one of the top 10 in the 1990 military/aerospace electronic systems market.

The defense electronics industry is expected to decline slightly over the next five years, and Westinghouse is moving to expand the Electronic Systems group into the commercial market in the early 1990s. In 1990, non-Department of Defense contracts rose to 27 percent of the segment's income. The company has entered such markets as commercial surveillance systems, aircraft accessories, and information systems. In 1990, Westinghouse strengthened its leading position as a supplier of radar to the FAA by beginning production on a contract of 40 long-range ARSR-4 radars designed to improve radar coverage between U.S. airports.

The Electronic Systems group has also successfully penetrated the international market, as international sales have grown to 23 percent of the group's revenue. In 1990, the company was selected to assist Morocco, Poland, Saudi Arabia, and the Soviet Union in upgrading their air traffic control systems.

Electronic Systems' sales totaled $3.2 billion in 1990, representing an 8.4 percent increase over the 1989 total of $2.9 billion. Net income rose 67.0 percent to $329 million in 1990, up from $197 million in 1989.

Power Systems

The Power Systems group is subdivided into two divisions—Power Generation and Energy Systems.

Power Generation saw a 50 percent increase in sales in 1990, reflecting both increasing energy needs and Westinghouse's victories on a number of major contracts. The Power Generation business works on power supply projects and operating plant service segments, serving independent power producers as well as traditional utility customers. Westinghouse's achievements in 1990 include the winning of the year's largest order for a coal-fired power plant; participation in the world's largest independent power project in England; and the production of superconducting magnets for the Department of Energy's Superconducting Super Collider in Texas.

©1991 Dataquest Incorporated October—Reproduction Prohibited

Energy Systems deals with the areas of nuclear power maintenance, process control systems, solar energy, and power plant design. In 1990, the company won an $80 million contract with the Department of Energy and the Electric Power Research Institute to complete the design of the AP600, a new reactor. Westinghouse also supplied products and maintenance to every operating nuclear power plant in the United States, winning 23 contracts in 1990 valued at over $100 million. The Power Systems group also strengthened its global presence by signing a contract with Skoda, a Czechoslovakian electrical equipment manufacturer, to serve as partners in both the Czech and global nuclear power markets.

Power Systems revenue increased 22.1 percent to $2.4 billion in 1990, while net income increased 58.3 percent to $323 million.

Environmental

The Environmental group was only recently created in the company's realignment of January 1991, but Westinghouse has been operating in the environmental market as an established leader for years. The group operates in the handling of a variety of nuclear, industrial, and municipal wastes and is active in the research and development of innovative waste-to-energy systems. The company owns the only privately held incinerator for nuclear commercial use and is active in six Department of Energy radioactive and hazardous waste sites.

Environmental's revenue totaled $1.3 billion in 1990, increasing 10.3 percent over the 1989 figure of $1.2 billion. Net income nearly doubled in 1990, rising 94.9 percent to $154 million.

Financial Services

As previously mentioned, WFSI and WCC experienced a difficult year in 1990. The major strategic redirection and downsizing that occurred in February 1991 resulted in a $975 million charge against fourth quarter earnings. As a result of the downsizing, the company is exiting the high-yield securities business and will concentrate on corporate lending, commercial and residential real estate financing, and leasing.

Revenue for Financial Services increased 13.5 percent to $1.2 billion in 1990, but as a result of the one-time restructuring charge net income decreased 614.6 percent to a net loss of $844 million in 1990.

Broadcasting

Westinghouse Broadcasting Company (Group W) provides a variety of communications services, primarily focusing on commercial broadcasting and program production and distribution. Group W currently operates the largest nonnetwork radio organization in the United States with 20 radio stations, the major markets located in New York, Los Angeles, and Philadelphia. Group W also operates 5 VHF television stations located in Baltimore, Boston, Philadelphia, Pittsburgh, and San Francisco, with local news the stations' strongest feature. Group W Satellite Communications remained active in the cable television market, with The Nashville Network (TNN) remaining one of the most successful ventures in cable television. Group W also syndicates the animated series "Teenage Mutant Ninja Turtles," which garnered the highest ratings for an animated show in 1990.

Group W's sales increased 13.6 percent in 1990, rising to $858 million from the 1989 figure of $755 million. Net income rose to $186 million in 1990, rising 46.5 percent from $127 million in 1989.

The Knoll Group

Formed in January 1991, The Knoll Group represents a new venture on the part of Westinghouse, entering the office furniture market seriously for the first time. The group was formed following the company's acquisition of Knoll International, a firmly established design company. Westinghouse also recently acquired Shaw-Walker Co., a metalworking company, and Reff Inc., a woodworking company. These three companies combine with Westinghouse's Furniture Systems division to tackle an industry that has been growing at an average rate of 8 to 10 percent a year.

Further Information

For more information about the company's business segments, please contact Dataquest's MilAero Technology service.

 ©1991 Dataquest Incorporated October—Reproduction Prohibited

Table 1
Five-Year Corporate Highlights (Millions of U.S. Dollars)

	1986	1987	1988	1989	1990
Five-Year Revenue	11,370.1	11,332.0	12,499.5	12,844.0	12,915.0
Percent Change	6.26	(0.34)	10.30	2.76	0.55
Capital Expenditure	441.8	419.9	421.8	424.0	401.0
Percent of Revenue	3.89	3.71	3.37	3.30	3.10
R&D Expenditure	917.8	808.3	706.0	769.0	1,015.0
Percent of Revenue	8.07	7.13	5.65	5.99	7.86
Number of Employees	117,267	112,478	119,640	122,000	116,000
Revenue ($K)/Employee	96.96	100.75	104.48	105.28	111.34
Net Income	172.9	900.5	822.8	922.0	268.0
Percent Change	(71.09)	420.82	(8.63)	12.06	(70.93)

1990 Fiscal Year	Q1	Q2	Q3	Q4
Quarterly Revenue	2,862.00	3,175.00	3,175.00	3,703.00
Quarterly Profit	210.00	252.00	255.00	(499.00)

Source: Westinghouse Electric Corporation
Annual Reports and Forms 10-K
Dataquest (October 1991)

Table 2
Revenue by Geographic Region (Percent)

Region	1986	1987	1988	1989	1990
North America	91.80	90.23	89.43	88.02	87.95
International	8.20	9.77	10.57	11.98	12.05

Source: Westinghouse Electric Corporation
Annual Reports and Forms 10-K
Dataquest (October 1991)

©1991 Dataquest Incorporated October—Reproduction Prohibited

1990 SALES OFFICE LOCATIONS

Information is not available.

MANUFACTURING LOCATIONS

North America

Aerospace Division, Defense and Electronics Center, Baltimore, Maryland

Avionics Division production and development activities include the APQ-66, -68, and -78 fire control radars for the F-16 and upgraded F-4; the APQ-164 offensive radar system for the B-1 bomber; the Ultra Reliable Radar (URR) program; the Small Aerostat Surveillance System (SASS); and avionics upgrade programs.

Electronic Warfare Division production and development activities include the ALQ-131 electronic countermeasure pod for the F-16, F-14, F-111, and other aircraft; development and production of the ALQ-165 Airborne Self-Protection Jammer (ASPJ) with ITT; ALQ-153 Tail Warning System for the B-52; and risk reduction studies and hardware for the Integrated Electronic Warfare System (INEWS) with TRW.

Command and Control Divisions, Defense and Electronics Center, Baltimore, Maryland

Surveillance Radar Division production and development activities include FPS-700 configuration of the TPS-70, the TPS-70 and TPS-75 tactical 3-D radars, the TPS-63/65 tactical 2-D radar, the vigilant family of tactical medium-range radars, the W-160 and SPS-65(V) shipboard surveillance and fire control radars, the SPS-40 radar solid-state transmitter, Advanced Missile Surveillance Radar (AMSR) and Multi-role Survivable Radar (MRSR) for the army, W-160 multifunctional naval fire control radar, and SPS-58/65 for naval point defense.

Systems and Airborne Surveillance Division production and development activities include airborne surveillance radars for U.S. and foreign E-3 Sentry (AWACS) aircraft, air traffic control systems for international customers, AP4-2 (AWACS) radar, and tactical and fixed air defense systems.

Communication Division production and development activities include TACAMO strategic communications programs; the Tethered Aerostat Antenna program; HF transmitters and multicouplers for shipboard communications; development of VHF and UHF systems by Xetron Company, a subsidiary; the mobile (Aerostat-Augmented) VLF/LF communications system; satellite services; and Voice Communication (VOCOM) systems.

Development and Operation Division, Defense and Electronics Center, Baltimore, Maryland

Space Division production and development activities include key synthetic aperture radar elements for SEASAT and SIR-A shuttle imaging radar; and Earth observation centers, which include infrared and visible primary data acquisition systems and data processors for the Defense Meteorological Satellite Program. The Space Division is the central headquarters for the Westinghouse SDI team.

Development and Engineering Division production and development activities include multisensor systems, advanced radar, electronic warfare, computer and signal processing, electro-optical systems and communications development; the Aquila remotely piloted vehicle payload; the Harpoon computer; Multi-role Survivable Radar; the Integrated Electronic Warfare System; and next-generation radar for the Advanced Tactical Radar.

Advanced Technology Division production and development activities include semiconductor and microwave devices and subsystems, very high-speed integrated circuits, gallium arsenide activities, acoustic optics charge-coupled devices, and visual and infrared sensors.

Design and Producibility Engineering Division activities encompass the design aspects of Digital Equipment Corporation (DEC) production hardware, including performance, quality, reliability, maintainability, standardization, design-to-cost, and value engineering for both hardware and software.

Manufacturing Operations Division responsibilities are the production of DEC systems including radar, electro-optical, communications, electronic warfare, battlefield electronics, signal processing systems and computers, and missile guidance and warning systems.

©1991 Dataquest Incorporated October—Reproduction Prohibited

Missile Systems Department responsibilities are advanced technological insertion and development of new missile systems with primary technological emphasis on multispectral seeker development and integration with fire control systems.

Electrical Systems Division, Lima, Ohio
This division designs and produces electrical generating equipment for commercial and military aircraft, including the variable speed constant frequency (VSCF) main electrical system for the AV-8B aircraft, the F-5G, and the auxiliary (VSCF) power system for the F-16. It also provides the primary electrical system for the F-16, B-1B, and M-1 battle tanks; specialty AC and DC motor systems for military applications; microprocessor-based surveillance systems for nuclear power plants; solid-state power controllers; and power conditioning equipment for the Space Shuttle and Space Station.

Integrated Logistics Support Divisions, Hunt Valley, Maryland
The Aerospace Logistics Support Division provides logistic support and services for aerospace avionics products such as the F-16 and B-1B radars, the ALQ-131 and ASPJ electronic countermeasures systems, and electro-optical systems.

The Command and Control Logistics Support Division provides worldwide logistics support and services for Westinghouse surveillance radars (TPS-43, TPS-63, TPS-70, Vigilant), air traffic control radars (ARSR-3, ASR-9), communications systems (TACAMO, LF/VLF Strategic and Civil Defense System, Wideband HF, VOCOM), airborne surveillance and control systems (E3-A AWACS), ship systems, air defense systems, and communications systems.

Marine Division, Sunnyvale, California
This division produces the capsule launcher subsystem for vertical launch of the Tomahawk Cruise Missile, the canister launching system for the Peacekeeper missile, and Trident missile launchers. It designs, manufactures, and supports U.S. Navy ship propulsion turbines and reduction gears and ships service turbine generator sets. Electromagnetic launcher (EML) technology development is being performed to support the Strategic Defense Initiative (SDI) and tactical weapons development.

Plant Apparatus Division, Wilkins Township, Pennsylvania
Production of naval nuclear reactor plant components is the responsibility of this division.

The Defense and Electronics Systems Company, Defense and Electronics Center, Baltimore, Maryland
This center provides the total management for the integration and delivery of complex technology systems. It supports a number of aerostat programs including the U.S. Customs CARIBALL and SOWRBALL programs and the Saudi Arabian Low Altitude Surveillance System (LASS). It also provides ongoing support for both the U.S. Naval Airship and NATO Frigate Programs.

The Oceanic Division, Annapolis, Maryland
Production and development activities of this division include undersea technology for the navy. Advanced acoustic, underwater vehicle, and information processing capability is being applied to meet defense needs for torpedoes, ASW systems, mine hunting, deep ocean search, and magnetic silencing. These projects include the AQS-14 mine-hunting sonar system; an acoustic transducer array for the MK48 advanced capability (ADCAP) torpedo; the SQQ-89 Ship ASW Combat System; development of the MK50 lightweight torpedo program with Honeywell; and submarine wide-aperture, hull-mounted sonar arrays.

Westinghouse Airship Industries, Baltimore, Maryland
This company, a joint venture with Airship Industries Ltd., is building a prototype of a new military blimp for the navy.

SUBSIDIARIES

North America

Challenger Electrical Equipment Corp. (United States)
Fortin Industries Inc. (United States)
Gladwin Corp. (United States)
Hittman Nuclear and Development Corp. (United States)
Longines-Wittnauer (United States)
Reff Inc. (United States)
Shaw Walker Co. (United States)

 ©1991 Dataquest Incorporated October—Reproduction Prohibited

TSC Inc. (United States)
Thermo King Corp. (United States)
Tinicum Inc. (United States)
Westinghouse Beverage Group Inc. (United States)
Westinghouse Broadcasting Co. Inc. (United States)
Westinghouse Canada Inc. (Canada)
Westinghouse Communities Inc. (United States)
Westinghouse Credit Corporation (United States)
Westinghouse Environmental and Geotechnical Services Inc.
Westinghouse Financial Services Inc. (United States)
Westinghouse International Technology Corp. (United States)
Westinghouse Overseas Service Corp. (United States)
Westinghouse Savannah River Co. Inc. (United States)
Xetron Corp. (United States)

Europe

Westinghouse Electric S.A. (Switzerland)
Westinghouse Fanal Schaltgerate GmbH (Germany)

ROW

Tyree Industries Ltd. (Australia)
Westinghouse de Puerto Rico Inc. (Puerto Rico)
Westinghouse Foreign Sales Corp. (Barbados)
Westinghouse Foreign Sales Corp. (Virgin Islands)

ALLIANCES, JOINT VENTURES, AND LICENSING AGREEMENTS

1991

Mitsubishi Electric Corporation

Westinghouse and Mitsubishi Electric signed a 10-year agreement to jointly develop advanced technologies for nuclear and thermal power generators.

Smart House, L.P.

Westinghouse signed a licensing agreement with the National Association of Home Builders' Smart House, L.P., for electronic security systems.

1990

Digital Equipment Corporation

Westinghouse's Perceptics Corporation signed an agreement with Digital Equipment Corporation, making it possible for DEC to sell Perceptics' optical storage subsystems.

Mitsubishi Heavy Industries

Westinghouse and Mitsubishi Heavy Industries entered into a joint development agreement under which the two companies will jointly develop large-capacity nuclear power reactors.

Skoda

Westinghouse entered into a cooperative agreement with Skoda, a Czechoslovakian state-owned engineering group. The agreement provides both parties with more access to the international power systems markets.

1989

ASEA Brown Boveri (ABB)

Westinghouse and ASEA Brown Boveri (ABB) formed a joint venture to supply nuclear services to Europe's electrical power industry. The joint venture will bring together Westinghouse's knowledge of pressurized water reactors and ABB's expertise in boiling water reactors.

Dravo Automation Sciences Inc. (DAS)

Westinghouse and DAS entered into a licensing agreement under which DAS will have exclusive worldwide license to manufacture and sell all products, technology, and services previously provided by Westinghouse's Voice System Division. DAS is a major systems integrator in the discrete manufacturing and process industries.

Mitsubishi Heavy Industries

Westinghouse and Mitsubishi Heavy Industries entered into a cooperative technology development, sourcing, and business agreement to enhance the steam turbine technology bases of each corporation. The agreement provides for exchanging existing steam turbine technology and cooperatively developing new steam turbine technology for the worldwide power generation market.

Tandem Computer

Westinghouse and Tandem Computer entered into a joint venture to design and market systems integration products and services. The two companies will also offer applications re-engineering and software development support services to the aerospace, electronics, and manufacturing industries. In addition, they will design and market computer systems.

 ©1991 Dataquest Incorporated October—Reproduction Prohibited

MERGERS AND ACQUISITIONS

1991

Schlage Electronics Co.
Westinghouse acquired Schlage Electronics, a producer of high-technology security systems.

1990

Airship Industries
Westinghouse, along with Airship International and Slingsby Aviation, have purchased the assets of Airship Industries. Westinghouse has taken over the marketing and intellectual property rights to the military versions of the Skyship 500, 500HL, and 600 designs.

Innovative Computing Corporation
Westinghouse acquired Innovative Computing Corporation (ICC), a leader in management systems for the trucking industry. The move signifies Westinghouse's attempt to move into the nonmilitary electronics market.

1989

Blindex Brown Boveri Electronica S.A.
Westinghouse acquired Blindex Brown Boveri Electronica, a Brazilian manufacturer of pilot and logic devices used in motor control centers.

Legacy and Metropolitan Broadcasting Companies
Westinghouse acquired the Legacy and Metropolitan Broadcasting Companies for $369 million.

KEY OFFICERS

Paul E. Lego
Chairman and chief executive officer

Theodore Stern
Senior executive vice president

Gary M. Clark
Senior vice president, Industries and Corporate Resources

George C. Dorman
Senior vice president, Human Resources and Total Quality

Warren H. Hollinshead
Senior vice president, Finance

Richard A. Linder
Senior vice president, Electronic Systems

Anthony A. Massaro, Jr.
Senior vice president, Environmental Systems

Robert F. Pugliese
Senior vice president, Legal and Corporate Affairs

John B. Yasinsky
Senior vice president, Power Systems

William A. Powe
Chairman, Westinghouse Financial Services

Maurice C. Sardi
Chairman, The Knoll Group Inc.

Burton B. Stanlar
Chairman, Westinghouse Broadcasting Company Inc.

PRINCIPAL INVESTORS

Citibank

FOUNDERS

Information is not available.

©1991 Dataquest Incorporated October—Reproduction Prohibited

Table 3
Balance Sheet
Fiscal Year Ending in December
(Millions of U.S. Dollars)

Balance Sheet	1986	1987[1]	1988[1]	1989	1990
Cash	163.1	615.4	295.0	466.0	492.0
Receivables	1,905.2	7,175.0	8,582.0	9,825.0	9,337.0
Marketable Securities	434.4	1,586.7	1,409.0	1,815.0	1,031.0
Inventory	1,161.6	1,237.5	1,300.0	1,354.0	1,249.0
Other Current Assets	971.0	915.1	1,572.0	2,115.0	4,890.0
Total Current Assets	4,635.3	11,529.7	13,158.0	15,575.0	16,999.0
Net Property, Plants	2,188.7	2,337.0	2,495.0	2,381.0	2,506.0
Other Assets	1,657.8	1,328.9	1,284.0	2,358.0	2,528.0
Total Assets	8,481.8	15,195.6	16,937.0	20,314.0	22,033.0
Total Current Liabilities	4,196.4	4,898.4	8,541.0	9,791.0	9,271.0
Long-Term Debt	518.2	823.3	4,042.0	4,365.0	6,091.0
Other Liabilities	734.0	6,231.0	538.0	1,603.0	2,603.0
Total Liabilities	5,448.6	11,952.7	13,121.0	15,759.0	17,965.0
Common Stock	183.1	183.4	183.0	184.0	370.0
Other Equity	769.2	762.2	(1,025.0)	795.0	(1,574.0)
Retained Earnings	2,080.9	2,297.3	4,637.0	3,405.0	5,101.0
Total Shareholders' Equity	3,033.2	3,242.9	3,816.0[2]	4,555.0[2]	4,068.0
Total Liabilities and Shareholders' Equity	8,481.8	15,195.6	16,937.0	20,314.0	22,033.0

[1]Numbers have been restated.
[2]Numbers include minority interest.

Source: Westinghouse Electric Corporation
Annual Reports and Forms 10-K
Dataquest (October 1991)

©1991 Dataquest Incorporated October—Reproduction Prohibited

Table 4
Consolidated Income Statement
Fiscal Year Ending in December
(Millions of U.S. Dollars, except Per Share Data)

Consolidated Income Statement	1986	1987[1]	1988[1]	1989	1990
Revenue	11,370.1	11,332.0	12,499.5	12,844.0	12,915.0
U.S. Revenue	10,438.3	10,224.7	11,178.8	11,305.0	11,359.0
Non-U.S. Revenue	931.8	1,107.3	1,320.7	1,539.0	1,556.0
Cost of Sales	8,261.3	8,249.0	9,101.8	9,289.0	10,215.0
R&D Expense	917.8	808.3	706.0	769.0	1,015.0
SG&A Expense	1,795.1	1,683.8	1,829.5	1,810.0	1,835.0
Capital Expense	441.8	419.9	421.8	424.0	401.0
Pretax Income	792.3	1,047.5	1,065.5	1,275.0	428.0
Pretax Margin (%)	6.97	9.24	8.52	9.93	3.31
Effective Tax Rate (%)	78.00	14.10	22.80	26.70	33.60
Net Income	172.9	900.5	822.8	922.0	268.0
Shares Outstanding, Millions	304.7	290.4	291.1	292.5	293.6
Per Share Data					
Earnings	0.58	3.12	2.83	3.15	0.91
Dividend	0.67	0.82	0.96	1.15	1.35
Book Value	9.95	11.17	13.11	15.57	13.86

[1]Numbers have been restated.

Source: Westinghouse Electric Corporation
Annual Reports and Forms 10-K
Dataquest (October 1991)

Table 5
Key Financial Ratios
Fiscal Year Ending in December

Key Financial Ratios	1986	1987[1]	1988[1]	1989	1990
Liquidity					
Current (Times)	1.10	2.35	1.54	1.59	1.83
Total Assets/Equity (%)	279.63	468.58	443.87	445.97	541.62
Current Liabilities/Equity (%)	138.35	151.05	223.82	214.95	227.90
Total Liabilities/Equity (%)	179.63	368.58	343.84	345.97	441.62
Profitability (%)					
Return on Assets	2.04	5.93	4.86	4.54	1.22
Return on Equity	5.70	27.77	21.56	20.24	6.59
Profit Margin	1.52	7.95	6.58	7.18	2.08
Other Key Ratios					
R&D Spending % of Revenue	8.07	7.13	5.65	5.99	7.86
Capital Spending % of Revenue	3.89	3.71	3.37	3.30	3.10
Employees	117,267	112,478	119,640	122,000	116,000
Revenue ($K)/Employee	96.96	100.75	104.48	105.28	111.34
Capital Spending % of Assets	5.21	2.76	2.49	2.09	1.82

[1]Numbers have been restated.

Source: Westinghouse Electric Corporation
Annual Reports and Forms 10-K
Dataquest (October 1991)

©1991 Dataquest Incorporated October—Reproduction Prohibited

The Boeing Company

COMPANY DIRECTIONS

The Boeing Company is increasing its place in key government markets by acquiring significant new military and space contracts such as the weapon control system for the Small Intercontinental Ballistic Missile (SICBM), V-22 Osprey, P-3 Avionics Update, Avenger air-defense system, SRAM II, and Space Station. These programs allow Boeing to further its association with all branches of the Department of Defense and mark the Company's return to an important position in civilian space programs. Boeing's emphasis will be to perform well on these new programs to bring the Company to full potential. Boeing is investing heavily to improve productivity by building new facilities and training its employees in techniques to improve efficiency.

By September 1988, the total value of Boeing's commercial air transport orders ($20.3 billion) had already surpassed 1987's record high of $20.2 billion orders. Boeing's latest air transport model, the 747-400, successfully completed a test flight in July 1988, carrying a record gross weight of 892,450 pounds. The 747-400, with expected deliveries in 1991, is identical in size to the 747-300 and incorporates advanced technology throughout. It includes a two-crew flight deck similar to those on the 757 and 767, a digital flight management system, lightweight materials, improved aerodynamics in the wing design, new fuel-efficient engines, and a highly adaptable and modernized passenger cabin with greatly improved storage capacity.

In June 1987, Boeing acquired ARGOSystems, a defense electronics firm involved with communications reconnaissance equipment, electronic warfare equipment, and studies and systems engineering in signal processing. The $275 million acquisition has helped to increase Boeing's presence in the national and international military electronics marketplace.

In the third quarter of 1987, Boeing announced that it was postponing the proposed advanced technology 7J7 program because market indicators continued to present differing requirements on airplane size and configuration. Product development efforts were refocused to concentrate on technological advancements that could be used on a new medium-size jet transport or could be used to make improvements on the current family of airplanes.

Boeing recently has formed a new operating division located in Seattle—Boeing Advanced Systems Company. This division's role is to focus resources on key developments in advanced military fixed-wing aircraft and systems technology activities. The Advanced Tactical Fighter (ATF) is the most notable program located in this division.

Boeing began the design of a $50 million missile component plant in Oak Ridge, Tennessee. The plant is expected to serve as a pilot plant for Boeing automation programs. The plant will utilize advanced computerized output technology such as generic cell controls to automatically record and transfer measurement data.

In early 1988, Boeing entered the telecommunications hardware market with a product to support special services telephone lines. The Company is also conducting research on semiconductor physics, sensors, information processing, secure

© 1989 Dataquest Incorporated March

communications, and space-electrical power for future company product growth. Boeing's High Technology Center has already developed thin-film, solar-cell technology with potential applications in many space programs.

In 1987, the Boeing 360, a company-funded research helicopter, made its first flight. The Model 360 was designed to help prove advanced technologies being used in other rotorcraft programs. The helicopter is the world's largest composite helicopter and the first aircraft to employ a glass cockpit in which cathode-ray tubes (CRTs) are used to display flight control, navigation, and engine and crew-alerting information electronically.

FINANCIAL INFORMATION

Although the overall company backlog rose to a record high of $33.2 billion in 1987, U.S. government backlog actually dropped slightly to $6.2 billion (see Table 1). As of June 1988, overall backlog was already close to the $40 billion level with U.S. government backlog accounting for 18 percent or $7 billion. Sales for the first half of 1988 were $8,322 million, significantly more promising than last year's comparable figure of $7,241 million. On the other hand, U.S. government and foreign military sales in the first half of 1988 totaled $2.4 billion, $0.2 billion lower than the comparable period of 1987. Company net earnings in 1987 dropped 28 percent to $480 million partly due to increased research and development, product improvements, and a high level of production costs. The level of expenditure for research and development is expected to have been lower in 1988.

Table 1

The Boeing Company
Financial Information

	1987	1986	1985
Mil/Aero Electronic Revenue ($M)	$ 1,514	$ 1,305	$ 1,076
Total Revenue ($M)	$15,813	$16,748	$13,745
Company R&D Expense ($M)	$ 824	$ 757	$ 409
Capital Expenditure ($M)	$ 388	$ 438	$ 281
Dollar Value of Contracts Awarded ($M)	$ 3,719	$ 3,529	$ 5,462
Return on Sales ($M)	$ 0.04	$ 0.06	$ 0.06
Company-Funded Backlog ($B)	$ 33.2	$ 26.4	$ 24.7
Government-Funded Backlog ($B)	$ 6.2	$ 6.3	$ 6.1

Source: The Boeing Company Annual Report
U.S. Department of Defense
Prudential-Bache

© 1989 Dataquest Incorporated March

The Boeing Company

In 1987, Boeing had an estimated 68 percent of the commercial transport aircraft market shares. By the end of the 1988 third quarter, Boeing had at least 119 orders for the Boeing 757s, 351 orders for 737s, 47 orders for 747s, and 57 orders for 767s (see Table 2).

Table 2

The Boeing Company
Aircraft Unit Backlog Orders

Model	1988 Third-Quarter Estimate	1987	1986
737	351	445	423
747	47	148	102
757	119	85	79
767	57	75	55
Total	574	753	659

Source: The Boeing Company Annual Report

DIVISIONS/SUBSIDIARIES

The Boeing Company is divided into nine principal divisions. Five of these—Boeing Aerospace, Boeing Advanced Systems, Boeing Electronics, Boeing Helicopters, and Boeing Military Airplanes—are involved with military/aerospace contracts (see Table 3).

© 1989 Dataquest Incorporated March

Table 3

The Boeing Company
Operations

Location	Number of Employees	Equipment
The Boeing Company Seattle, WA (Parent)	125,980	Headquarters
ARGOSystems, Inc. Sunnyvale, CA	1,064	Communications reconnaissance equipment
Boeing Aerospace Seattle, WA	18,000	ICBM missiles, tactical missiles, contract research and development services, ground-based defense and information systems, space booster solid fuel propulsion systems
Boeing Electronics Seattle, WA	5,470	Automated avionics and missile test equipment, multi-layered circuit boards electronics digital controllers, CSEU (control systems electronics), FSEU (flap-sat electronics unit), WEU (warnings electronics unit), power supplies, embedded processors, thick- and thin-film hybrid circuits
Boeing Military Airplane Company Wichita, KS	N/A	Cruise missile integration systems for the B-52 bomber, military training systems, re-engining services for the KC-135 tanker, unpiloted aircraft systems, offensive avionics systems for the B-1B bomber
Boeing Mississippi, Inc. Greenville, MS	315	Defense/government services, transportation services
Boeing Vertol Company Philadelphia, PA	N/A	Model CH-47 military helicopter, model 234 commercial helicopter, commercial passenger and cargo aircraft
Huntsville Division Huntsville, AL	2,000	Combat simulation systems, training range equipment, computerization consulting services, applications/systems software programming services, communication network consulting and management services

Other Divisions/Subsidiaries

Boeing Commercial Airplane Co.--Seattle, WA
Boeing Computer Services Co.--Bellevue, WA
Boeing Louisiana, Inc.--Lake Charles, LA
Boeing Technology Services--Greenville, MS

N/A = Not Available

Source: Dataquest
March 1989

© 1989 Dataquest Incorporated March

The Boeing Company

COMPANY DIRECTIONS

The Boeing Company is increasing its place in key government markets by acquiring significant new military and space contracts such as the weapon control system for the Small Intercontinental Ballistic Missile (SICBM), V-22 Osprey, P-3 Avionics Update, Avenger air-defense system, SRAM II, and Space Station. These programs allow Boeing to further its association with all branches of the Department of Defense and mark the Company's return to an important position in civilian space programs. Boeing's emphasis will be to perform well on these new programs to bring the Company to full potential. Boeing is investing heavily to improve productivity by building new facilities and training its employees in techniques to improve efficiency.

By September 1988, the total value of Boeing's commercial air transport orders ($20.3 billion) had already surpassed 1987's record high of $20.2 billion orders. Boeing's latest air transport model, the 747-400, successfully completed a test flight in July 1988, carrying a record gross weight of 892,450 pounds. The 747-400, with expected deliveries in 1991, is identical in size to the 747-300 and incorporates advanced technology throughout. It includes a two-crew flight deck similar to those on the 757 and 767, a digital flight management system, lightweight materials, improved aerodynamics in the wing design, new fuel-efficient engines, and a highly adaptable and modernized passenger cabin with greatly improved storage capacity.

In June 1987, Boeing acquired ARGOSystems, a defense electronics firm involved with communications reconnaissance equipment, electronic warfare equipment, and studies and systems engineering in signal processing. The $275 million acquisition has helped to increase Boeing's presence in the national and international military electronics marketplace.

In the third quarter of 1987, Boeing announced that it was postponing the proposed advanced technology 7J7 program because market indicators continued to present differing requirements on airplane size and configuration. Product development efforts were refocused to concentrate on technological advancements that could be used on a new medium-size jet transport or could be used to make improvements on the current family of airplanes.

Boeing recently has formed a new operating division located in Seattle—Boeing Advanced Systems Company. This division's role is to focus resources on key developments in advanced military fixed-wing aircraft and systems technology activities. The Advanced Tactical Fighter (ATF) is the most notable program located in this division.

Boeing began the design of a $50 million missile component plant in Oak Ridge, Tennessee. The plant is expected to serve as a pilot plant for Boeing automation programs. The plant will utilize advanced computerized output technology such as generic cell controls to automatically record and transfer measurement data.

In early 1988, Boeing entered the telecommunications hardware market with a product to support special services telephone lines. The Company is also conducting research on semiconductor physics, sensors, information processing, secure

© 1989 Dataquest Incorporated March

communications, and space-electrical power for future company product growth. Boeing's High Technology Center has already developed thin-film, solar-cell technology with potential applications in many space programs.

In 1987, the Boeing 360, a company-funded research helicopter, made its first flight. The Model 360 was designed to help prove advanced technologies being used in other rotorcraft programs. The helicopter is the world's largest composite helicopter and the first aircraft to employ a glass cockpit in which cathode-ray tubes (CRTs) are used to display flight control, navigation, and engine and crew-alerting information electronically.

FINANCIAL INFORMATION

Although the overall company backlog rose to a record high of $33.2 billion in 1987, U.S. government backlog actually dropped slightly to $6.2 billion (see Table 1). As of June 1988, overall backlog was already close to the $40 billion level with U.S. government backlog accounting for 18 percent or $7 billion. Sales for the first half of 1988 were $8,322 million, significantly more promising than last year's comparable figure of $7,241 million. On the other hand, U.S. government and foreign military sales in the first half of 1988 totaled $2.4 billion, $0.2 billion lower than the comparable period of 1987. Company net earnings in 1987 dropped 28 percent to $480 million partly due to increased research and development, product improvements, and a high level of production costs. The level of expenditure for research and development is expected to have been lower in 1988.

Table 1

The Boeing Company
Financial Information

	1987	1986	1985
Mil/Aero Electronic Revenue ($M)	$ 1,514	$ 1,305	$ 1,076
Total Revenue ($M)	$15,813	$16,748	$13,745
Company R&D Expense ($M)	$ 824	$ 757	$ 409
Capital Expenditure ($M)	$ 388	$ 438	$ 281
Dollar Value of Contracts Awarded ($M)	$ 3,719	$ 3,529	$ 5,462
Return on Sales ($M)	$ 0.04	$ 0.06	$ 0.06
Company-Funded Backlog ($B)	$ 33.2	$ 26.4	$ 24.7
Government-Funded Backlog ($B)	$ 6.2	$ 6.3	$ 6.1

Source: The Boeing Company Annual Report
U.S. Department of Defense
Prudential-Bache

© 1989 Dataquest Incorporated March

The Boeing Company

In 1987, Boeing had an estimated 68 percent of the commercial transport aircraft market shares. By the end of the 1988 third quarter, Boeing had at least 119 orders for the Boeing 757s, 351 orders for 737s, 47 orders for 747s, and 57 orders for 767s (see Table 2).

Table 2

The Boeing Company
Aircraft Unit Backlog Orders

Model	1988 Third-Quarter Estimate	1987	1986
737	351	445	423
747	47	148	102
757	119	85	79
767	57	75	55
Total	574	753	659

Source: The Boeing Company Annual Report

DIVISIONS/SUBSIDIARIES

The Boeing Company is divided into nine principal divisions. Five of these—Boeing Aerospace, Boeing Advanced Systems, Boeing Electronics, Boeing Helicopters, and Boeing Military Airplanes—are involved with military/aerospace contracts (see Table 3).

© 1989 Dataquest Incorporated March

Table 3

The Boeing Company Operations

Location	Number of Employees	Equipment
The Boeing Company Seattle, WA (Parent)	125,980	Headquarters
ARGOSystems, Inc. Sunnyvale, CA	1,064	Communications reconnaissance equipment
Boeing Aerospace Seattle, WA	18,000	ICBM missiles, tactical missiles, contract research and development services, ground-based defense and information systems, space booster solid fuel propulsion systems
Boeing Electronics Seattle, WA	5,470	Automated avionics and missile test equipment, multi-layered circuit boards electronics digital controllers, CSEU (control systems electronics), FSEU (flap-sat electronics unit), WEU (warnings electronics unit), power supplies, embedded processors, thick- and thin-film hybrid circuits
Boeing Military Airplane Company Wichita, KS	N/A	Cruise missile integration systems for the B-52 bomber, military training systems, re-engining services for the KC-135 tanker, unpiloted aircraft systems, offensive avionics systems for the B-1B bomber
Boeing Mississippi, Inc. Greenville, MS	315	Defense/government services, transportation services
Boeing Vertol Company Philadelphia, PA	N/A	Model CH-47 military helicopter, model 234 commercial helicopter, commercial passenger and cargo aircraft
Huntsville Division Huntsville, AL	2,000	Combat simulation systems, training range equipment, computerization consulting services, applications/systems software programming services, communication network consulting and management services

Other Divisions/Subsidiaries

Boeing Commercial Airplane Co.--Seattle, WA
Boeing Computer Services Co.--Bellevue, WA
Boeing Louisiana, Inc.--Lake Charles, LA
Boeing Technology Services--Greenville, MS

N/A = Not Available

Source: Dataquest
March 1989

© 1989 Dataquest Incorporated March

The Boeing Company

CONTRACT ACTIVITY

Boeing has been chosen to create the Weapon Control System for the Small Intercontinental Ballistic Missile (SICBM), to develop launch control centers for the SICBM, and to integrate the electronics for the SICBM's hard mobile launchers. The Company also received a $236 million contract to develop the air force rail-garrison basing system for the MX Missile.

Boeing received a $1.6 billion contract from Great Britain and France to supply six AWACS aircraft beginning in 1991. The Boeing Aerospace Division also received a $240 million contract in fiscal year 1987 to upgrade the air force's E-3 AWACS. The improvement includes adding electronic support measure detection systems and enhancements in communications, data processing, and navigation systems.

Along with Lockheed and General Dynamics, Boeing won a $691 million contract to develop a prototype of the air force advanced tactical fighter (ATF YF-22A). Boeing is responsible for developing the wing and aft sections of the fuselage; installing the engines, nozzles, and auxiliary power unit; and providing an avionics ground prototype and flying testbed utilizing a 757.

Under a $244 million contract, Boeing is developing a modernized antisubmarine warfare system (ASW) and system avionics for the P-3C fleet and the Long Range Air ASW Capable Aircraft. A prototype P-3 will be delivered to the navy for evaluation in 1990. Additional options could extend the P-3 avionics program more than 10 years.

Boeing is the lead contractor for the B-1B bomber offensive avionics and is building flight simulators for the bomber. Boeing also will supply a flight control computer for the Short Range Attack Missile (SRAM II) and integrate the electronics systems for this missile, which is to be deployed on the B-1B bomber.

Boeing ranked second in fiscal year 1987 contract awards valued at $152 million for the Strategic Defense Initiative (SDI). Boeing's largest single program for SDI is the Airborne Optical Adjunct (AOA) system, which has already made its first flight. Boeing will also adapt commercial flight deck technology for large military transports for the air force, develop an eye/respiration protection system for flight crews, and develop several unmanned air vehicles to attack or suppress radar systems.

The Boeing Helicopter/Bell Helicopter Textron team has begun fabrication prototypes and test articles for one of the Company's most significant programs—the V-22 Osprey tilt-rotor aircraft. The Boeing team won a full-scale engineering development contract in 1985 for $1.7 billion from the Naval Sea Systems Command. The program has a $30 billion potential and a 20-year production life, and it may have commercial potential.

Boeing Helicopters received a $199 million award from the Army Special Operations Office to upgrade and rebuild the CH-47D helicopter. New features will include increased fuel capacity, in-flight refueling, an upgraded engine, and an integrated night vision flight deck.

© 1989 Dataquest Incorporated March

The Boeing Company

Other significant army programs that Boeing is involved with are the pedestal-mounted Stinger air-defense system and the Boeing Robotic Air Vehicle-3000 unmanned air vehicle multiple-launch rocket system. The Robotic Air Vehicle will provide a "smarter" battlefield weapon, one more capable than current missiles, yet compatible with the army's current system. The weapon can be preprogrammed for a variety of missions such as search-and-attack and electronic countermeasures.

Boeing is utilizing the 707 airframe, on which the E-3 is based, as the platform for the navy's E-16A submarine communications aircraft. The navy plans a fleet of 16 E-6s, with deliveries of production aircraft to begin in 1989.

Most recently, the Boeing/Hughes team won a $125 million contract for the Fiber Optic Guided Missile (FOG-M). Boeing Military Airplane, the prime contractor, will develop the gunner's station for both the light and heavy versions of FOG-M.

Table 4 shows a summary of other major contracts received during the last two years.

Table 4

The Boeing Company Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
Space Station	NASA	$750	12/87	RDT&E	Prime	Manned pressurized modules
SRAM II	Aero. Systems Division	$214 $165	 9/88	FSD	Prime	Successor to SRAM deployed on B-52
P-3 Orion	Naval Air Systems Cmnd.	$244	7/87	FSD	Prime	Modernized avionics system
Peacekeeper MX	AF Ballistic Missile Cmnd.	$236	9/87	RDT&E	Sub	First phase of rail-based deployment scheme
Stinger	Army Missile Cmnd.	$206	8/87	P	Sub	273 Stinger air defense fire units
C-135 Stratolifter	AF Aero. Systems Division	$19 $173	4/87 4/88	P	Prime	Additional work on & 50 KC-135R aircraft reengine modification kits
A-6E	Navy	$170	3/88	P	Prime	54 composite wings
CH-47 Helicopters	Army Aviation Systems Cmnd.	$157	11/88	P	Prime	Price adjustment for 48 CH-47 helicopters; sole-source contract initiated 6/84

(Continued)

© 1989 Dataquest Incorporated March

Table 4 (Continued)

The Boeing Company
Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
IUS Full Scale Development System	AF Space Division	$15 $48 $150	8/87 12/87 2/88	P	Prime	Inertial upper stage vehicle spares, 3 additional vehicles, one solid rocket motor
E-6A	Naval Air Systems Cmnd.	$138 $284	3/88 11/88	P	Prime	Seven TACAMO aircraft
E-3A	AF Electronic Systems Division	$21 $98	3/87 5/87	RDT&E	Prime	Electronic support measures and data processing
VSX Aircraft Replace S-2E	Naval Air Systems Cmnd.	$99 $53 $28	1/87 3/87 4/87	RDT&E	Prime	N/A
MX-Missile	AF Ballistic Missile Office	$31 $15 $75 $23	5/87 6/87 7/87 11/87	RDT&E P	Sub	MX-missile subsystems
LGM-30 Minuteman	Ogden Air Logistics Center	$22 $18 $64	6/87 9/87 1/88	P	Sub	Missile components, class IVB modification to the hardened intersite cable system
Missile/Space Engineering Development	AF Ballistic Missiles Office	$47 $58 $70	2/87 4/87 7/87	RDT&E	Prime	Missile system research
Weapons Adv. Development	Naval Sea Systems Cmnd.	$50	10/87	RDT&E	Prime	N/A
COMSEC	AF Electronics Systems Division	$49 $29	2/87 3/87	P	Prime	Communications security equipment and components
B-1	AF Aero.Systems Division	$48 $14	7/87 8/87	P	P-2	Miscellaneous electronics
Guided Missiles	AF Aero. Systems Division	$41	10/87	P	Prime	Additional work for procurement of missiles
Ballistic Missile Defense System	Army Ballistic Defense Systems Cmnd.	$41	10/87	RDT&E	Prime	Additional missile work
F-4 Phantom II	AF Ogden Logistics Center	$27 $39	1/87 9/87	RDT&E P	Sub	F-4 upgrade
AGM-86	AF Aero. Systems Division	$30 $14	4/87 5/87	RDT&E	Prime	Missile/space advanced device
E-6A	Naval Air Systems Cmnd.	$18	4/88	FSD	Prime	TACAMO aircraft weapons system

N/A = Not Available
P = Production
RDT&E = Research, Development, Test, and Evaluation
FSD = Full-Scale Development
P-2 = Prime Contractor--Team of 2

Source: U.S. Department of Defense

© 1989 Dataquest Incorporated March

(Page intentionally left blank)

© 1989 Dataquest Incorporated March

General Electric Company

COMPANY DIRECTIONS

General Electric Company (GE) is virtually a sole participant in the aircraft gun market, is the largest supplier of military aircraft engines, and is a leader in radar and C^3I. Its role in the weapons market is increasing as is its participation in Strategic Defense Initiative (SDI) contracts. GE is also an emerging player in electronic warfare, developing a key avionics system for next-generation fighter aircraft—the integrated electronic warfare system (INEWS).

General Electric continues its strategy of being the leader in its key businesses—technology, services, and core manufacturing. As a result, the Company has removed itself from businesses and product lines not central to its strategy. In businesses where GE has remained, it has made an effort to become more cost-effective by consolidating facilities and investing $16.7 billion to develop new products and improve productivity. GE intends to hold the number one or number two position in the world in markets where it participates. GE Aerospace, for example, holds the first or second position in two-thirds of its 35 different product lines—all of which depend increasingly on advanced electronics technology. It is a leader in areas such as visual simulation systems, high-performance military aircraft controls, and automated test systems.

In August 1988, GE agreed to sell its Solid State Division to Harris. The semiconductor unit, which is expected to be sold for approximately $250 million, fabricates semiconductor chips for automotive, military, and industrial markets. The sale does not include the division's Microelectronic Center Research. In another strategic move, GE acquired CGR, a European-based medical diagnostic imaging business owned by Thomson, in exchange for GE's consumer electronics business. The CGR acquisition strengthens GE's position in Latin America and Europe.

GE has completed the installation of solid-state radar systems in Saudi Arabia, Canada, South Korea, and Taiwan. The Company launched four new satellites, bringing the number of satellites placed in orbit for communications, meteorology, science, and defense purposes to more than 150. In addition, GE's aerospace group has finished the development of full-authority digital engine controls and the application of large-screen liquid crystal displays for aircraft cockpits.

GE also formed alliances with Garrett Turbine Engine, Textron Lycoming, and Alfa Romeo to develop small and medium-size aircraft engines. Ruston Gas Turbines of England will produce components for GE aircraft engines.

FINANCIAL INFORMATION

Revenue in military and aerospace electronics was up 10 percent in 1987 from 1986. This was a result of overall volume increases (see Table 1). The sales mix was as follows: radar 20 percent, spacecraft 25 percent, aircraft 10 percent, communications 10 percent, test and measurement 10 percent, and classified 15 percent. The operating

© 1989 Dataquest Incorporated March

profit for the aerospace segment remained flat because of costs from the completion of RCA purchase cost allocations. GE's Aircraft Engines Group topped the $12 billion mark in orders set for delivery during 1988's third quarter.

Table 1

General Electric Company/RCA
Financial Information
(Millions of Dollars)

	1987	1986	1985
Mil/Aero Electronic Revenue ($M)	$ 4,209	$ 3,818	$ 3,897
Total Revenue ($M)	$40,515	$ 36,728	$29,240
Company-Funded R&D Expense ($B)	$ 1.2	$ 1.3	$ 1.1
R&D Expense under Contract ($B)	$ 1.8	$ 2.0	$ 1.5
Company Capital Expenditure ($M)	$ 1,778	$ 2,042	$ 1,953
Dollar Value of Contracts Awarded ($M)	$ 5,990	$ 6,839	$ 5,880
Return on Sales ($M)	$ 0.05	$ 0.07	$ 0.08
Company-Funded Backlog ($M)	$22,737	$23,943	$23,117

Source: General Electric Annual Report
U.S. Department of Defense
Prudential-Bache

DIVISIONS/SUBSIDIARIES

GE's defense electronics operations are conducted under the umbrella of its Aerospace Group. Aerospace combines the operations of GE Aerospace and RCA Aerospace and Defense, which together make GE one of the largest and most diversified aerospace manufacturers in the world (see Table 2).

© 1989 Dataquest Incorporated March

Table 2

General Electric Company Operations

Location	Number of Employees	Equipment
General Electric Company Fairfield, CT (Parent)	300,000	
Aerospace Group		
Aerospace Electronic Systems Department Utica, NY	3,500	Computer-based aerospace data systems, EW warfare alarm systems, EW communication systems, ECM equipment, infrared/electro-optical multimode radar systems, airborne surveillance radar
Aerospace Control Electronic Systems Erie, PA	6,100	Control systems
Armament and Electronics Systems Division Burlington, VA	17,000	Aircraft armament including the MG1A1, 20mm automatic weapon, F-16 ammunition loading system, universal ammunition loader, 25mm gun systems for AV-8B, vulcan system for army
Government Systems Division Burlington, MA	1,000	Protocol and relocation data links, REMBASS system, TSW-2A air traffic control systems, CASS system
Defense Systems Division Pittsfield, MA	44,000	Armored personnel carriers, torpedoes, fire control equipment, launchers, guided missile control equipment, missile guidance systems, power systems, engine propulsion systems, system simulation/training services
Reentry Systems Operation Philadelphia, PA	N/A	Advanced guided missile development, MK21 vehicle for the small ICBM, EM projectile guidance MK21 missile arming and freezing assembly, maneuvering test vehicle, Have Fury Peacekeeper missile program, MK21 Reentry Vehicle for Peacekeeper, Defense Satellite Communications System
RCA Aerospace and Defense Group		
Astro-Space Division Princeton, NJ	5,000	Automated missile system test equipment, CASS system, command/control equipment, satellite pre- and post-launch services, software consulting services, design engineering, communications services, data loggers, ground control and check-out equipment, ICBM reentry systems, satellite components, guidance systems, space nuclear power systems
Government Communications Division Camden, NJ	500	Trident systems, TSC-94A/100A terminals, low-rate multiplexers, radio receivers, ground wave emergency network, ARC-161
Electronics Systems Department Moorestown, NJ	5,500	C-band range instrumentation radars, radar systems, engineering, Aegis integration and function test facility, MK7 Aegis combat system, MK99 Aegies fire control system and SPY-1B multifunction radar, VLSI design work, phased array antenna, crossbow generic radar, submarine combat systems, satellite communication service, multiple object tracking radar

(Continued)

© 1989 Dataquest Incorporated March

Table 2 (Continued)

General Electric Company
Operations

Location	Number of Employees	Equipment
Radar Systems Department Syracuse, NY	N/A	Sonar and radar systems, TR-317 transducers, SQS-53B(V) and 53C(V) sonar, refurbish SQQ-14 sonar, TPS-59 radar, shipboard electronics systems, SQR-19, naval counter-measures systems, FPS-117 early warning radar, OTH-B radar system, transducers, SEEK-IGLOO, north warning long-range radars, shore-based electronic equipment, SPY-1(V) phased array radar, BSY-2 combat control system, long-range radar for NATO and Iceland
Other Pertinent Operations		
Elano Corp. Xenia, OH	550	Metals and alloys, transportation services, connectors/ packaging, mechanical devices, air/spacecraft propulsion
Space Systems Huntsville, AL	N/A	Patriot contract
Machinery Apparatus Operation Schenectady, NY	N/A	Naval nuclear propulsion systems for naval vessels
Microelectronics Center Research Triangle Park, NC	N/A	Integrated circuits research, CMOS and SOS 1.25-micron, memory, 1750 A microprocessor, gate arrays, and cell-based ICs
Simulation and Control Systems Daytona Beach, FL	N/A	Simulation systems

Other Divisions/Subsidiaries

Aircraft Control Systems Dept.--Utica, NY
Aircraft Engine Business--Cincinnati, OH
AZDEL, Inc.--Shelby, NC
Calma Co.--Milpitas, CA
Components Marketing Operation--Richmond Heights, OH
Drive Systems Operations--Salem, VA
Elano East Corp.--Rowley, MA
GE American Communications, Inc.--Princeton, NJ
GE Lighting--Cleveland, OH
GE Nuclear Energy--San Jose, CA
Ladd Petroleum Corp.--Denver, CO
Medical Systems Group--Milwaukee, WI
Motor Business Group--Fort Wayne, IN
Power Supply Operation Division--Fort Wayne, IN
Projection Display Products Operation--Syracuse, NY
Quartz Marketing and Sales Operations--Richmond Heights, OH
Silicone Products Division--Waterford, NY
Thomson-CGR Medical Corp.--Columbia, MD

N/A = Not Available

Source: Dataquest
March 1989

© 1989 Dataquest Incorporated March

CONTRACT ACTIVITY

The Aerospace Group's biggest developments have been in the area of contract awards, especially in the space and submarine programs. NASA has picked GE to develop a free-flying, unmanned space platform; a satellite-servicing facility; and space station communications. The navy awarded GE a $1.6 billion contract for the AN/BSY-2 combat-control system for the SSN-21 Seawolf-class submarine. In April 1988, the Company was given $950 million in additional funding for the system.

GE is the prime contractor in several major ground-based surveillance radar programs. The largest is the over-the-horizon backscatter (OTH-B) radar, designated FPS118, potentially worth $313 million. GE also is producing FPS-117 radars as part of an upgrade to the distant early warning line, which is a U.S./Canadian air and missile defense surveillance system.

RCA is delivering the SPY-1(V) phased array radar, the "eyes" of navy CG-47 class cruisers. RCA is the prime contractor for the remotely monitored battlefield sensor (REMBASS), which provides the army with a tactical warning system consisting of seismic, acoustic, and magnetic sensors, combined with communications equipment. RCA is also prime contractor for the Trident submarine integrated radio room and ground wave emergency network. Since its acquisition, RCA continues its work on the Aegis-equipped cruisers. In fiscal year 1987, the Company won a $63 million award to install Aegis missile systems for the navy. In June 1988, RCA won a $243 million subcontract from Boeing to design the major communication links for the small intercontinental ballistic missile (SICBM) control system.

GE is teamed with Lockheed for the INEWS program. GE's participation brings microelectronic infrared and active radar skills to the team. GE's Aircraft Electronics Division participates in the air force silent attack warning system (SAWS) development efforts. The division is supplying the surveillance system for the APS-125, for E-2C Hawkeye aircraft. GE is also under contract to develop an engine for the advanced tactical fighter (ATF) program. Testing of the YF120 ATF demonstrator began in 1987, and prototype engines are expected to be ready for flight testing by 1990. GE is also in charge of the multifunction displays for the YF22A.

The navy has awarded GE 30 percent of the fiscal year 1988 purchase of MK 15 Phalanx close-in shipboard defense systems. GE, as prime contractor for the CASS (consolidated automated support system), also will produce 22 prototypes and associated software for the navy under a $164 million contract.

GE is involved with the Strategic Defense Initiative (SDI) and is responsible for systems engineering and integration of interceptor missiles and sensors and communications links. The Company is a subcontractor in charge of subsystem modeling disk memory for the ASAS/ENSCE.

© 1989 Dataquest Incorporated March

GE delivered its first F110 fighter engines to the U.S. Navy in 1987, for use on the F-14 and F-16N aircraft. In addition, the F110 continued to win a substantial share of U.S. Air Force orders in competitive bidding for F-16 fighter engines. GE also won the maximum 70 percent of U.S. Navy orders for F404 engines. In May 1988, GE won a $530 million five-year contract to build 751 helicopter engines for the UH-60 and 405 CH-60 engines, with deliveries beginning in March 1989.

GE's Unducted Fan (UDF) engine completed its flight tests with McDonnell Douglas and was selected by Boeing as the prime engine for its new medium-size aircraft to be introduced in the 1990s. UDF is expected to save airlines up to 40 percent in fuel costs over current turbofan models. The CF6-80C2 engine captured approximately 65 percent of available orders in 1987. DFM International, a joint company of GE and SNECMA, received large orders for its recently introduced CFM56-5 engine for Airbus A-320s and A-340s.

Table 3 shows a summary of major contracts received during the last two years.

 © 1989 Dataquest Incorporated March

Table 3

General Electric Company/RCA Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
F-100	AF Aero. Systems Division	$600 $391	3/87 3/88	P	Prime	Gas turbo jet engines
AEGIS	Naval Sea Systems Cmnd.	$387 $374	3/87 1/88	P	Prime	Aegis weapon parts; MK 7 Aegis weapon systems for CG-69, 71, 71, 72, and 73
Space-Based Defense Sys.	SDIC	$236	5/88	RDT&E	Prime	Engineer and integrator for system
F-14 Tomcat	AF Aero. Systems Division	$235	2/87	P	Prime	Gas turbo jet engines
F-18 Hornet	Naval Air Systems Cmnd.	$220 $212	7/87 3/88	P	Prime	Gas turbo jet engines
CVN-68	Naval Sea Systems Division	$204	2/88	P	Prime	Naval nuclear propulsion components
BFV	Army Arm, Munitions, Chem. Cmnd.	$167	9/87	P		501 Turret Drive Systems for Bradley Fighting Vehicle
T-700	Army Aviation Systems Cmnd.	$139	11/86	P	Prime	Gas turbo jet engines
Aircraft Adv Device	AF Aero. Systems Division	$100 $ 53	1/88 2/88	RDT&E	Prime	Additional work for system
Fleet Ballistic Missile	Strategic Systems Prog. Office	$ 89	4/88	P		Fire control systems
A-10	AF	$ 83	3/88	P	Prime	Modification for 655 A-10 aircraft
ICNIA/INEWS	AF	$ 48	6/86	Dm/V	P-2	
HMPT-500	Army Tank-Automotive Cmnd.	$ 40	8/87	P	Prime	569 hydro-mechanical power transmissions
UGM-96 Trident	Navy Special Projects Office	$ 28 $ 31	8/87 9/87	RDT&E	Sub	
F-111	AF Aero. Systems Division	$ 31	3/87	P	Prime	Radar equipment, airborne
LAV-AD	Marine Corps	$21	3/88	RDT&E	P-2	Two prototype systems
Trident	Naval Sea Systems Cmnd.	$30	12/87	RDT&E	Sub	Ship systems exploratory device weapon system
F-10 Sky Light	AF Ballistic Missile Office	$27	2/87	P	Prime	Aircraft equipment weapon system

P = Production
RDT&E = Research, Development, Test, and Evaluation
Dm/V = Demonstration and Evaluation
SS = Second Source
P-2 = Prime Contractor--Team of 2; P-4 = Prime Contractor--Team of 4

Source: U.S. Department of Defense

© 1989 Dataquest Incorporated March

GM Hughes Electronics Corporation

COMPANY DIRECTIONS

Aggressive business strategies for GM Hughes Electronics Corporation (GMHE) are paying off as the Company once again heads the top 50 in military and aerospace electronics. These strategies include product quality improvement, increased manufacturing efficiency, and greater reductions in costs. Creative worldwide marketing, key acquisitions, and technology developments are also helping GMHE maintain its leadership position.

Last year, Hughes Ground Systems Group (GSG) began new programs to develop a variety of high-technology defense systems. One system that enables army troops to selectively disperse mines on a battlefield by remote control is already in production. Another system on the production line is an antijam, high-frequency radio program. Development of a new form of sonar capability was begun for the U.S. Navy.

GSG also made a significant advance in command and control capability of tactical field commanders when the first production units of the Position Location Reporting System (PLRS) were delivered to the marine corps. This automated digital communications network enables commanders to pinpoint the location of their troops, tanks, artillery, aircraft, and other forces on the battlefield.

The Radar Systems Group (RSG) supplies airborne radar or weapon control systems for the air force TR-1 reconnaissance aircraft, the air force F-15 fighter, the navy's F-14D Super Tomcat, and the F/A-18 Hornet. The group was in charge of developing an improved and more capable radar for F-15. The first production units were delivered in 1987. This same radar will be used in the Special Operations Forces' AC-130 Gunship program. RSG is also in charge of developing an advanced radar for F-14 that combines long-range, multiple-target advantages with improved target detection/tracking, better electronic counter-countermeasures, and beyond-visual-range target identification and raid assessment capabilities. The technology used by RSG to develop the common integrated processor for the Advanced Tactical Fighter (YF-22A) is the foundation for the next generation of avionics architecture.

The Electro-Optical and Data Systems Group (EDSG) conducted several successful tests on the Hughes thermal weapon sight, an infrared device that will be used to aim machine guns and shoulder-launched missiles. The group was also able to successfully track, engage, and destroy a drone target missile in flight using a high-energy laser beam director. The test was part of a navy project to assess the potential of high-energy laser systems.

The Space and Communications Group (SCG) was selected by British Satellite Broadcasting to build the United Kingdom's first direct broadcast system. The group will provide satellites that will beam high-power television channels to U.K. homes equipped with antennas as small as one foot in diameter. To further boost its presence in satellite communications, Hughes acquired M/A-COM Telecommunications Division. The new organization, renamed Hughes Network Systems, is the nation's leader in very small aperture terminals (VSATs). Other events surrounding the SCG include the launching of three Hughes-built spacecrafts, communications satellites for Australia and Indonesia,

© 1989 Dataquest Incorporated March

and a weather satellite for the United States. Hughes is also a 30 percent equity partner in Japan Communications Satellite Co. Inc. (JCSAT), which will launch its first commercial satellite in 1989. In early 1988, Hughes reached an agreement in principle with Western Union to buy its Westar satellite system, which consists of three satellites in operational orbit. The proposed acquisition would double the number of satellites operated by the Company from three to six.

In 1987, the Industrial Electronics Group (IEG) introduced the following new image display products:

- A new thermal video system model that provides real-time thermographic TV imagery in full color and a new full-color version of the Hughes graphics projector

- A high-frequency imaging and radar cross section measurement system for aircraft, ships, and ground vehicles

- An all-digital passenger entertainment and service system for the Boeing 747-400 jetliner

- An advanced electronic switch that can switch thousands of amperes of current at tens of thousands of volts with high reliability and long life

Hughes will face Raytheon as a second source on the advanced medium-range, air-to-air missile (AMRAAM), Phoenix, and Maverick. Having lost to Raytheon to become the second source for the Stinger program, Hughes is taking action to improve its competitive position. As a result, Hughes Missile Systems Group (MSG) recently decided to lay off close to 300 employees and move another 300 from its Canoga Park, California, facility to Tucson, Arizona.

In 1988, Hughes Aircraft acquired Rediffusion Simulation of Arlington, Texas, from Great Britain-based BET for $283 million. The acquisition will yield an estimated 35 percent of the world market for simulators and 45 percent of the British market. For Hughes, the pairing gives the Company an entrance into the European market and significantly boosts the Company's low level of activity in the simulator market.

FINANCIAL INFORMATION

Despite tighter defense budgets, total military and aerospace electronics sales for GMHE increased slightly by 4 percent to $5,847 million in 1987. The Company's year-end backlog increased by 8 percent to $11.4 billion (see Table 1). The Delco Systems Operations, responsible for all Delco Electronics aerospace and defense activities, contributed $273 million in sales. Capital expenditures for GMHE declined $231 million in 1987, in line with General Motors' decision to reduce capital spending. The Company made a $348 million investment to increase productivity, improve quality, and reduce production costs.

 © 1989 Dataquest Incorporated March

Table 1

GM Hughes Electronics Corporation
Financial Information

	1987	1986	1985
Mil/Aero Electronic Revenue ($M)	$ 5,847	$ 5,635	$5,128
Total Revenue ($M)	$10,481	$10,440	$9,504
R&D Expense ($M)	$ 416	$ 408	$ 393
Capital Expenditure ($M)	$ 374	$ 379	$ 421
Dollar Value of Contracts Awarded ($M)	$ 4,108	$ 5,012	$1,578
Return on Sales ($M)	$ 0.08	$ 0.08	$ 0.06
Government-Funded Backlog ($M)	$ 11.4	$ 10.5	$ 11.9

Source: GM Hughes Electronics Corporation Annual Report
U.S. Department of Defense
Prudential-Bache

DIVISIONS/SUBSIDIARIES

Hughes is organized into six operating groups besides its four support organizations. Five of the operating groups are engaged in prime contract business; the sixth group supplies high-technology components for a variety of industrial, defense, commercial, and scientific applications (see Table 2). Included with these groups are Delco Systems Operations units, which are involved with defense contracts.

GMHE has an extensive in-house semiconductor and hybrid manufacturing capability with California facilities in Carlsbad, Newport Beach, and Torrance. With more than 32,000 square feet of clean room, GMHE's technology includes 1.5-micron CMOS, NMOS, BICMOS, SOS ASICs, silicon, analog, GaAs analog, MMICs, digital GaAs, discrete GaAs, and focal plane arrays. In addition, Delco's semiconductor operations in Kokomo, Indiana, which specialize in automotive applications, work with the military/aerospace groups.

© 1989 Dataquest Incorporated March

Table 2

GM Hughes Electronics Corporation Operations

Location	Number of Employees	Equipment
GM Hughes Electronics Corp. Detroit, MI (Parent)	760,000	Headquarters
Delco Electronics Group Kokomo, IN	N/A	Semiconductor test equipment, automotive test equipment, communications integrated circuits
Delco Systems Operations Goleta, CA Milwaukee, WI	1,700	Computers, ordnance systems/equipment, ground support equipment
Electro-Optical & Data Systems Group El Segundo, CA	N/A	Defense ground support equipment, ordnance systems, government software, measuring/sensing/controlling
Ground Systems Group Fullerton, CA	N/A	Command and control systems, radar systems, electronic warfare systems, sonar systems, sonar-guided torpedoes, data processing and display systems land mining warfare systems, communication systems
Hughes Optical Products Des Plaines, IL	250	Broadcasting/receiving equipment
Industrial Electronics Group Torrance, CA	1,000	Microwave and millimeter wave instruments, systems and components, imaging systems and devices, lasers, communications equipment, hybrid and monolithic micro-circuits, connectors, and cables
Microelectronic System Division Irvine, CA	900	Military communications, fiber optic secure communications equipment, security systems
Electron Dynamics Division Torrance, CA	N/A	Traveling wave tubes, electronic warfare elements
Connecting Devices Division Irvine, CA	1,400	Fiber optics and related equipment, cylindrical connectors
Microwave Products Division Torrance, CA	N/A	GaAs, analog ICs, MMICs, GaAs digital ICs, discrete devices
Solid State Products Division Newport Beach, CA	N/A	Custom gate arrays, VLSI devices based on CMOS, NMOS, BICMOS, and SOS technology, hybrid assembly
Spectrolab, Inc. Sylmar, CA	170	Solar panels, solar cells

(Continued)

© 1989 Dataquest Incorporated March

Table 2 (Continued)

GM Hughes Electronics Corporation Operations

Location	Number of Employees	Equipment
Missile Systems Group Canoga Park, CA Tucson, AZ La Grange, AZ	N/A	Advanced tactical guided missiles, Phoenix (AIM-54C), TOW, Maverick, AMRAAM (AIM-120A, Angle Rate Bomb Set (ARBS), IR guidance section for AF GBU-15 weapon
Radar Systems Group El Segundo, CA	N/A	Aeropsace radars, radar-based avionic systems, airborne weapon control systems, aerospace display and control, airborne electronic countermeasures, counter-measures equipment, airborne computers
F/A-18 Program Division Tampa, FL	200	Avionics radar, launchers
F-14 Program Division Los Angeles, CA	335	Multimode multirole airborne weapons control radar systems - AWG-9, AWG-71, (launchers and avionics radar)
F-15 Program Division Los Angeles, CA	300	Multimode multirole airborne weapons control radar systems - EPG-70 (launchers and avionics radar)
Space & Communications Group El Segundo, CA	N/A	Satellites for telecommunications, earth observation & meteorology, vehicles and payloads for space exploration, space communications equipment
Support Systems Long Beach, CA	N/A	Test equipment, integrated logistics support of aerospace products, range systems engineering, site activation and operation, training and engineering simulators (realscene)

Other Divisions/Subsidiaries

Advanced Program Division--Los Angeles, CA
Cunadata--Richardson, TX
Electronic Data Systems Corp.--Bethesda, MD
Electronic Data Systems Corp.--Southfield, MI
Engineering Division--Los Angeles, CA
Finance and Insurance Group--Plano, TX
GMF Robotics--Troy, MI
Hughes Research Laboratories--Malibu, CA
Optimum Systems Division--Rockville, MD
Santa Barbara Research Center Corp.--Goleta, CA
Technical Services--Dallas, TX

N/A = Not Available

Source: Dataquest
March 1989

© 1989 Dataquest Incorporated March

CONTRACT ACTIVITY

GMHE is involved with programs in command, control, communications, and intelligence (C^3I); electro-optics; data processing; radar; microelectronics; and missiles and space. Military and aerospace electronics sales reached $5,847 million in 1987, accounting for 56 percent of total sales.

The Missile Systems Group (MSG) is a leading designer and manufacturer of tactical guided missiles, guidance and control systems, and launchers. Hughes is the prime contractor for the IR-Maverick missile. The air force awarded Hughes with a $231 million contract for production of 2,420 missiles. Hughes was also awarded a $135 million contract for 153 long-range, air-to-air Phoenix missiles. The Company is also involved in full-scale development for the advanced, medium-range, air-to-air missile (AMRAAM). In July 1988, the air force awarded a $125 million contract to Hughes for production of 105 missiles. Hughes is teamed with Raytheon for the navy's advanced air-to-air missile (AAAM) that will replace Phoenix in the future. Other Hughes missile programs are the antiarmor TOW and the Angle Rage Bombing Set.

The Ground Systems Group (GSG) addresses programs in C^3I, air defense, radar, and electronic warfare. GSG was selected as a second source for the navy's SLQ-32 countermeasures and self-protection system production program. Other major programs include the UYQ-21 naval tactical display and the Mk 48 torpedo.

The Electro-Optical and Data Systems Group (EDSG) won a $495 million multiyear contract from the army for thermal imaging systems and the laser range finder for the M1 tank. The army also awarded Hughes a $190 million follow-on production contract for weapon subsystems for the Bradley fighting vehicle.

In addition to supplying airborne radar or weapon control systems, the Radar Systems Group (RSG) designs and builds airborne avionics systems, airborne radar reconnaissance and electronic warfare systems, data links, and related displays and controls.

General Motors took home $41 million in SDI contract awards in 1987. Hughes is a subcontractor for MILSTAR as well as for the defense meteorological satellite program (DMSP). The Space and Communications Group (SCG) scored an important win in August, receiving a $120 million contract for the navy's next-generation UHF satellite program.

Delco Systems Operation (DSO) is involved with the production of digital avionics computers for the F-16, low-altitude navigation target infrared for fight pod (LANTIRN), and the inertial upper stage guidance system. DSO supplies inertial guidance systems for the Titan II, III, and IV space boosters as well as the guidance computer for the Delta space booster. DSO also provides aircraft inertial navigation systems for 60 of the world's airlines, the U.S. Air Force, Army, Navy, and 14 foreign governments. In 1987, DSO won a $58 million contract for additional inertial navigation units for the air force. DSO's armament systems unit produces a two-man turret for the U.S. Marine Corps' light armored vehicle. Vetronics, the land-based equivalent of avionics, is also being developed for the new army combat vehicles.

 © 1989 Dataquest Incorporated March

Table 3 shows a summary of other major contracts received during the last two years.

Table 3

GM Hughes Electronics Corporation
Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
AGM-65 Infrared Maverick Missile	Aero. Systems Division	$231 $209 $132	4/87 4/87 5/88	P	Prime	2,420 missiles
ASW	Naval Sea Systems Commications	$185	1/86	P	Prime	Mk 48 torpedoes
AMRAAM	JSPO	$125 $20M	2/87 8/87	P	Prime	500 advanced medium-range air-to-air missiles
FOG-M	Army Missile Cmnd.	$125	12/88	FSD	P-2	TV and infrared versions of missile
AAAM	Navy	$120	10/88	RDT&E	P-2	Develop advanced air-to-air missile
HS 601 UHF Satellite	Navy	$120	8/88	P	Prime	One satellite
MGM-71 TOW	Army Missile Command	$113 $81 $35	8/87 9/87 5/88	P	Prime	Missile systems
NATCALS	Navy Space/Warfare Center	$81	9/87	P	Prime	Radio and TV communications equipment
AN/TPQ-37	Army Communications and Electronics Cmnd.	$80	8/87	P	Prime	Radar
AN/UYQ-21 NTDS	Naval Sea Systems Cmnd.	$80	7/87	P	Prime	N/A
AH-1 Cobra	Army Aviation Systems Cmnd.	$67	7/87	P	Prime	Night targeting system for helicopter
UGM-96 Trident	Navy Special Projects Office	$17 $59 $53	2/87 8/87 10/87	RDT&E	Sub	Missile/space engineering device
F-18 Hornet	Navy Aviation Supply	$54	7/87	P	Prime	Missile remote control system
MIMIC	DARPA	$49	6/88	D	P-2	Microwave/millimeter-wave monolithic integrated circuits
A-6 Intruder	Naval Air Systems Cmnd.	$48 $40	1/87 8/87	P	Prime	Additional work on radars
AN/UYA-4NTDS	Naval Sea Systems Cmnd.	$47 $22	2/87 9/87	P	Prime	Spares
M-81 Fire Control Systems	Naval Sea Systems Cmnd.	$22	9/87	P	Prime	Fire control system spares
F-14 Tomcat	Naval Air Systems Cmnd.	$18 $37	1/87 6/87	P	Prime	Missile remote control system

(Continued)

© 1989 Dataquest Incorporated March

Table 3 (Continued)

GM Hughes Electronics Corporation Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
Optical Sighting & Ranging Equip	Army Munitions and Chemical Cmnd.	$43	4/87	P	Prime	Additional work for sighting equipment
Guided Missile Launcher	AF Armament Division	$37	2/87	P	Prime	Launcher systems
Misc Weapons	Naval Sea Systems Cmnd.	$27	5/87	P	Prime	Weapon parts
Land Mines	Army Munitions and Chemical Cmnd.	$19	9/87	P	Prime	32,00 radio controlled mines, 1,600 modules control mines, 580 MOPMS
AN/UYQ-21	Naval Sea Systems Cmnd.	$17 $34	5/87 9/87	P	Prime	Electronic countermeasures equipment
Maverick	Aero Systems Division Wright Pat AFB	$21	8/88	RDT&E	Sub	Maverick missile depot upgrade
GBU-15 Bomb	AF Armament Division	$16	9/87	P	Prime	Additional work for munitions
AIM-54 C Phoenix	Naval Air Systems Cmnd.	$21	8/88	P	SS	Improve missile's programmable memory board, low sidelobe antenna, and transmitter

N/A = Not Available
P = Production
RDT&E = Research, Development, Test, and Evaluation
Dm/V = Demonstration and Evaluation
SS = Second Source
P-2 = Prime Contractor--Team of 2; P-4 = Prime Contractor--Team of 4

Source: U.S. Department of Defense

© 1989 Dataquest Incorporated March

Lockheed Corporation

COMPANY DIRECTIONS

Lockheed Corporation has significant core programs in space relating to national security, surveillance, communications, strategic defense, basic science, transportation, and exploration. Lockheed has moved aggressively to gain Strategic Defense Initiative (SDI) contracts and is now in the best position of any SDI contractor. Missiles and space systems comprise 46 percent of Lockheed's total sales; space work accounts for 69 percent of that number. Lockheed continues to be NASA's leading supplier of flight-qualified life science equipment. The Company is involved in helping NASA develop spacecraft systems and payloads, design simulations, set up robotic and expert systems, and design extra-vehicular activity systems as well as systems for guiding, navigating, and controlling spacecraft. Lockheed also continues to provide the navy with Trident II missiles; the funded backlog for this program was $1.7 billion in 1987.

In aeronautical systems, which account for 40 percent of company sales, Lockheed is completing the C-5B program and will continue producing the Hercules transport for at least another decade. As a prime contractor for the Advanced Tactical Fighter (ATF YF-22), Lockheed is on a leading edge for future aircraft.

Lockheed's investment strategy will be one of improved focus and planning on its core business. Its direction is leading into areas of growth opportunity that include programs in space, strategic defense, and data management.

In 1988, Lockheed consolidated its C^3I operations, taking a major step to increase its visibility in the major surface battle management program. The new C^3I Systems Division, located in Washington D.C., will combine operations from Lockheed's Austin, Texas, division and segments of its Space Systems Division in Sunnyvale, California. The unit will support the use of space technology to conventional warfare.

Three of Lockheed's units--Lockheed California Company, Lockheed Georgia Company, and Lockheed Aircraft Services--were integrated into one unit--Lockheed Aeronautical Systems Company (LASC). The consolidation is expected to increase the efficiency of the company's aircraft operations in light of a slowing C-5B program.

Lockheed expects its defense electronics to account for 50 to 60 percent of total revenue by 1991. The missiles, space, and electronics segment was divided into the missiles and space and electronics systems segment, demonstrating Lockheed's increased participation in defense electronics and space systems.

Both a $40 million Automated Center and an $87 million Weapons Systems Simulator Center were recently dedicated. The Automated Center is an advanced circuit board production facility in which all aspects of production are electronically integrated by computer systems. The development of the facility is intended to improve Lockheed's ability to compete for ground and space systems. The Weapons Systems Simulator Center forms part of a five-year program to upgrade aeronautical system's research, development, and production capabilities. Work is under way on a microelectronics center in Sunnyvale, California, to fabricate, assemble, and test very large integrated circuits (VLSI) based on silicon.

© 1989 Dataquest Incorporated March

Lockheed's shipbuilding operations were discontinued in light of a poor market outlook and its noncompetitive cost structure. The Company's Advanced Marine Systems Organization has been transferred to the Missiles and Space Systems Group.

FINANCIAL INFORMATION

Lockheed's estimated defense electronic sales have increased impressively from $1.2 billion in 1981 to $4.0 billion in 1987 (see Table 1). (Sanders contributed approximately $725 million in 1987.) In the electronics systems segment, sales more than doubled in 1988 to $862 million, while sales in the Missiles and Space Systems Group increased 3 percent, and sales in the Aeronautical Systems Group increased 4 percent. Expenditures for company-sponsored research and development, including the advanced tactical fighter and other development programs, increased 13 percent to $549 million. The decline in 1987 total backlog was primarily due to the Trident II and C-5B production programs.

Table 1

Lockheed Corporation
Financial Information

	1987	1986	1985
Mil/Aero Electronic Revenue ($M)	$ 4,036	$ 3,756	$3,556
Total Revenue ($M)	$11,321	$10,161	$9,386
Company R&D Expense ($M)	$ 549	$ 486	$ 426
R&D under Contract ($B)	$ 2.9	$ 2.7	$ 2.9
Capital Expenditure ($M)	$ 419	$ 482	$ 450
Dollar Value of Contracts Awarded ($M)	$ 5,558	$ 5,140	$5,085
Company-Funded Backlog ($B)	$ 8.4	$ 9.6	$ 8.8

Source: Lockheed Corporation Annual Report
U.S. Department of Defense
Prudential-Bache

© 1989 Dataquest Incorporated March

Lockheed Corporation

DIVISIONS/SUBSIDIARIES

Lockheed is organized into four main groups: Missiles and Space Systems, Aeronautical Systems, Electronic Systems, and Information Systems (see Table 2).

Table 2

Lockheed Corporation
Operations

Location	Number of Employees	Equipment
Lockheed Corporation Calabasas, CA (Parent)	99,300	Headquarters
Aeronautical Systems Group		
Lockheed Aero. Sys. Co. Burbank, CA	42,000	Vehicle modernization, triple sonic jets, land-based patrol planes, reconnaissance planes, carrier-based patrol planes
Murdock Engineering Irving, TX	478	Missiles and related equipment, general manufacturing services, ground support equipment
Lockheed Georgia Marietta, GA	14,000	Aircraft
Lockheed Aircraft Services Ontario, CA	1,700	Custom designed discrete communications systems, aircraft modification, data recording equipment, aerospace training equipment
Lockheed Air Terminal Burbank, CA	800	Aircraft fueling airport
Missiles and Space Group		
Lockheed Engineering and Management Services Houston, TX	3,300	Computer hardware and software development, computer R&D services environmental remote sensing services, environmental sampling services, test range engineering services, propulsion testing and spacecraft materials, high-energy laser testing services, spacecraft systems and payload development services, space/life services

(Continued)

© 1989 Dataquest Incorporated March

Table 2 (Continued)

Lockheed Corporation
Operations

Location	Number of Employees	Equipment
Lockheed Missiles & Space Co. Sunnyvale, CA	29,800	Conventional missiles, nuclear missiles, torpedoes, missile components/support equipment, automated weapon control systems, solar panels, solar power systems, matrix switches, hybrid microelectric circuits, special purpose tape recorders, data processors
Lockheed Space Operations Titusville, FL	2,160	Ground processing shuttle launch and recovery
Advanced Marine Systems Division	450	R&D for wire guided airborne mine neutralization equipment, and navy deep sea vehicle modification and engineering service:
Electronics Group		
C^3I Division Fairfax, Washington D.C.	12,000	N/A
Lockheed Electronics Plainfield, NJ	2,100	Automated weapons control systems, automated test equipment design services, ordnance product design services, electronic warfare systems design services, custom hybrid microcircuit design services, storage/retrieval software, navy radar systems
Sanders Associates Co. Nashua, NH	11,400	Headquarters
Microwave Division Manchester, NH	N/A	Electronic warfare equipment, connectors/packaging, electromechanical devices, electronic subsystems, passive components, measuring/sensing/controlling, data communications equipment, satellite systems/equipment, ground support equipment
Surveillance Sys. Division Hudson, NH	N/A	Antisubmarine warfare equipment, command/control equipment, data communications equipment

(Continued)

Table 2 (Continued)

Lockheed Corporation
Operations

Location	Number of Employees	Equipment
Countermeasures Division Nashua, NH	N/A	Test equipment/ATE, electronic warfare equipment, training/simulation equipment, data communications equipment, ground support equipment
Information Sys. Group Calcomp Communications Div.	3,000	Peripherals, facilities management software, engineering/technical software
Datacom Sys. Corp. Teaneck, NJ	538	Data processing services
Lockheed Dataplan Inc.	80	On-line weather satellite and radar information, on-line weather advisory services, on-line interactive and batch processing flight plan development services

Other Divisions/Subsidiaries

Aeromod--Arlington, TX
Analytx Electronic Systems, Inc.--Hudson, NH
Avicom International--Burbank, CA
Defense Information System Division--Nashua, NH
Digitizer Division--Scottsdale, AZ
Display Products Division--Hudson, NH
Flexprint Division--Manchester NH
Metier Management Systems Inc.--Houston, TX
Plotter Division--Anaheim, CA

N/A = Not Available

Source: Dataquest
March 1989

© 1989 Dataquest Incorporated March

CONTRACT ACTIVITY

Lockheed Missiles and Space Company is the prime contractor for MILSTAR, working under a $1.05 billion full-scale engineering development contract for the program. Lockheed is also a leading player in the Strategic Defense Initiative (SDI) program, for which the Company has won seven major and several minor contracts valued at approximately $2 billion when fully funded. The Company is the prime contractor for ERIS under a program currently valued at $493 million. Other SDI programs include: the army's ground-based free electron laser technology integration experiment (GBFEL-TIE), for which Lockheed won a multiyear contract valued at between $600 million and $800 million; a boost surveillance and tracking system (BSTS), for which it won a $304 million design contract; the space surveillance and tracking system (SSTS); the large optics demonstration experiment (LODE); the shuttle-based Starlab pointing and tracking experiment; and Zenith Star, a space-based laser experiment for which Lockheed is a subcontractor. The Company is also working on the submarine laser-communications satellite (SLCSAT) program for the navy.

Lockheed is on three of four teams to work on NASA's space station with work valued at $1 billion. The Company is the prime contractor for the software support environment program and is a major subcontractor to Boeing for the life-science portion of the space station's laboratory module. Lockheed is also NASA's shuttle processing contractor in a program valued at $400 million a year through the next decade.

Lockheed is the producer of the Trident II missile, for which funded backlog is $1.7 billion. The Hercules transport, the P-3 Orion, and S-3 Viking are also Lockheed products. Currently, Lockheed is in the process of upgrading electronic systems on 144 S-3s under a program valued at $400 million.

Lockheed is involved in a variety of aircraft contracts. The last of 50 aircraft for the $6.6 billion C-5B production program will be delivered in 1989. The Company has won a $1 billion contract from McDonnell Douglas for production of wing components for the air force's C-17. Teamed with Boeing and General Dynamics, Lockheed won a contract to design and build prototypes for the air force's multibillion dollar advanced tactical fighter (ATF). Lockheed is directing overall development of the aircraft and is developing and constructing the cockpit and forward fuselage. Recently, Lockheed won a $4 billion to $5 billion contract from the navy who will buy up to 125 long-range antisubmarine-warfare-capable aircraft (LRAACA). Lockheed is also a subcontractor for the B-2 program.

Ranking among the leading producers of electronic warfare, Lockheed's two biggest programs are the ALQ-126 jammer for navy tactical aircraft valued at $700 million and the USM-464 test system valued at approximately $400 million.

Table 3 shows a summary of other major contracts received during the last two years.

 © 1989 Dataquest Incorporated March
0002993

Table 3

Lockheed Corporation Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
C-5 Galaxy	AF Aero. Systems Division	$1,300 $250 $24 $20	1/87 12/86 3/87 12/87	P	Prime	Aircraft, fixed wing
Space Station/ Shuttle	NASA	$655	3/87	RDT&E	Prime	Space station subsystems
GBFEL-TIE	SDIO	$600	10/88	RDT&E		Strategic Defense Initiative R&D
Trident II	Navy Special Projects Office	$458 $22 $275 $459 $315	1/87 3/87 4/87 11/87 12/87	RDT&E	Prime	Missiles
BSTS	SDIO	$330	3/88	Dm/V	P-2	Boost surveillance and tracking system
Space Station	NASA	$200	5/88	RDT&E	Prime	Automated software systems for designing and developing software to control station operation
LOBE	SDIO	$179	4/88	RDT&E	Prime	Beam control system
C-130h	AF	$19 $166 $11 $60 $18	2/87 3/87 1/88 4/88 9/88	P	Prime	Aircraft equipment and production, engineering and modification services, production of aircraft
LCU, Landing Craft	Naval Sea Systems Cmnd.	$115	7/87	P	Prime	Began first interceptor
AN/ALQ-126 ECM	Naval Air Systems Cmnd.	$112 $11	7/87 10/87	P	Prime	Electronic counter-measures equipment
C-5B	AF	$34 $87	3/87 6/87	P	Prime	Spare parts and radar maintenance and equipment for army/aircraft improvements
P-3C	Navy	$66 $93 $30	3/87 4/88 9/88	P	Prime	Aircraft work, aircraft production/missile engineering services
High-Energy Laser	Army	$80	3/87	RDT&E	Prime	Laser research and development

(Continued)

© 1989 Dataquest Incorporated March

Table 3 (Continued)

Lockheed Corporation Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
FA-18 AV-8B	Navy	$75	7/87	P	Prime	Electronic counter-measures equipment
S-3B	Navy	$50	5/87	P	Prime	Aircraft avionics test equipment
INEWS	Navy	$48	5/86	Dm/V	P-2	VHSIC & MIMIC technologies--production to begin 1993
FA-18	Navy	$37	7/87	P	Prime	Electronic counter-measures equipment for Spain and Australia
S-3A	Navy AF	$35	12/87	P	Prime	Aircraft improvements for Navy/aircraft engineering services for air force
AN/ALQ-137	AF Warner Robins Logistics Center	$35	8/87	P	Prime	Electronic counter-measures equipment
U-2	AF Space Division	$34	1/87	P	Prime	Aircraft, fixed wing
SSTS	SDIO	$32	7/88	RDT&E	P-2	Space surveillance and tracking system
C-5A	AF	$13 $10	9/87 6/88	P	Prime	Aircraft equipment engineering services
Aircraft Technology	AF Army	$27	9/87	P	Prime	Aircraft manufacturing technology, material research, electron counter-measures equipment
ASW Aircraft	AF Aviation Systems Cmnd.	$27	3/87	P	Prime	Subchasers
Ballistic Missile Reentry Vehicle	Navy	$25 $23	12/87 6/88	P	Prime	Ballistic missile reentry vehicle equipment
UGM-27 POLARIS	Navy Special Projects Office	$26	4/87	P	Prime	Complete missile systems
Space Transportation Systems	NASA Marshall Space Flight Center	$21	1/87	RDT&E	Prime	Space transportation research and development
P-3 Orion	Customs Service	$20	6/87	S	Prime	Modified P-3 aircraft as an early-warning radar plane to track drug smugglers

(Continued)

© 1989 Dataquest Incorporated March

Table 3 (Continued)

Lockheed Corporation
Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
C-141	AF	$18	6/87	P	Prime	Repair aircraft and improve production plant facilities
Bombs	Army Ballistic Missile Defense Systems Cmnd.	$16	12/87	P	Prime	Bomb system procurement
I-2000	AF	$16	2/88	P	Sub	Case assemblies for I-2000; follow-up orders call for production of 9,000 ($80M)
Tomahawk	Navy	$16	6/88	P	Sub	Improvements on missile software
Space Transportation System	NASA Johnson Space Center	$15	1/87	RDT&E	Prime	Space transportation research and development
PLSS	AF	$15	10/87	RDT&E	Prime	Sensors (precision location strike system)

P = Production
RDT&E = Research, Development, Test, and Evaluation
Dm/V = Demonstration and Evaluation
SS = Second Source
P-2 = Prime Contractor--Team of 2; P-4 = Prime Contractor--Team of 4

Source: U.S. Department of Defense

© 1989 Dataquest Incorporated March

Raytheon Company

COMPANY DIRECTIONS

Raytheon Company continues to dominate portions of the defense electronics market. Its diversified operations include the design and manufacturing of tactical missiles, phased-array radars, surface-ship electronic warfare, and submarine systems. Raytheon has also entered two new areas that offer great potential—the airborne expendable and militarized computer markets. The Company is involved in commercial electronics, including air-traffic control systems and communications equipment.

Raytheon's investment in quality and manufacturing efficiency has been successful in making it the leader in several defense electronic markets. The Company's objective of producing good products at low cost is becoming a critical factor in securing awards as defense budgets decline and more emphasis is placed on efficiency. Raytheon's "Transition from Development to Production" program, which is intended to eliminate schedule delays, cost overruns, and engineering changes, reflects the Company's recent philosophy. Raytheon's Andover, Massachusetts, plant, for instance, was the first one chosen by the army as a certified production plant, substantially reducing the time and effort required for audits, inspections, reports, and travel.

Raytheon's largest business area continues to be electronics. Raytheon has become the second-source manufacturer of several missile systems including the Phoenix, Standard-2, Maverick, Stinger, and advanced medium-range antiaircraft missile (AMRAAM). Having won an impressive number of defense contracts this year, Raytheon is assured future growth.

Raytheon opened a $45 million gallium arsenide-based monolithic microwave integrated circuit (MMIC) center next to its Microelectronics Center in Andover, Massachusetts. These two facilities will be consolidated into the Advanced Device Center. In July 1988, the Company received one of ten Defense Department VHSIC Pioneer Awards for its leadership role in the development of very high speed integrated circuits (VHSICs). More than 60 VHSIC chips are being designed and fabricated to be used in Raytheon's defense systems. Combined with Raytheon's facility in Mountain View, California, the Advanced Design Center provides a substantial proportion of the Company's internal semiconductor needs.

Raytheon completed the renovation of its plant in Quincy, Massachusetts, for design and production of high-reliability hybrid microcircuits for defense and medical applications. The plant also offers improved facilities for design and production of special-purpose cathode-ray tubes (CRTs) and laser material processing systems.

In April 1988, Raytheon introduced three new militarized VAX computers. Raytheon Equipment Division (ED) redesigned and adapted Digital Equipment Corporation's VAX 6200 commercial computer to meet military specifications. The models use the same architecture and software as the Digital Equipment machine, with six custom CMOS chips acting as core processors. The system is compatible with the software system mandated by the U.S. Department of Defense (DOD) for inclusion in mission-critical equipment.

© 1989 Dataquest Incorporated March

FINANCIAL INFORMATION

Military and aerospace electronics, with sales of $3,569 million, continued to be the largest contributor to Raytheon's total sales in 1987 (see Table 1). Continued strength in second-source contracting will enable Raytheon to reap the benefits of producing weapon systems without incurring research and development (R&D) expenses or risks associated with developing new programs. Also in 1987, total government-funded backlog achieved record levels at $6,362 million, a 17 percent growth over the previous year.

Table 1

Raytheon Company
Financial Information

	1987	1986	1985
Mil/Aero Electronic Revenue ($M)	3,569	3,253	2,844
Total Revenue ($M)	7,659	7,308	6,409
Company R&D Expense ($M)	266	254	260
Capital Expenditure ($M)	230	221	164
Dollar Value of Contracts Awarded ($M)	3,817	4,050	2,990
Return on Sales ($M)	0.06	0.05	0.06
Company-Funded Backlog ($B)	8.5	7.8	6.5
U.S. Government Funded Backlog ($B)	6.4	5.4	4.5

Source: Raytheon Company
Annual Report
U.S. Department of Defense
Prudential-Bache

DIVISIONS/SUBSIDIARIES

Raytheon has several divisions involved with military and aerospace contracts. These include the Missile Systems Division, Equipment Division, Electromagnetic Division, Submarine Signal Division, and Beech Aircraft (see Table 2).

© 1989 Dataquest Incorporated March

Table 2

Raytheon Company Operations

Location	Number of Employees	Equipment
Raytheon Company Lexington, MA (Parent)	76,500	
Apelco Marine Electronics Tampa, FL	15	Measuring/sensing/controlling, marine systems and equipment
Beech Aircraft Corporation Wichita, KS	7,925	Aircraft missile targets, contract aircraft parts manufacturing services, jet aircraft (Beechjet), single-engine piston airplanes, twin-engine piston airplanes (Baron), Turboprops (King Air)
Electromagnetic Systems Division Goleta, CA	1,750	ECM equipment, airborne escort/standoff jammers, aircraft electronic support measures, ground EW systems, receivers, transmitters
Equipment Division Wayland, MA	NA	Defense computer systems, tactical communications equipment, ship fire-control systems, ballistic-missile guided electronics, digital group multiplexers, tactical displays, ground radar systems, air traffic control systems, satellite ground systems, shipboard radar
Industrial Components Division Quincy, MA	800	Specialty and vernier knobs, special-purpose cathode-ray tubes, thick-film hybrid circuits
Machlett Laboratories, Inc. Stamford, CT	500	Medical monitoring equipment, optics and related equipment, connectors/packaging, electron tubes
Advanced Device Center Andover, MA	N/A	Design and development of ASICs and GaAs ICs (MMICs)
Microwave & Power Tube Division Waltham, MA	3,200	Microwave subsystems, test equipment, CRTs, thick-film hybrids, IR
Missile Systems Division Bedford, MA	N/A	Smart munitions--Sea Sparrow, IR Maverick, AMRAAM, Sidewinder, Skyguard, Hawk, and Patriot missiles
Planar Microwave Santa Clara, CA	50	Electromechanical devices, electronic subsystems, measuring/sensing/controlling, satellite, and microwave
Raytheon Laser Products Burlington, MA	50	Assembly/manufacturing systems, lasers/laser-related equipment

(Continued)

© 1989 Dataquest Incorporated March

Table 2 (Continued)

Raytheon Company Operations

Location	Number of Employees	Equipment
Raytheon Marine Company Hudson NH	200	Shipboard VHF radio telephones, shipboard LORAN-C navigation systems, shipboard radar systems, shipboard doppler speed logs and fax systems
Sedco Systems, Inc. Melville, NY	1,500	Test equipment/ATE, electronic warfare equipment, electromechanical devices, broadcasting/receiving equipment, data communications equipment satellite and microwave, transmission systems/equipment
Semiconductor Division Mountain View, CA	1,200	Bipolar programmable read-only memory (PROM), semicustom linear macro cell arrays, advance linear integrated circuits, (digital logic) devices, linear integrated circuits, CMOS gate arrays bipolar gate arrays, small signal transistors
Special Microwave Devices Operations Northborough, MA	N/A	Laser machining systems, SAW and YIG filters, ferrite devices, microwave integrated circuits, microwave semiconductors, infrared detectors
Submarine Signal Division Portsmouth, RI	N/A	Antisubmarine warfare equipment, electronic warfare equipment, training/simulation equipment, marine systems/equipment

Other Subsidiaries/Divisions

Badger Co., Inc.--Cambridge, MA
Cedarapids, Inc.--Cedar Rapids, IA
Composite Prototype Division--Mojave, CA
D.C. Heath and Co.--Lexington, MA
El-Jay Division--Eugene, OR
Raytheon Service Co.--Burlington, MA
Research Division--Lexington, MA
Scaled Composites--Mojave, CA
Seiscor Technologies, Inc.--Tulsa, OK
Seismograph Services Corp.--Tulsa, OK
Sorensen Co.--Chicago, IL
Stearns-Rogers Division--Denver, CO
Switchcraft, Inc.--Chicago, IL
UE&C-Catalytic, Inc.--Philadelphia, PA
United Engineers & Constructors Inc.--Philadelphia, PA

N/A = Not Available

Source: Dataquest
March 1989

© 1989 Dataquest Incorporated March

Raytheon Company

CONTRACT ACTIVITY

Raytheon maintained its number one ranking in army contract awards. The Company is a prime contractor for the Hawk, Sparrow, Sidewinder, and Patriot missile systems. In fiscal year 1987, Raytheon received a $3.5 billion contract for the army's Patriot Defense System, for delivery of 4,500 missiles over the next several years; a $215 million contract from the navy for 1,927 Sparrow missiles; and an $83 million award to provide 430 Hawk missiles to the marines. It is estimated that Patriot will generate approximately $1.3 billion in annual sales, Hawk will total $500 million in sales, and Sparrow will generate $350 million over the next two years.

In December, Raytheon won a competition for the MARK XV/NIS IFF (Identification, Friend, or Foe) program along with team member Allied-Signal. The program is valued at approximately $4 billion to $10 billion over the next 15 years.

Raytheon provides second-source contracting for AMRAAM (advanced medium-range air-to-air missile), Maverick, Phoenix, Stinger, and Standard missiles. The navy awarded Raytheon a $231 million research and development contract for the SM-2 Block IV update. The Maverick award is estimated at more than $2 billion over the life of the program.

Major Raytheon surveillance/early warning radar programs include Cobra Dane, Cobra Judy, Pave Paws, and Relocatable OTH Radars (R-OTH-R). Raytheon received a $300 million navy award to build an R-OTH-R unit for Pacific ocean surveillance. A fifth Pave Paws unit is being built in Flingdales, England, at a contract cost of approximately $150 million.

Major shipboard radar and weapons fire-control programs the Company is involved with include Aegis, Tartar, Seasparrow/SPS-49. Combined annual revenue is estimated at approximately $375 million.

Raytheon is also participating in major military communications programs such as MILSTAR and DSCS (Defense Satellite Communications System), for which it will provide satellite ground-control terminals. The Company is also the prime contractor of electronic warfare programs that include ALQ-99, ALQ-142, SLQ-32, and ALQ-184. Although the AN/ALQ-99 jamming system has been considered Raytheon's Electromagnetic Systems Division (ESD) "bread and butter" program for years, generating about $50 million, the AN/ALQ 184 has become one of ESD's most important programs with expected revenue of $75 million in 1989.

Table 3 shows a summary of other major contracts received during the last two years.

© 1989 Dataquest Incorporated March

Table 3

Raytheon Company Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
Patriot	Army Missile Cmnd.	948 790	3/87 11/87	P	Prime	45 Patriot missiles and 45 fire units
Air Traffic Display Equipment	FAA	500	7/88	P	Sub	IBM subcontract
CCS	Naval Sea Systems Cmnd.	405	9/88	P	Prime	Combat control system MK 2 system upgrade
AIM-7 Sparrow	Naval Air Systems Cmnd.	216	3/87	P	Prime	Missile components & spares
AMRAAM Missiles	AF Armament Division	125 153 162	2/87 11/87 7/88	P	SS	75 advanced medium-range air-to-air missiles & work; 200 AIM-120 missiles
SM-2	Naval Sea Systems Cmnd.	131	1/88	P	SS	509 Standard Missile-2
BMEWS	AF Systems Cmnd. Electronic Systems Division	168	6/88	P	Prime	Upgrade ballistic missile early warning system
Infrared Maveric Missile	AF Aero Systems Division	148	4/87	P	SS	2438 missiles 1889 AGM-65Ds and AGM65s
MIM-23 Hawk	Army Missile Cmnd.	122	7/87	P	Prime	Additional work on missiles
Hawks	Army Missile Cmnd.	109	10/88	P	Prime	525 Hawk missiles
UGM-96 Trident	Strategic Systems Prog. Office	32 65 57	8/87 10/87 2/88	RDT&E P	Sub	 Guidance system components
PAVE PAWS	AF Systems Cmnd. Electronic Systems Division	72	6/88	P	Prime	Upgrade first two precision acquisition vehicle entry phased array warning systems
AN/BQQ-6 Sonar	Naval Sea Systems Cmnd.	67	4/87	P	Prime	Sonar sound equipment
AIM-54 Phoenix	Naval Air Systems Cmnd.	50 13 39	2/87 4/87 11/87	P	SS	Additional work on missile systems
AIM-9 Sidewinder	Naval Air Systems Cmnd.	40	6/87	P	Prime	Missile spares
MIMIC	Navy	69	5/88	RDT&E	P-4	Phase 1
Sidekick EWC	Naval Sea Systems Cmnd.	24	9/88	P	Prime	10 Sidekick electronic warfare countermeasure subsystems
AN/SLQ-32	Naval Sea Systems Cmnd.	41	9/87	P	Prime	Electronic countermeasure equipment

(Continued)

© 1989 Dataquest Incorporated March

Table 3 (Continued)

Raytheon Company Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
AFSATCOMM	AF Electronic Systems Division	36 40	3/87 8/87	RDT&E	Prime	Electronic and communication equipment engineering device
AN/SPS-49	Naval Sea Systems Cmnd.	35	9/87	P	Prime	Long-range air-search radar for Aegis class cruiser
AEGIS	Naval Sea Systems Cmnd.	30 20 29	2/87 5/87 9/87	P	Prime	Fire-control directors
AN/TRC-170 Radio	AF Electronic Systems Division	28	6/87	P	Prime	Communication equipment
Stinger	Army Missile Cmnd.	26	9/87	P	SS	Missile subsystem
Communications Equipment	Navy Avionics Facility	20	8/87	P	Prime	N/A
RIM-67 Standard Missile	Naval Sea Systems Cmnd.	19	7/87	RDT&E	SS	Miscellaneous electronics
AN/SQS-53 Sonar	Naval Sea Systems Cmnd.	18	3/87	P	Prime	N/A
MILSTAR	USAF Electronic Systems Division	19	4/88	P	Sub	Modify terminals
Laser Guided Weapon	Picantiny Arsenal	17	1/88	RDT&E	Sub	New seeker combining semiactive lasers with infrared homing device for advanced Copperhead laser-guided artillery
AN/SPG-51 Radar	Naval Sea Systems Cmnd.	18	9/87	P	Prime	N/A
Elec. & Comm. Equip. Dev.	Navy Space/ Warfare Center	15	3/87	RDT&E	Prime	N/A
Ballistic Missile Defense System	Army Ballistic Missile Defense Systems Cmnd.	13	3/87	RDT&E	Prime	N/A
AN/BSY-1	Naval Sea Systems Cmnd.	12	7/25	P	Sub	Spares for the AN/BSY-1(V) program

N/A = Not Available
P = Production
RDT&E = Research, Development, Test, and Evaluation
Dm/V = Demonstration and Evaluation
SS = Second Source
P-2 = Prime Contractor--Team of 2; P-4 = Prime Contractor--Team of 4

Source: U.S. Department of Defense

© 1989 Dataquest Incorporated March

(Page intentionally left blank)

Rockwell International Corporation

COMPANY DIRECTIONS

Rockwell International Corporation is one of the nation's leading participants in command, control, communications, and intelligence (C^3I); guidance and navigation; tactical weapons; and shipboard electronics and sensors. In avionics, Rockwell is a worldwide leader in advanced-technology products and systems for both commercial and government markets.

In an effort to better respond to market competition and tightening demand due to the DOD's budget restrictions, Rockwell's defense electronics operations have been restructured and reorganized. The Company consolidated its satellite systems divisions, its electronics operations, electro-optical systems and the strategic defense division to form a new Satellite and Space Electronics Division. Rockwell intends to expand its position in international defense electronics markets.

Several of the following units were acquired or sold during 1987.

- Soma Europe Transmissions was acquired from Valeo of France.
- Rockwell-Rimoldi was sold to Industriali of Italy for $116 million.
- Communications Machinery was acquired for $40 million.
- Rockwell is seeking a buyer for the Measurement and Control Division as Rockwell exits the low-technology field.

In one of Rockwell's key roles as the leader in commercial and defense avionics, the Company is developing avionics systems with flat-panel, liquid-crystal cockpit displays and integrated digital technology for the next generation of commercial airliners and general aviation aircraft. Rockwell's new generation, lightweight digital avionics systems are standard or standard options on business jet and turboprop aircraft.

While the B-1B production program was completed in 1988, modifications and spare parts production are expected to generate sales of approximately $500 million annually into the next century. The B-1B set 36 world records for speed, payload, and distance over two courses at average speeds of 670 and 655 miles per hour.

In December 1988, Rockwell announced its intention to buy Eaton Corp.'s AIL Division. This deal subsequently fell through.

Rockwell's space operations first priority has been to work with NASA to return the Space Shuttle to flight status. The Company is also working on designs for the Shuttle-C, a heavy lift unmanned launch system derived from shuttle technology. The Company's Rocketdyne Division is the major supplier of liquid fuel propulsion systems.

© 1989 Dataquest Incorporated March

Rockwell established the Strategic Defense Center, a 200,000-square-foot building in Seal Beach, California, to coordinate and integrate the resources and skills of its aircraft and space and electronics organizations participating in the SDI programs. The center will serve as a focal point for SDI programs that are currently valued at approximately $1 billion.

FINANCIAL INFORMATION

Despite a 1 percent drop in total sales from 1986 to 1987, Rockwell's earnings increased 10 percent over the same period. The slight reduction in sales was due mainly to a $472 million drop in aerospace revenue in 1987. Electronic revenue decreased slightly from $2,384 million in 1986 to $2,370 million in 1987. Although capital expenditures for Rockwell actually dropped 12 percent, the Company has invested $2.7 billion in the last five years and plans to continue an aggressive capital expenditure program (see Table 1). Cash generated internally has been sufficient to fund capital expenditures.

Table 1

Rockwell International Corporation
Financial Information

	1987	1986	1985
Mil/Aero Electronic Revenue ($M)	$ 2,370	$ 2,384	$ 2,035
Total Revenue ($M)	$12,123	$12,296	$11,338
Company Funded R&D Expense ($M)	$ 424	$ 408	$ 367
Company R&D Expense ($B)	$ 1.4	$ 1.4	$ 1.5
Capital Expenditure ($M)	$ 275	$ 365	$ 432
Dollar Value of Contracts Awarded ($M)	$ 2,239	$ 5,623	$ 6,260
Return on Sales ($M)	$ 0.05	$ 0.05	$ 0.05
Company-Funded Backlog ($B)	$ 12.0	$ 11.6	$ 14.6

Source: Rockwell International Corporation Annual Report
U.S. Department of Defense
Prudential-Bache

© 1989 Dataquest Incorporated March

DIVISIONS/SUBSIDIARIES

Major Rockwell divisions involved with defense and aerospace contracts include: Autonetics divisions, Collins divisions, North American Aircraft operations, North American Space operations, Rocketdyne, and Satellite and Space Electronics (see Table 2).

Rockwell has a large, commercial semiconductor operation based in Newport Beach, California, which specializes in telecommunications circuits. It also has a government-sponsored GaAs facility, Rockwell Microelectronic Research and Development Center, in Anaheim, California. With 12,000-square-feet of clean room area, it produces high-density GaAs SRAMs (16K) and gate arrays (6K).

Table 2

Rockwell International Corporation
Operations

Location	Number of Employees	Equipment
Rockwell International Corp. Pittsburgh, PA (Parent)	116,418	Headquarters
Autonetics ICBM Sys. Division Anaheim, CA	9,000	Guidance and control systems
Autonetics Marine Sys. Division Anaheim, CA	N/A	Submarine navigation systems
Autonetics Sensors and Aircraft Division Anaheim, CA	9,000	Tactical and strategical sensor systems, ground electrical systems
Collins Defense Comm. Division Cedar Rapids, IA Santa Ana, CA Richardson, TX	5,000	Airplane console radios, radio transmitters,transportable radio systems, defense communications systems
Collins General and Air Transport Aviation Division Cedar Rapids, IA	3,500	Test equipment/ ATE, ground support equipment, cockpit instrumentation

(Continued)

© 1989 Dataquest Incorporated March

Table 2 (Continued)

Rockwell International Corporation Operations

Location	Number of Employees	Equipment
Collins Govt Avionics Division Cedar Rapids, IA	3,500	Functional ATE, portable/field service ATE, avionics test equipment for military aircraft, cockpit instrumentation
Electronic Components Division El Paso, TX	N/A	Passive components
Maine Electronic Group Lisbon, ME	400	Connectors/packaging
Missile Systems Division Duluth, GA	N/A	Nuclear missiles, missile components
North American Aircraft Operations Los Angeles, CA	N/A	Conventional missiles, military aircraft, airframe structures, spacecraft
Rocketdyne Division Canoga Park, CA	8,000	Nuclear missiles, nuclear energy components, space stations, engine systems, rocket engines, space shuttle main engines, space power systems
Rockwell DEL, Inc. Huntington Beach, CA	60	EW communications systems, parallel tube transmitters, airbourne jamming systems, combat simulation systems, optical collimators, RF environmental generators
Satellite and Space Electronics Division Seal Beach, CA	2,500-4,999	Spacebourne processors, surveillance satellites, laser radar, space-based laser R&D, signal/data processing equipment for space, satellite transponders, spacebourne receivers, navigation satellites, laser radar, infrared sensors
Semiconductor Products Division Newport Beach, CA	1,500	Microcomputers, intelligent display controllers, computer ICs, microprocessors, modem chip sets, data modem modules, image modem modules, secure communication ICs, cell-based ICs

(Continued)

© 1989 Dataquest Incorporated March

Table 2 (Continued)

Rockwell International Corporation Operations

Location	Number of Employees	Equipment
Space Transportation Systems Division Downey, CA	9,000	Advanced launch systems, national aerospace planes, space shuttle orbiter, shuttle C, space-based interceptors
Strategic Defense Center El Segundo, CA	N/A	EW equipment, defense/government services, design engineering services

Other Divisions/Subsidiaries:

Allen Bradley Co., Inc.--Milwaukee, WI (subsidiary/holding company)
Automated Quality Systems Division--Highland Heights, OH
Communications Division--Ann Arbor, MI
DataMyte Corp.--Minnetonka, MN
Decision Software Co., Inc.--Cambridge, MA
Drives Division--Cedarburg, WI
Electronics Corp.--Waltham, MA (subsidiary/holding company)
Fireye Division--Waltham, MA
Graphic Systems Division--Chicago, IL
Industrial Computer Group--Highland Heights, OH
Intelligent Motion Control Division--Highland Heights, OH
Intelligent Sensing Products Division--Milwaukee, WI
Microelectronics Research & Development Center--Anaheim, CA
Miehle Products Business Unit--Westmont, IL
Network Interface Products Division--Downers Grove, IL
Network Transmission Systems Divsion--Richardson, TX
Operator Interface & Logic Products Division--Milwaukee, WI
Packaged Control Products Division--Milwaukee, WI
Photoswitch Division--Waltham, MA
Power Products Divsion--Milwaukee, WI
Programmable Controller Division--Highland Heights, OH
Rockwell Int. and Suspension Systems Co., Inc.--Troy, MI
Science Center--Thousand Oaks, CA
Springs & Stampings--Logansport, IN
Switching Systems Division--Downers Grove, IL
Systems Division--Waltham, MA
Winding Products Division--Reading, PA

N/A = Not Applicable

Source: Dataquest
March 1989

© 1989 Dataquest Incorporated March

CONTRACT ACTIVITY

Rockwell was NASA's largest contractor, receiving 25 percent of all contracts awarded in fiscal year 1987. NASA has selected Rockwell as one of the three contractors for the low-earth orbit X-30 National Aerospace Plane (NASP) development. It is designed to fly up to 25 times the speed of sound. Rockwell is also working under a $25 million three year contract to design and test X-30 airframe components, and the Rocketdyne Division won an $85 million contract to develop a hypersonic engine for the aircraft.

The Space Operations Division won a $1.3 billion contract to replace the space shuttle Challenger. A potential of approximately $4 billion exists for this division to manage shuttle flight preparation, training, and sustained engineering under a long-term contract.

Demand is increasing for Rocketdyne-built liquid-fueled propulsion systems for a variety of unmanned, expendable launch vehicles for DOD, NASA, and commercial customers. Under a $103 million contract, Rocketdyne is building an additional 25 fourth stages for the air force's Peacekeeper ICBM, which went into service in mid-1987. Rocketdyne is also a lead in NASA's space station program working on the power system under a $1.6 billion contract.

The Satellite and Space Electronics Division developed and is producing the network of NAVSTAR Global Positioning System (GPS) satellites. The first of 28 Block II satellites was delivered in mid-1987 under a $1.3 billion contract.

Rockwell's Strategic Defense Center has been awarded a total of $1 billion in contracts on SDI projects. These include elements of the Space Based Interceptor program; Boost Surveillance and Tracking System (BSTS); and concept development of the National Test Bed, a computer network to simulate strategic defense concepts and systems. In June 1988, the Space and Transportations Division won a $209 million contract for development of a space-based kinetic-kill vehicle program.

Rockwell is teamed with Messerschmitt-Bolkow-Blohm of West Germany on the X-31A Enhanced Fighter Maneuverability program for the U.S. and West German defense departments. This $80 million program is to develop fighters that allow more effective close-in combat than existing aircraft. Flight tests schedules in 1989 are designed to demonstrate technologies that "break the stall barrier." Rockwell was also awarded an air force contract for $155 million, with options for another $300 million, to outfit new C-130 cargo planes as highly sophisticated AC-130U gunships.

Guidance and navigation programs form the largest sector of Rockwell's defense electronics business. Under a $190 million contract form the air force, the Company continued production of Peacekeeper guidance and control systems. Rockwell also recently qualified as second source for the MX inertial measurement unit for fiscal year 1988. Rockwell is delivering improved guidance systems for the deployed Minuteman force and is also developing systems for the new generation of Small Intercontinental Ballistic Missiles (SICBM). Earlier this year, the Company was awarded a $162 million contract for the launch control system for the Rail Garrison MX program.

 © 1989 Dataquest Incorporated March

Rockwell International Corporation

Rockwell is the sole supplier for the navy's Polaris and Trident submarine fleet's inertial navigation systems. During 1987, the Company was named team leader on a $575 million contract to supply combat systems for six Royal Australian Navy submarines. The first submarine was delivered in September 1987.

Rockwell continues to produce a ground-based and air-launched version of the antiarmor Hellfire laser-guided missile for the U.S. Army and Marine Corps. Sweden placed an order for $65 million for a ground-launched antiship version of Hellfire.

Rockwell has been active in the C^3I programs for several years. It is developing advanced, jam-resistant, radiation-hardened communications terminals for the MILSTAR satellite network. The Company is now the principal supplier of very low frequency (VLF) equipment to the DOD. In the fourth quarter of 1987, a C^3I team led by Rockwell and Marconi Communications, of the United Kingdom, began developing advanced high-frequency, antijam communications systems for the U.S. Navy. While the initial contract is for $42 million, the program has long-term, multibillion-dollar sales potential.

In commercial avionics, Rockwell's Advanced Railroad Electronics System (ARES) employs GPS technology to pinpoint train locations and enhanced energy management by monitoring fuel consumption, engine settings, and maintenance. In defense avionics, in 1988, GPS user equipment moved into production for the DOD. Rockwell has won $235 million in GPS production contracts with options for an additional $215 million.

Table 3 shows a summary of other major contracts received during the last two years.

Table 3

**Rockwell International Corporation
Contracts**

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
Rocket Engines	NASA Marshall Space Flight Center	$83	1/87	P	Prime	Rocket systems and components
		$45	2/87			
		$28	4/87			
		$883	6/87			
		$56	8/87			
		$36	10/87			
		$37	11/87			
		$66	12/87			
SRAM II	Aero Systems Division	$132	9/88	PSD	Prime	B-1B weapons system/ Short Range Attack Missile II
B-1B	Aero. Systems Division	$121	5/87	P	Prime	Additional work for aircraft accessories enhancement function level IV retrofit
		$77	1/88			
SICBM	AF	$110		PSD	Prime	Guidance and control integration
OV-10A	Navy	$121	8/88		Prime	Upgrade OV-10A to an OV-10D configuration

(Continued)

© 1989 Dataquest Incorporated March

Table 3 (Continued)

Rockwell International Corporation Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
Space Transport System	NASA Johnson Space Center	$51	1/87	RDT&E	Prime	Space system development
		$83	2/87			
		$91	3/87			
		$24	5/87			
		$43	6/87			
		$28	7/87			
		$49	8/87			
		$36	9/87			
		$33	10/87			
		$51	11/87			
NAVSTAR	AF Space Division	$64	5/87	RDT&E	Prime	Additional work for NAVSTAR engineering development
		$38	7/87	P		spares
		$69	4/88			5,387 additional line replaceable units
Bombs	AF Armament Division	$42	9/87	P	Prime	Additional work for spares
UGM-96 Trident	Navy Special Projects Office	$64	5/87	P	Prime	Missile equipment
Missile/Space Adv Dev	AF Ballistic Missile Office	$29	3/87	RDT&E	Prime	AC-23
		$33	5/87			
X-31 EFM	Navy	$47	9/88	RDT&E	Prime	Enhanced Fighter Maneuverability vectored thrust, integrated control systems, and aircrew assistance
Electronic and Communications Equipment	Navy Space/ Warfare Center	$28	10/87	RDT&E	Prime	N/A
Radio & TV Comm Equip	AF Warner Robins Logistics Center	$28	9/87	P	Prime	Aircraft upgrades
AN/WSN-2	Naval Sea Systems Cmnd.	$27	10/87	P	Prime	Additional work for AN/WSN-2 parts
C-130 Hercules	AF Aero. Systems Division	$26	7/87	RDT&E	Prime	Aircraft upgrades
F-111	AF Sacramento Air Logistics Center	$23	9/87	P	Prime	Radar

N/A = Not Available
P = Production
RDT&E = Research, Development, Test, and Evaluation
Dm/V = Demonstration and Evaluation
SS = Second Source
P-2 = Prime Contractor--Team of 2; P-4 = Prime Contractor--Team of 4
FSD = Full-Scale Development

Source: U.S. Department of Defense

© 1989 Dataquest Incorporated March

Thomson–CSF

COMPANY DIRECTIONS

Thomson–CSF is one of the world's leading electronics companies. In the defense market, the Company is involved with sophisticated military electronic equipment, aerospace, weapons systems, and detection control and communications systems. It is also a leader in military simulation markets and produces head–up displays and navigation equipment.

Thomson–CSF Activites Sous–Marines (ASM) is a world leader in mine warfare field implements and produces combat systems such as Eledone. This system is currently in operation on–board the submarines of several countries. Thomson–CSF ASM also produces a complete range of digital panoramic sonars, as well as airborne ASW systems such as the DSAX1.

Thomson–CSF's efforts have been directed toward concentrating on and improving its primary business. In September 1986, this strategy led Thomson–CSF to reorganize its defense electronics activities into three main group headings: aerospace, systems and weapons systems, and detection control and communications systems. In May 1987, a new special components group was formed to handle activities in the field of military semiconductors. The Company also relocated its U.S. headquarters to Washington, D.C., to improve links with the Department of Defense (DOD).

Acquisitions and divestitures have formed an integral part of Thomson–CSF's strategic efforts. In 1987, Thomson–CSF formed a joint venture with General Electric and VDO Luftfahrtgerate (West Germany) to design, develop, and manufacture liquid crystal displays (LCDs). In April 1987, Thomson–CSF formed a merger with an Italian chipmaker, SGS Microelecttronica (STET), combining semiconductor operations. This new entity is called SGS–Thomson.

At the beginning of 1988, Thomson–CSF acquired Wilcox Electric Inc., a subsidiary of Northrop in the United States, which specializes in manufacturing navigation and landing aids microwave landing system/instrument landing system (MLS/ILS) for military and civil applications. The move made the Company a world leader in this field. The Company also acquired OMERA radar activities in 1988 from the TRT group. OMERA specializes in designing and manufacturing airborne radars for helicopters and transport aircraft. In another strategic move during 1988, Thomson–CSF announced its intention to buy Allied–Signal's Ocean Defense antisubmarine unit. The sale, which was canceled, would have increased Thomson–CSF's antisubmarine sales by more than 30 percent.

In August 1988, Thomson–CSF's Electron Tube Division announced that it was developing a line of helix traveling wave tubes (TWT) for applications in electronic warfare. With the TWTs, the next generation of electronic warfare (EW) transmitter design will be able to perform electronic countermeasures (ECMs) and radar functions. Thomson–CSF has also invested $25 million in ANADIGICS, a three–year–old company that recently unveiled a GaAs fiber–optic chip for high–data–rate transceiver applications.

© 1989 Dataquest Incorporated March

Thomson–CSF

In September 1988, Thomson announced that, as part of a realignment of its overall aerospace equipment operations, the Company would sell off its Thomson–Lucas operation, which comprises three affiliates—Auxilec, ABG–Semca, and Bonzavia.

FINANCIAL INFORMATION

More than 70 percent of Thomson–CSF's research and development (R&D) expenditures and approximately 50 percent of capital expenditures are used for the electronics and defense systems segment (see Table 1). This segment also accounts for most of the backlog orders. In spite of a decline in gross margin, return on sales for the Company actually improved 20 percent in 1987, reflecting a tighter hand on Company expenses. In 1987, the debt–to–equity ratio also improved markedly from 80 percent to 40 percent.

Table 1

Thomson–CSF
Financial Information

	1987	1986	1985
Mil/Aero Electronic Revenue ($M)	$ 2,709	$3,044	$2,432
Total Revenue ($M)	$ 6,099	$5,047	$3,587
Company R&D Expense ($M)	$ 551	$ 494	$ 325
Company Capital Expenditure ($M)	$ 394	$ 465	$ 369
Dollar Value of Contracts Awarded	N/A	N/A	N/A
Return on Sales ($M)	$ 0.07	$ 0.06	$ 0.03
Company-Funded Backlog ($M)	$10,710	$9,940	$8,360

N/A = Not Available

Source: Thomson-CSF Annual Report
U.S. Department of Defense
Prudential-Bache

DIVISIONS/SUBSIDIARIES

Major subsidiaries involved with defense and aerospace contracts include LMT Radioprofessionnelle, CIMSA, and Thomson SINTRA Activites Sous–Marines (see Table 2). The Company's total work force is approximately 63,000 people. About 42,000 employees are involved in electronics and defense systems, and 15,000 are in the aerospace group.

© 1989 Dataquest Incorporated March

Thomson–CSF

Table 2

Thomson–CSF
Operations

Location	Equipment
Thomson-CSF Paris, France (Parent Company)	Headquarters
Aerospace Group Boulonge Billancourt, France	Headquarters
CEBM--Centre Electronique de Brest-Morlaix Brest Cedex, France	Headquarters
CIMSA SINTRA Division (DCS) Colombes, France	Manufacture of data processing and display equipment
Defense & Control Systems Division (SDC), Bagneux, France	Development and production of surface radars and display systems
Electronics Systems Division Bagneaux Cedex, France	Development and production of weapon systems
General Avionics Division Issy les Moulineaux Cedex, France	General avionic equipment
LCTAR - Le Centre Thomson d'Applications Radars Velizy Villacoublay, France	Headquarters
LMT - Radio Professionelle Boulonge-Billancourt Cedex, France	Military communications, ground surveillance radar
Radar, Countermeasures and Missile Electronics Div (RCM) Malakoff, France	Manufacture of airborne radars, countermeasures and missile electronics
Simulator Division Trappes Cedex, France	Development and production of simulators for aircraft, tanks, ships, and submarines

(Continued)

Table 2 (Continued)

Thomson-CSF
Operations

Location	Equipment
TEK - Thomson-CSF Electronik GmbH Koblenz, West Germany	Headquarters
Thomson-CSF Radant Les Ulis Cedex, France	Headquarters
Thomson SINTRA Activites Sous-Marines (ASM) Cagnes-sur-Mer, France	Development and production of sonars, torpedo homing heads, and airborne ASW equipment
U.S. Subsidiaries	
Burtek Tulsa, OK	Aircraft training/simulation equipment
Phonon Corp. Simsbury, CT	Defense ground support equipment, electronic subsystems, passive components, measuring/sensing/controlling, data communications equipment
SGS-Thomson Microelectronics, Inc. Carrollton, TX	Computers, semiconductors/devices

Other Divisions

SODETEG--Societe d'Etudes Techniques et d'Enterprises Generales--Plessis-Robinson Cedex, France
Thomson-CSF Cooperation--Versailles, France
TEX--Division Traveaux Exterieurs et Services--Saint-Denis Cedex, France
Telecommunications Division (DTC)--Gennevilliers Cedex, France
Syseca--Saint-Cloud Cedex, France
Electron Tube Division--Boulonge Billancourt, France

Source: Dataquest
March 1989

 © 1989 Dataquest Incorporated March

Thomson-CSF

Thomson-CSF has both semiconductor fabrication and hybrid assembly capabilities. Thomson Composants Militaires et Spatiaux, located in Saint Egreve, France, is dedicated to supplying products such as ASICs (bipolar and CMOS), memories (DRAMs, SRAMs, and EPROMs), microprocessors (68XXX, 29XX, and COPS), standard linear, and discretes.

CONTRACT ACTIVITY

Thomson-CSF has provided all air-to-air radars for French combat aircraft since the Mirage III. In exchange for its radar technology, Texas Instruments will receive information on air-to-air radar techniques and will join with Thomson-CSF to develop an active-array radar for next-generation European-designed aircraft.

Thomson-CSF is actively engaged with GTE in supplying battlefield communications systems (RITA/MSE) to the U.S. Army, a $4.3 billion program expected to run through 1994.

The Thomson SINTRA ASM division has a major role in the undersea and surface naval electronics markets. The division provides the Eledone range of sonar systems and also makes passive countermeasures. Thomson SINTRA ASM teamed with Raytheon for the development of the SQQ-32 mine-hunting sonar. In early 1988, this division also won contracts from the Dutch navy to supply hull-mounted and tactical towed-array sonars for eight Dutch navy M-class frigates. It also furnished the Norwegian and Danish navies with degaussing systems.

In 1988, Hamilton Standard and Thomson-CSF jointly received a U.S. Army contract for 56 VH 100 head-up displays (HUDs), which are a part of the Air-to-Air Stinger (ATAS). The HUD is entirely electronic and has a field vision of 20 degrees, and its sighting system can be linked to any type of air-to-air weapon.

Thomson-CSF produces the Raphael side-looking airborne radar, the heliborne Orchidee system for battlefield surveillance, and a wide range of shipborne radars and image-processing systems. In 1987, contracts for radar systems included a RASIT battlefield surveillance radar, selected by the People's Republic of China; TRS-22XX long-range 3-D air defense radars to enhance ground detection capabilities for the French air force; and 23 Triton-G surveillance radars for the West German navy. Thomson-CSF was also selected to supply angle-of-attack sensors for the ATR-72 airliner and full-flight simulators for the French domestic carrier, Air Inter.

Missile electronics is a major area of Thomson-CSF's participation. The Company supplies seekers for the West German Navy's Kormoran antiship missile, for MLRS and AS30L missiles, and for guided bombs. The Crotale and Shahine surface-to-air ground and naval systems were developed and are in production by the Company. The Mygale short-range air defense system, which detects, identifies, and designates hostile air

© 1989 Dataquest Incorporated March

targets for up to eight man-portable missile launchers such as Mistral or Stinger, was also developed by the Company and recently has been ordered by the French army. Thomson-CSF and LTV jointly offer the Liberty Air-Defense System, which was recently ordered by Finland and is a contender for the Army Mobile Air Defense System.

In the command, control, and communication (C^3I) markets, the Company is bidding for NATO's Air Command and Control System (ACCS). Thomson-CSF also provides France with the Ramses strategic forces communications network, which is interoperable with the Joint Tactical Information Distribution System (JTIDS).

© 1989 Dataquest Incorporated March

TRW, Inc.

COMPANY DIRECTIONS

TRW, Inc., is a leader in space electronics and C^3I systems, participating in multiple programs in these areas. The Company also has established a leadership position in next-generation avionics as a participant in the INEWS and ICNIA programs. These systems will serve as the common electronic warfare and identification, communications, and navigations systems for the ATA, ATF, and LHX programs.

In space and defense, the Company intends to concentrate on C^3I and national strategic programs of high priority where its technology can create a sustainable advantage. In February 1988, in preparation for U.S. Department of Defense (DOD) program budget cuts, TRW announced plans to pare its space and defense work force by as much as 10 percent or roughly 3,000 workers.

To focus more on its three high-technology fields—space and defense (45 percent), automotive (40 percent), and information systems (8 percent)—TRW has been divesting itself of several of the following slow-growing peripheral businesses:

- Motorola bought TRW's RF semiconductor division, which has plants located in Lawndale, California, and Bordeaux, France.
- Optec Technology in McKinney, Texas, acquired TRW's optoelectronics division with facilities in Juarez, Mexico, and Carollton and Mineral Wells, Texas.
- TRW plans to sell its LSI Products Division, which makes integrated and hybrid circuits.

In September 1989, TRW Electronic and Technology Division, Redondo Beach, California, is scheduling a demonstration of the world's first self-healing microelectronic "superchip"—called central processing unit arithmetic extended (CPUAX). CPUAX will be an integral part in Phase II of the DOD's very high speed integrated circuit (VHSIC) program in which TRW is one of three teams. The division is also a participant in the program sponsored by the Defense Advance Research Projects Agency (DARPA) to develop and apply monolithic millimeter and microwave integrated circuit (MIMIC) technology.

The TRW Space and Technology Group has opened a $6 million, 22,000-square-foot building at Space Park, Redondo Beach, California, for assembling, testing, and integrating space shuttle class payloads. Employees now are working on the Gamma Ray Observatory, a $250 million contract for a 17-ton spacecraft scheduled for launch in 1990. TRW also hopes to build other space payloads such as the Advanced X-Ray Astrophysics Facility. Other efforts that will support the observatory are the Orbital Maneuvering Vehicle to be used to reboost and service the Observatory's and NASA's Tracking and Data Relay Satellite that will send the findings of the great observatories to earth.

© 1989 Dataquest Incorporated March

TRW, Inc.

TRW Space and Technology Group has a strong track record in scientific spacecraft, including the building of 175 scientific, defense, and communications spacecraft; the development of more than 200 advanced space instruments; and the integration of some experiments in the host spacecraft.

FINANCIAL INFORMATION

In 1987, sales in space and defense rose 16 percent and accounted for 45 percent of the company's $6.8 billion net sales (see Table 1). A backlog of orders for space and defense increased 25 percent to approximately $4.5 billion at the end of 1987. Operating profit for this group rose 19 percent to $237 million. Capital expenditures and research and development (R&D) expenditures for this group have remained relatively level for the last three years.

Table 1

TRW, Inc.
Financial Information

	1987	1986	1985
Mil/Aero Electronic Revenue ($M)	$2,906	$2,434	$2,370
Total Revenue ($M)	$6,821	$6,036	$5,917
Company R&D Expense ($B)	$ 329	$ 339	$ 324
R&D Under Contract ($M)	$1,545	$1,349	$1,238
Capital Expenditure ($M)	$ 216	$ 210	$ 202
Dollar Value of Contracts Awarded ($M)	$1,113	$1,039	$1,067
Return on Sales ($M)	$ 0.04	$ 0.04	0
Company Funded Backlog ($B)	$ 4.5	$ 3.6	N/A

N/A = Not Available

Source: TRW, Inc., Annual Report
U.S. Department of Defense
Prudential-Bache

© 1989 Dataquest Incorporated March

DIVISIONS/SUBSIDIARIES

TRW's major subsidiaries include the Defense Systems Group, Electronic Systems Group, Federal Systems, and Space and Technology Group (see Table 2).

Table 2

TRW, Inc.
Operations

Location	Number of Employees	Equipment
TRW Inc. Cleveland, OH	77,931	Headquarters
Ballistic Missile Division San Bernadino, CA	1,100	Defense/government services
Carr Division Niagara Falls, NY	2,000	Electronics manufacturing services, relays, electronic function controls, time-measuring equipment
Connector Division Elk Grove Village, IL	N/A	Splicing equipment, connectors, sockets, adapters
Cylindrical Connector Division Fairfax, VA	350	Fiber-optic contacts, cable assemblies and harnesses, coaxial and power contacts, cylindrical connectors, filter-pin contacts
ESL, Inc. Sunnyvale, CA	2,600	Military communications systems, strategic reconnaissance systems, tactical reconnaissance systems, defense simulation systems
Federal Systems Group Fairfax, VA	1,000 to 2,499	Defense/government/telecommunication services
Military Electronics Division San Diego, CA	N/A	EW communications systems, space defense systems, surveillance/tracking systems, defense warning systems, military aircraft
System Development Division Redondo Beach, CA	2,100	Mission control centers, satellite ground stations, real-time command/control systems, sensor data processing, telecommunications

(Continued)

© 1989 Dataquest Incorporated March

Table 2 (Continued)

TRW, Inc.
Operations

Location	Number of Employees	Equipment
TRW Electronic Products Colorado Springs, CO	N/A	DC-to-DC converters, RF communications systems, multiplexers, signal-processing equipment, digital-communications systems
TRW Electronics and Defense Redondo Beach, CA	N/A	ASW equipment, EW equipment, missile launch vehicles, ordnance systems, military satellites, scientific satellites, reentry vehicles

Other Subsidiaries/Divisions

Brandt Solids Control Division--Conroe, TX
Electronic Assemblies Division--Schaumburg, IL
Fasteners Division--Cambridge, MA
Globe Motors--Dayton, OH
Heavy Duty Parts Division--Lemoyne, PA
Information Networks Division--Torrance, CA
Mission Drilling Division--Houston, TX
Mortgage Systems, Inc.--Orange, CA
Nelson Stud Welding Division--Lawrence, KS
Ross Gear Division--Lafayette, IN
Title Data, Inc.--Englewood, CO
Transportation Electronics Division--Framington Hills, MI
TRW Communications Group--Los Angeles, CA
TRW Financial Systems, Inc.--Berkeley, CA
TRW Pleugger--Statesville, NC

N/A = Not Available

Source: Dataquest
March 1989

© 1989 Dataquest Incorporated March

TRW, Inc.

CONTRACT ACTIVITY

TRW was the fourth-largest recipient of Strategic Defense Initiative (SDI) funds in fiscal year 1987 with contracts worth $779 million and obligations of $425 million. Work in the SDI program includes the space-based alpha laser and the ground-based free electron laser, space surveillance and tracking systems (SSTS), as well as battle management/command control and communications (C^3I) systems.

The Company is developing the electronic payload for the MILSTAR communications satellite, work valued at approximately $1 billion. Major prime contracts received in 1987 were a $743 million contract from the air force to build satellites for the defense support program and an $813 million contract from the army for lightweight radio units. TRW continues to be the largest contractor supplying software in Ada.

TRW is the prime contractor for the navy's fleet satellite communications systems (FLTSATCOM) and defense support program satellites (DMSP). The Company is participating on three out of four teams for ICNIA and INEWS. TRW also is designing new avionics systems for the advanced tactical fighter.

TRW is a leader in defense information systems (C^3I) and is currently working on a $225 million ocean surveillance information system, a $59 million forward area air defense system, an $87 million battlefield information processing system, and a $37 million antisubmarine warfare operations center system.

Table 3 presents a summary of other major contracts received during the last two years.

© 1989 Dataquest Incorporated March

Table 3

TRW, Inc. Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
Space Vehicle Components	AF Space Division	$129	7/87	P	Prime	
MIMIC	DARPA	$58	6/88	RDT&E	P-4	Microwave/millimeter-wave monolithic integrated circuits
LGM-30 Minuteman	AF Ogden Logistics Center	$22	10/87	P	Prime	Management service-systems engineering
MX-Missile	AF Ballistic Missile Office	$36 $11 $10	11/87 11/87 12/87	RDT&E	Prime	Missile/space engineering development
Ships	AF Space Division	$11	7/87	RDT&E	Prime	Operational systems
Misc. Comm. Equipment	AF Electronic Systems Division	$11	8/87	P	Prime	Communication equipment
Space Vehicles	NASA Marshall Space Flight Center	$12 $13	8/87 9/87	P	Prime	Space hardware and services
Misc. Comm. Equipment	AF Gunter	$17	1/87	P	Prime	Communication equipment
BDM	Naval Underwater Systems Center	$46 (est.)	2/88	P	Prime	Engineering and technical service for designing, development, and fabrication of surface ship BDM
ICNIA, INEWS	AF	$48	6/86	Dm/V	P-2	
Booster Rockets Tomahawk Missile	Navy	$27	4/88	P	P-2	Booster rockets
AN/PRC-17 (X)	Army Communications Electronics Cmnd.		2/88	P	Prime	49 radios
SICBM	AF Ballistic Missile Office	$60	11/88	RDT&E	Prime	Engineering/technical assistance
UHF	Navy	$21	11/88	P	Sub	11 dual-channel processors

P = Production
RDT&E = Research, Development, Test, and Evaluation
Dm/V = Demonstration and Evaluation
SS = Second Source
P-2 = Prime Contractor--Team of 2; P-4 = Prime Contractor--Team of 4

Source: U.S. Department of Defense

© 1989 Dataquest Incorporated March

Unisys Corporation

COMPANY DIRECTIONS

Unisys Corporation was formed in 1986 as the product of the merger between Sperry and Burroughs and is a major provider of information processing systems. The Company designs, engineers, manufactures, markets, and supports electronics-based information systems for communications, defense, and commercial applications. It specializes in the manufacture of mainframe, mini-, and high-end microcomputers and a wide range of peripherals.

Unisys Defense Information Group provides defense electronics through five major lines: shipboard and ground systems, systems development, communications systems, system support, and computer systems. Unisys supplies the defense market with some of the most sophisticated information systems in the world, based on its unique understanding of the military's operational, tactical, and technical capabilities. Unisys is also a prime supplier to the ministries of defense of U.S. allies and to federal government agencies.

Unisys is developing a third-generation airborne battlefield command and control center (ABCCC3) in a capsule for specially modified air force EC-130s to provide contingency command control for forward areas of the battlefield. The center serves as an airborne extension of several ground-based control agencies.

Culminating a ten-year cooperative effort by Unisys and four government agencies, next-generation weather radar (NEXRAD) is now entering production under a $450 million, multiyear contract. By the mid-1990s, 175 NEXRAD systems will be installed for commercial use and at military sites worldwide.

Unisys expects to be a leader in avionic systems for the 1990s. Consequently, it has expanded its role in advanced modular avionics and very high speed integrated circuit (VHSIC) central computers for U.S. combat aircraft during the last year. The Unisys Common Module family that includes various standard modules currently consists of: 16-bit 1750 MPU modules; 32-bit MPU modules planned; communication modules (1553B, high speed, dual speed); memory (EEPROM, CMOS); and power modules.

FINANCIAL INFORMATION

Unisys plans to double the size of its total business to $20 billion by the early 1990s. Growth will come through internal expansion and acquisitions in selected high-growth areas. In 1987, Unisys had total sales of $9.71 billion (a growth of approximately 30 percent over 1986) and ranked eighth in defense electronics sales with sales of $2.43 billion or 25 percent of total sales (see Table 1).

© 1989 Dataquest Incorporated March

Unisys Corporation

Table 1

Unisys Corporation
Financial Information

	1987	1986	1985
Mil/Aero Electronic Revenue ($M)	$2,428	$2,765	$2,488
Total Revenue ($M)	$9,713	$7,432	$5,038
Company R&D Expense ($M)	$ 597	$ 441	$ 285
R&D under Contract ($M)	$ 722	$ 550	$ 230
Capital Expenditure ($M)	$ 721	$ 553	$ 450
Dollar Value of Contracts Awarded ($M)	$2,326	$1,856	N/A
Return on Sales ($M)	$ 0.06	0	$ 0.05

N/A = Not Available

Source: Unisys Corporation
Annual Report
U.S. Department of Defense
Prudential-Bache

Cost savings accrued from the structural changes made since the 1986 merger are being transformed into opportunities for long-term growth through research and development (R&D), whose budget increased 20 percent in 1988. In fiscal year 1987, Unisys ranked fifth in electronic vendors R&D expenditures, having invested $597 million in R&D.

DIVISIONS/SUBSIDIARIES

Unisys defense electronics operations are grouped under Unisys Defense Systems. Divisions in the Defense Systems Group are Shipboard and Ground Systems, Computer Systems, Systems Development Group, Systems Support Group, and Communication Systems Division (see Table 2).

Table 2

Unisys Corporation Operations

Location	Number of Employees	Equipment
Unisys Corporation Detroit, MI (Parent Company)	92,500	Headquarters
Defense Systems St. Paul, MN	26,000	Headquarters
Communication Systems Group Salt Lake City, UT	N/A	Telecommunications, intelligence, data communications, computers
Computer Systems Division Eagan, MN	N/A	Information processing systems, militarized computer products & displays
Shipboard & Ground Systems Group Great Neck, NY	2,500 to 4,999	Sonar equipment, EW communication systems, sonar countermeasures equipment, ground defense radar systems, shipboard navigation equipment, shipboard radar equipment
System Development Group Camarillo, CA	N/A	N/A
System Support Group McLean, VA	N/A	Technical services, facilities management, integrated systems
Timeplex, Inc. Woodcliff Lake, NJ	1,500	Utility software, data communications equipment
Unisys Knowledge Systems Organization Paoli, PA	100 to 249	Artificial intelligence

Other Divisions/Subsidiaries

Foundation Computer Systems--Cary, NC
GRAFTEK, Inc.--Boulder, CO
Memorex--Santa Clara, CA
Pasadena Plant--Pasadena, CA

N/A = Not Available

Source: Dataquest
March 1989

© 1989 Dataquest Incorporated March

CONTRACT ACTIVITY

The navy accounts for a major percentage of Unisys defense revenue. Unisys is an alternate supplier for the Aegis combat system that will be used aboard more than 50 guided missile cruisers and destroyers. In April 1988, the Unisys/Westinghouse team won a $10 million qualification contract that will lead to becoming second-source producers for the Aegis SPY-1D electronic radar. Unisys, a leading supplier of shipborne computers, is replacing the navy's old, small general-purpose computers with the embedded computer system family--UYK43 and UYK44. Unisys also has won a $280 million contract to supply microcomputers throughout the defense department.

The navy awarded Unisys a $509 million contract in March 1988 for the initial production of navigation systems for D-5 Trident II missile-firing submarines. Installation on the first Trident submarine, the USS Tennessee, was completed and integration tests started in 1987. The Company is also a second-source contractor for the MK 99 fire control system for the navy.

The Unisys design for the Next Generation Weather Radar (NEXRAD) was selected jointly by the National Oceanic and Atmospheric Administration (NOAA), the Federal Aviation Administration (FAA), and the U.S. Air Force. Using Doppler radar, the program will improve detection of severe weather and increase the warning times for weather hazards. The contract is potentially worth $450 million.

The air force selected Unisys for the YF-23 advanced tactical fighter (ATF) avionics processor. Unisys also was selected to be one of the two major suppliers to the air force's rapid deployment, high-capacity voice communications project—the AN/TRC—170 Troposcatter Digital Microwave Communication System.

At the end of 1987, the Royal Thai Air Defense System (RTADS), which Unisys is designing, integrating, and installing was more than half complete. The Unisys $1.1 billion contract covering electronic combat systems for six Canadian frigates assigned to the Unisys Canadian subsidiary, Paramax Electronics Inc., was extended by $1 billion to enable it to supply systems for six more frigates.

Unisys is instrumental in the FAA's air traffic control automation and modernization program and supplies all of the FAA's terminal automation systems. The first intelligent expanded memory displays for the New York Terminal Radar Approach Control (TRACON) was delivered to the FAA for testing during 1987. The system will regulate more than 6,000 daily flights serving New York City.

Table 3 shows a summary of other major contracts received during the last two years.

© 1989 Dataquest Incorporated March

Table 3

Unisys Corporation Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
F-16	Navy	$101	5/88	P	Sub	Support equipment for F-16 and shipboard firing systems
UGM-96 Trident	Naval Sea Systems Cmnd.	$87	11/87	RDT&E	Sub	Missile system development
AN/TRC-170 Radio	AF Electronic Systems Division	$38	6/87	P	Prime	Radio, miscellaneous electronics
AN/SPG-55	Naval Sea Systems Cmnd.	$35 $14 $14	2/87 9/87 10/87	P	Prime	Radar antenna
AN/AYK-14(V)	Naval Sea Systems Cmnd.	$30	5/88	P	Prime	65 units with option to build 365 additional airborne computers
Electrical and Electronic Comp.	Maryland Procurement Office	$30	7/87	P	Prime	Miscellaneous equipment
Comm. Equipment	Maryland Procurement Office	$30	7/87	P	Prime	Security equipment and components
MK-92	Naval Sea Systems Cmnd.	$27 $28	3/87 6/87	P	Prime	Additional work for fire control system
ADP Input/Output	Naval Sea Systems Cmnd.	$25	9/87	P	Prime	Additional work for I/O equipment
UYK-43 Computers	Naval Sea Systems Cmnd.	$16	4/88	P	Prime	
Combat System	Navy	$16	9/88	P	Prime	Combat systems for Spanish frigate
AN/UYK-7 Computer System	Naval Sea Systems Cmnd.	$14 $15	3/87 4/87	P	Prime	Computer Equipment
ABCCC III Units	AF Electronic Systems Division	$14	5/88	P	Prime	8 units to be installed in EC-130E aircraft
Armament Training Dev.	Army Munitions and Chem. Cmnd.	$13	9/87	P	Prime	Training equipment
MATCALS	Navy Space/Warfare Center	$13	12/87	P	Prime	Radar equipment

(Continued)

© 1989 Dataquest Incorporated March

Table 3 (Continued)

Unisys Corporation
Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
C-135 Stratrolifter	AF Oklahoma Logistics Center	$13	3/87	P	Prime	Additional work for aircraft equipment
AEGIS Air Defense Equipment	Navy	$11	2/88	P	Prime	AEGIS add-on
Plant Equipment	Navy DC Purchase Office	$10	10/87	P	Prime	Miscellaneous materials handling equipment
AN/APN-59 Radar	AF Warner Robins Logistics Center	$10	4/87	P	Prime	Weather radar

P = Production
RDT&E = Research, Development, Test, and Evaluation
Dm/V = Demonstration and Evaluation
SS = Second Source
P-2 = Prime Contractor--Team of 2; P-4 = Prime Contractor--Team of 4

Source: U.S. Department of Defense

 © 1989 Dataquest Incorporated March

Westinghouse Electric Corporation

COMPANY DIRECTIONS

Westinghouse Electric Corporation continues to maintain its key role in the radar market. Its technological leadership in the F-16 radar helped make the Company a winner of the radar competition for both ATF teams. More than 3,000 aircraft in the United States are equipped with F-16 radar. Westinghouse's presence is also being felt in the electronic countermeasures market where it continues to receive key contracts. In the weapons market, Westinghouse continues to provide launchers for navy torpedoes and is also an important supplier of propulsion systems for the navy.

In January 1988, Westinghouse reorganized into seven groups to serve its markets more effectively and created an independent Defense Group. The new Defense Group, which formed part of the Energy and Advanced Technology Group, will continue its activities in C^3I, radar, electronic and naval warfare systems, and countermeasures equipment. The Company's technological depth and innovative research and development have played an integral role in the success of the Westinghouse Defense Group, whose sales and operating profit have steadily increased despite the tightening defense budget.

Also in 1988, Westinghouse Defense Electronics purchased Gould Ocean Systems Division for $100 million. The Ocean Systems subsidiary makes undersea systems, including heavy torpedoes. With the acquisition, Westinghouse will be able to supply surface, air, and submarine-launched torpedoes.

Westinghouse has been a leading participant in the Very High Speed Integrated Circuits (VHSIC) program including both the development and insertion phases. The Company's principle semiconductor operations are located in the Advanced Technology Division in Baltimore, Maryland. Based on 1.25- and 0.7-micron CMOS, SOS, GaAs, CCD, and bipolar technologies, the Company produces gate arrays (up to 54K gates), SRAMs, nonvolatile memory, data conversion, and various interface components. In 1987, Westinghouse created the Chesapeake Group to market its gate array family.

FINANCIAL INFORMATION

In 1987, both research and development (R&D) and capital expenditures dropped for the second consecutive year for the Energy and Advanced Technology Group (see Table 1). Sales for the Energy and Advanced Technology Group, which included the Defense Group in 1987, fell 3 percent during 1987. The Defense Electronics Group continued its sales and operating profit increases and greatly contributed to the 7 percent improvement in operating profits for the Energy and Technology Group. Backlog for this group remained at the $8.4 billion level.

© 1989 Dataquest Incorporated March

Table 1

Westinghouse Electric Corporation
Financial Information

	1987	1986	1985
Mil/Aero Electronic Revenue ($M)	$ 1,807	$ 1,720	$ 1,605
Total Revenue ($M)	$10,679	$10,731	$10,700
Company R&D Expense ($M)	$ 152	$ 174	$ 176
R&D under Contract ($M)	$ 552	$ 629	$ 695
Capital Expenditure ($M)	$ 198	$ 221	$ 229
Dollar Value of Contracts Awarded ($M)	$ 1,653	$ 1,708	$ 1,953
Return on Sales ($M)	$ 0.07	$ 0.06	$ 0.06
Company-Funded Backlog ($B)	$ 8.4	$ 8.6	$ 9.1

Source: Westinghouse Electric Corporation
Annual Report
U.S. Department of Defense
Prudential-Bache

DIVISIONS/SUBSIDIARIES

In January 1988, Westinghouse reorganized into seven groups: broadcasting, defense electronics, financial services, industries, commercial, energy and utility systems, and international. Subsidiaries and divisions that receive defense and space contracts include Defense and Electronics Systems, Defense Unit, and Integrated Logistics Support (see Table 2).

© 1989 Dataquest Incorporated March

Table 2

Westinghouse Electric Corporation
Operations

Location	Number of Employees	Equipment
Westinghouse Electric Corporation Pittsburgh, PA (Parent)	112,000	Headquarters
Defense and Electronics Systems Center Baltimore, MD	N/A	Ordnance systems/equipment, lasers/ laser-related equipment, electron tubes, broadcasting/receiving equipment, data communications equipment
Defense Unit Baltimore, MD	N/A	Avionics radar, ship and ground radar, radar test equipment, FLIR systems, sonar, airborne and spaceborne computers, electronic warfare, torpedoes, missile subsystems, reconnaissance systems, communications and navigation systems, hybrid circuits, CMOS and SOS, gate arrays, memories, interface components, microwave components
Energy and Advanced Technology Group Monroeville, PA	4,808	Defense ground support equipment, alternative energy systems, optoelectronic devices
Fortin Industries, Inc. Sylmar, CA	525	Epoxy fiberglass laminates, copper-clad laminates, prepegs, flexible materials, mass moldings, flexible circuits
Industrial and Government Tube Division Sylmar, CA	700	Test equipment, displays, optoelectronic devices, connectors/packaging, electromechanical devices, electronic subsystems, electron tubes, mechanical devices, semiconductors/ devices, measuring/sensing/ controlling
Integrated Logistics Support Divisions Hunt Valley, MD	N/A	Communications test equipment, aerospace test equipment, engine test equipment, military test equipment

(Continued)

© 1989 Dataquest Incorporated March

Table 2 (Continued)

Westinghouse Electric Corporation
Operations

Location	Number of Employees	Equipment
Technology Service Corp. Santa Monica, CA	250	Research in COMINT/ELINT workstations, experimental radar systems, radar environmental simulators, radar displays, defense research services, radar systems analysis services
Westinghouse Defense and Electronics Systems Company Baltimore, MD	180	Tethered balloons (satellite and microwave)

Other Divisions/Subsidiaries

Advanced Industrial Systems Division--Pittsburgh, PA
Advanced Power Systems Division--Pittsburgh, PA
Automation Division--Pittsburgh, PA
Combustion Control Division--Orrville, OH
Control Division--Oldsmar, FL
Fauske & Associates, Inc.--Burr Ridge, IL
Manufacturing & Electronic Systems Division--Baltimore, MD
Micarta Division--North Hampton, SC
Nuclear Fuel Unit--Pittsburgh, PA
Nuclear Services Integration Division--Pittsburgh, PA
Power Systems Unit--Pittsburgh, PA
Powerex, Inc.--Youngwood, PA
Technology Service Corp.--Silver Spring, MD
Utility Delivery Systems Division--Pittsburgh, PA
Westinghouse Broadcasting Group--New York, NY
Westinghouse Industrial Group--Pittsburgh, PA
Westinghouse Voice Systems--Pittsburgh, PA

N/A = Not Available

Source: Dataquest
March 1989

© 1989 Dataquest Incorporated March

CONTRACT ACTIVITY

Westinghouse swept the field in the competition to provide radar systems for the Advanced Tactical Fighter (ATF). It won contracts from both competing teams vying to develop the fighter aircraft. Contracts for electrical generators and integrated electronic countermeasures for the ATF are expected to produce billions of dollars in sales for Westinghouse in the future. Production continued on established contracts for the F-16 fighter AN/APG-66 and AN/APG-68 radars, power generators, and electronic countermeasures. Nearing the $3 billion sales mark, the radar systems are the largest defense program for Westinghouse to date. F-16 fighter radar is being applied to older aircraft with the coast guard and Customs Service Drug Enforcement Agency. The air force, in fact, has chosen Westinghouse to supply a radar network in Carribean countries to monitor aircraft traffic and to thwart international drug smuggling.

The Airborne Self Protection Jammer (ASPJ), a new, highly advanced electronic countermeasures system, was successfully flight-tested on air force F-16 and navy F-18 aircraft, resulting in a $376 million production verification contract for Westinghouse and its joint-venture partner, ITT. Numerous other aircraft are also candidates to use this system. This year, Westinghouse also won a $65 million air force contract to produce additional AN/ALQ-131 electronic countermeasures systems.

Other major contracts received during the year include a $169 million contract to develop a prototype airship for the navy fleet defense and a $72 million air force contract to produce launcher subsystems for the navy's Trident missiles.

Westinghouse and team members Martin Marietta and Argotech won an initial $7.5 million contract to prepare for production of the Mk 50 advanced lightweight torpedo. Westinghouse, as a second source, will compete with Honeywell for production contracts in 1990, potentially worth $2 billion. Westinghouse is the prime contractor for the Mk 50 and will provide systems integration and produce the torpedo's acoustic sensor.

Westinghouse and team member TRW are working on full-scale development of the Integrated Electronic Warfare System (INEWS) for the Advanced Tactical Fighter (YF-23) produced by the Northrop team. In September 1988, the Westinghouse/TRW team was given a 23-month extension to enable them to better integrate INEWS with its primary platform. Westinghouse is also a subcontractor for the navy's A-12 Advanced Tactical Aircraft (ATA), for which it will develop a multifunction forward-looking infrared (FLIR) unit.

Westinghouse is also a team member with Unisys on a second-source qualification contract for the SPY-1D radar for the Aegis weapon system. A six-month Phase 1 contract totals $10 million, setting the stage for a two-and-a-half year, $90 million Phase 2 contract, under which the two firms will actually manufacture the radar system. Earlier this year, Westinghouse was awarded a Strategic Defense Initiative Office (SDIO) study contract for AN/TPS-70 radar. The Company also won a $41 million subcontract from Grumman for APG-66 radars for Chinese F-8-II interceptor aircraft.

© 1989 Dataquest Incorporated March

The Company began delivery of 109 ASR-9 airport air traffic control radars for the Federal Aviation Administration (FAA). This advanced equipment will display simultaneously both weather conditions and aircraft. This radar, plus the ARSR-3 enroute radars in service throughout the FAA system, makes Westinghouse the leading air traffic radar supplier in the world.

Table 3 shows a summary of other major contracts received during the last two years.

Table 3

Westinghouse Electric Corporation
Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
CVN-68	Naval Sea Systems Cmnd.	$506	2/88	P	Prime	Naval propulsion components
Air Route Surveillance Radar	FAA	$272	7/88	P	Prime	Radar replacement system
Peacekeeper MX	AF Ballistic Missile Cmnd.	$168	7/88	RDT&E	Prime	Rail-based missile launch car
F-16	AF Aeronautical Systems Division	$100 $88 $67 $172 $86 $155	3/87 4/87 9/87 12/87 1/88 9/88	P	Prime	Airborne radar equipment
AN/ALQ-131	AF Warner Robins Logistics Center	$126	6/87	P	Prime	Electronic countermeasures equipment
MX Missile	AF Ballistic Missile Office	$76	8/87	P	Sub	Handling and service equipment
Nuclear Reactors	Naval Sea Systems Cmnd.	$62	10/87	P	Prime	Nuclear propulsion systems
Propulsion Components	Naval Sea Systems Cmnd.	$58 $16 $86	12/87 3/88 10/88	P	Prime	Ship propulsion equipment
UGM-96 Trident	Navy Special Projects Office	$22 $50	7/87 9/87	P	Sub	Launchers
Trident	Naval Sea Systems Cmnd.	$30 $35	5/87 12/87	RDT&E	Sub	Weapon systems
Trident	Naval Sea Systems Cmnd.	$60	6/88	P	Sub	Missile equipment for United States and Great Britain
Mark 48 Torpedoes	Navy	$55	9/88	P	Sub	Torpedo procurement

(Continued)

Table 3 (Continued)

Westinghouse Electric Corporation Contracts

Name	Sponsor	Amount ($M)	Date	Contract Type	Contractor	Equipment
BGM-109 Tomahawk	Navy Joint Cruise Missile Office	$24	3/87	P	Sub	Additional work on launchers
Trident	Naval Sea Systems Cmnd.	$22	11/87	P	Sub	Nuclear reactor cores
P-111	AF San Antonio Logistics Center	$21	2/87	P	Sub	Additional work for repair shop equipment
AN/SPS-40	Naval Sea Systems Cmnd.	$18 $22	3/87 12/87	P	Sub	Additional work for radar equipment
LASS	Space and Naval Warfare Systems Cmnd.	$14	12/88	P	Prime	Modification for a previously awarded Low Altitude Surveillance System

P = Production
RDT&E = Research, Development, Test, and Evaluation

Source: U.S. Department of Defense

© 1989 Dataquest Incorporated March

(Page intentionally left blank)

© 1989 Dataquest Incorporated March