1987: The Beginning Of A New Era In Data Processing

By E. F. Codd

The announcement by Tandem Computers Inc. of their new product NonStop SQL (see *InformationWEEK*, March 23) represents a major advance in data processing as significant as the introduction of:

- Virtual memory into computer design.
- Transistors as basic components.
- Multiprogramming as a new type of auxiliary storage.

Clearly, then, I do not consider this to be "just another routine announcement by a vendor." I heartily congratulate Roberta Henderson and her excellent team of developers for their significant contributions to data processing.

Codd: All vendors should produce versions of a relational database

The reason for this enthusiasm is that the new Tandem DBMS represents a unique combination of relational database management; very high performance that is improvable even more by adding more interconnected processing units; fault-tolerant architecture pioneered by Tandem; support for distributed databases with distribution independence.

With this combination, nonrelational DBMSes have finally become obsolete! After all, why should anyone now sacrifice the many established advantages of going relational for alleged performance advantages of nonrelational when these latter advantages no longer exist?

The Dual Database Strategy

A few years ago, IBM announced its relational DBMS products, SQL/DS and DB2. Since then, IBM has widely proclaimed its "dual database strategy," involving the continued marketing of the old, nonrelational IMS as well as the new DB2. Since this strategy was based on the myth that one could not achieve performance with a relational DBMS, both the strategy and IMS are now doomed to the collapse which I quietly predicted many years ago.

A few software-only vendors have tried to correct their declining position in the DBMS market by rushing out and buying relational DBMSes developed by small companies, then modifying these systems and renaming them to look like a part of their product line. This approach has caused at least one of them to fall into the dual database strategy trap.

My advice to these vendors is to follow the example of Tandem: In other words, invest the time and effort of your best technical people in understanding the relational model and the approach to database management based on it (several hundred technical papers on this subject have been published), then request these people to use their own ingenuity in developing a high-performance implementation.

However, a warning may be appropriate: To achieve the very high performance of Tandem's NonStop SQL, Tandem modified their own operating system, and it now seems highly unlikely that the Tandem level of performance can be achieved without modifying other vendors' operating systems also.

A clear result of the Tandem NonStop SQL product announcement is that the dual database strategy together with the false claims on which it is based are finally dead. Why should any user acquire two DBMS products to do the job that one (NonStop SQL) can do? It should now be clear to everyone that all the unproved and unintelligent allegations that relational DBMSes were unable to provide performance as good as nonrelational DBMSes were (and are) weak and unacceptable excuses by certain vendors and certain consultants for not having invested enough people and brainpower into solving the problem.

Performance

Our staff was called in by Tandem to provide a technical audit of the performance tests. Tom Sawyer checked numerous aspects of the testing (including the cabling, the coding, and the timing) and witnessed the performance of NonStop SQL on a banking debit-credit type of workload consisting of on-line transaction processing equivalent to that arising from 25,000 terminals of the automatic-bank-teller type. The installation consisted of 32 interconnected Tandem VLX processing units plus one EXT unit plus 80 Tandem disk drives.

The system showed it could handle 208 transactions per second with 90% of those transactions completed in two seconds or less. It could also handle more transactions per second than 208 with a transaction response time of three seconds or less. In addition, with more processing units than the 32 in the test installation, this system could demonstrate transaction rates of more than 1,000 per second with response times for each transaction of the same order of magnitude as before.

Although I am not familiar with the details of Tandem's approach to automatic optimization of the target code from the source SQL code, they do support both compilation and automatic recompilation when necessary. Moreover, I do not believe they would be able to demonstrate such outstanding performance unless the optimization techniques were well conceived and well implemented.

Fault Tolerance

In the middle of a heavy load of transactions, Sawyer of our staff shut down the power to one processing unit to simulate a failure. The remainder of the system continued to operate when the transactions were not processed by the disabled unit, and when that unit was switched on again, the system recovered automatically—including successful re-execution of those transactions adversely affected by the unit that was turned off. It is worth noting that, in contrast to earlier approaches to fault tolerance by vendors other than Tandem, no processing unit plays the role of a standby that is completely idle until a fault is detected.

Fidelity To Relational Model

Neither NonStop SQL nor IBM's DB2 is 100% faithful to the relational model (an example is the way they treat missing information). However, NonStop SQL is more faithful than IBM's DB2. It supports every feature DB2 supports plus the semantic feature known as the primary key concept.

This concept is an important step on the way to referential integrity, although an important extra step (among other things not yet supported) is the foreign key concept. In the future, both of these concepts must be supported, not only for referential integrity, but also to implement a systematic approach to view updatability as required by the relational model.

The extent of support for the relational model is enough for the product to qualify today as a genuine (but not fully) relational database management system. Tandem can extend the NonStop SQL DBMS in future releases to become fully relational without upsetting their customers' investment in application programming and in training of end users at terminals. Although Tandem has not yet declared their intention to make such extensions of NonStop SQL, I feel confident that they will exert leadership in this direction also.

A final note: The same version of Tandem NonStop SQL software runs correctly on presently available Tandem hardware (specifically the processing units of all sizes) whether small, medium, or large in scale.

Distributed DBMSes

Tandem's NonStop SQL is a leader in this respect. Most of the DBMS products released to date (I am, of course, ignoring prototypes) do not support distributed database management at all. A few support retrieval of data from distributed databases, but do not support remotely requested insertions, updates, and deletions. Tandem supports all four kinds of activities: retrieval, insertion, update, and deletion with a certain degree of distribution independence.

Tandem Computer Corp.

Tandem's EXT system supports the firm's new NonStop SQL database manager

In part, Tandem's leadership in this area is due to the fact that its NonStop architecture requires treating data that is stored entirely locally in a single database as if that database were distributed. This architecture represents a more significant departure from the classic von Neumann architecture than merely supporting concurrent access to data in auxiliary storage. It is a departure in which *many* full-scale processing units are interconnected and are operating in parallel (that is, concurrently with respect to each other), and an innovation which I expect many other vendors to copy.

Conclusion

The motivation for other vendors to follow Tandem's example is that NonStop SQL provides effective support for the many companies that are staking their business on systems that manage databases efficiently and provide powerful control over the maintenance of logical and semantic integrity.

An important reason for these companies to feel secure about their investment is that the relational approach to database management (in contrast to all other approaches) has a precise mathematical foundation. Although everyone is free to attack and destroy this foundation if they can find and demonstrate an uncorrectable technical or theoretical error, no one has yet managed to do this (and my first publication in this area was in August 1969).

A common remark among data processing professionals was: "One never gets fired for selecting IBM machines." A more appropriate saying for today is: "He who fails to consider Tandem systems as a candidate is bound to be fired." Incidentally, I don't own any Tandem stock, but if I were not a vendor-independent consultant I would certainly do so.

Congratulations to Tandem for this major advance, for laying to rest the incorrect allegations that relational DBMSes cannot perform well, and for disproving similar allegations that distributed versions of relational DBMSes cannot perform well. It has been a rewarding experience to meet the team that developed Tandem's NonStop SQL, people who are willing to consider ideas on their merits instead of being slaves to dogma.

—E.F. Codd is president of the Relational Institute, a nonprofit company based in San Jose, Calif., that specializes in educating the business world on database management. H[...] is also chief scientist of Codd & Da[...] Consulting Group, which numb[...] Tandem Computers Inc. amon[...] many vendor clients. Duri[...] lengthy career at IBM, Codd [...] originator of the relational [...] model.

To: Distribution

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From: Eiichi Watanabe

Date: June 30, 1987

Subj: Japan Technology and Industry Report No. 1
(Focus on Industry Overview, OLTP Market, Tandem's Presence)

I plan to publish a quarterly report "Japan Technology and Industry Report", starting Q3 FY'87. The "report" is intended to be an in-depth study compared to a "newsletter". (Previously, I have started a monthly newsletter "Japan Electronic and Industry Newsletter", which is a straight translation of articles appeared in the Japanese industry press, with my occasional comments.)

I thought it would be a good idea to start this series with a report of Tandem's business environment in Japan. Therefore, the first issue forcuses on the following areas:

- Overview of Computer Industry in Japan
- OLTP Market and "3rd Gen. On-Line System"
- Tandem's Presence in Japan

In addition to industry information, I intend to cover technical areas such as joint efforts of Japanese government, academia, and manufacturers in fault-tolerant systems, R & D efforts in advanced software techniques, advanced electronic devices, superconductive devices, etc, in future reports.

I would appreciate your feedback as to areas of your intyerests, and names who should be added to or deleted from the distribution list.

Sincerely,

Eiichi Watanabe

JAPAN TECHNOLOGY AND INDUSTRY REPORT

Quarterly Issue No. 1

Focus on

Industry Overview, OLTP Market, Tandem's Presence

June 30, 1987

Eiichi Watanabe

Corporate Technical Liaison

CONTENTS

I. OVERVIEW OF COMPUTER INDUSTRY IN JAPAN

Japanese corporations suffered from deteriorating business in 1986 under the high yen situation, but they seem never slackened their computer investment. This is a good news for computer companies.

Overall Market Size

According to statistics (a survey conducted by the Ministry of International Trade and Industry), shipment of computer systems to Japanese customers (domestic sales) shows steady growth, 13% p.a. in terms of sales value in the past 10 years.

The surevy classifies computer systems in terms of price range; large, medium, small and super small systems:

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Large System (LS):    >= 250,000,000 Yen (>=1,786,000 USD)
Medium System(MS):    >=  40,000,000 Yen (>=  286,000 USD)
Small System (SS):    >=  10,000,000 Yen (>=   71,000 USD)
Super Small (SSS):    <   10,000,000 Yen (<    71,000 USD)
 System
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Although the survey does not indicate relationships between this classification and conventional category, i.e. mainframe, mini and PC(or micro), I think it could be interpreted as follows:

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Large -- Mainframe
Medium -- Lower class of mainframe, super-mini, mini
Small  -- Lower class of mini, "office computer"
Super small -- Lower class of office computer, PC
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For Tandem, we might be interested in Large and Medium system categories only (see "Office Computer Market" below). Therfore, in the following tables, "Sub-Total" column is created to show sub-total figures for LS and MS.

In Table 1.1 (see next page), the entire computer investment in Japan is shown. It is about 7,637 billion Yen (55 billion USD).

In Table 1.2 (see next 2nd page), the computer investment in one year (for the year of fiscal '85 (Apr.'85-Mar.'86) is shown. It can be seen that 1,802 billion Yen (13 billion USD).

Table 1.1 Total Installed Base in Japan

(Cummulative number of installed systems and their values)

	Large Systems	Medium Systems	Sub Total	Small Systems	Super Small Systems	
No. of Installed Systems	5,356	16,406	21,762	54,779	167,607	
Share	2.2	6.7	8.9	22.4	68.7	
Growth Rate	10.6	6.2	9.8	11.2	45.0	
Value of Installed Systems	4,291,528	1,616,553	5,908,081	986,794	741,586	M Yen
	30,654	11,547	42,201	7,049	5,297	M USD
Share	56.2	21.2	77.4	12.9	9.7	
Growth Rate	14.8	10.2	13.5	11.0	24.0	
Average Price	801	99	271	18	4.4	M Yen
	5.7	0.7	1.9	0.13	0.03	M USD

Source: MITI's statistics (As of March 1986)

Table 1.2 Installed SYstems in FY'85 in Japan

Installed systems during the Japanese Fiscal Year '85

(Apr.'85 - Mar.'86)

	Large Systems	Medium Systems	Sub Total	Small Systems	Super Small Systems	
Number of Installed Systems	866	2,450	3,316	6,699	53,041	
Share	1.4	3.9	5.3	10.6	84.1	
Growth Rate	1.8	-1.6	-0.8	2.0	94.2	
Value of New Systems	731,662	291,149	1,022,811	134,767	148,901	M Yen
	5,226	2,080	7,306	962	1,064	M USD
Share	56.0	22.3	78.3	10.3	11.4	
Growth Rate	25.7	12.0	21.5	6.3	41.3	
Average Price	845	119	308.5	20	2.8	M Yen
	5.7	0.7	1.9	0.13	0.03	M USD
Value of Add-on Equipment	388,710	86,540	475,250	17,758	3,530	M Yen
	2,777	618	3,395	127	25	M USD
Share	78.3	17.4	95.7	3.6	0.7	
Growth Rate	-	-	-	-	-	
Total Value	1,120,372	377,689	1,498,061	152,525	152,431	M Yen
	8,003	2,698	10,700	1,089	1,089	M USD
Share	62.1	20.9	83.0	8.5	8.5	

Source: MITI's statistics (As of March 1986)

Investment Trends

Banks and securities companies are now pushing ahead so-called "Third Generation On-Line Systems" (see section II). Leading commecial banks are expected to invest an average of 70 to 80 billions yen (500M to 570M dollars) each on computers this year. (Refer to the same author's newsletter; JEIN No.2 May Issue "Daiichi Kangyo Bank Integrates Fujitsu, IBM and Hitachi")

With financial liberalization and deregulatin, Japanese banks face tough competition from foreign banks and securities companies, and they can not afford to relax computer investments.

The same is true for manufacturing companies, since it is vital for manufacturers to invest in computers so as to rationalize production processes and strengthen R & D activities.

Mainframe Market

There are seven major players in the mainframe market in Japan. IBM, Fujitsu, Hitachi, NEC, Univac, Burroughs and NCR. This market is so highly competitive that IBM is compelled to be content with less than 30% of the value of the market in Japan.

Adding to this situation, Mitsubishi is reportedly going to enter this market this year (Refer to JEIN June Issue No. 3 "Mitsubishi Challenges Mainframe Market Again). The driving force for Mitsubishi to enter this market is explained by a rapidly changing situation of the industry now in progress, i.e. a "restructuring" of the computer industry.

Once Toshiba withdrew from the mainframe market 9 years ago. However Toshiba is actively working on streamlining its supermini and medium computer products and strengting its sales force. It is said that Toshiba is now approaching to IBM Japan for possible alliance.

The "alliance" of computer manufacturers are formed global basis also; Between NEC and Honeywell-Bull, between Hitachi and Unisys for future high end mainframe.

On the other hand, Burroughs and Univac Japan are going to be merged in the near future in Japan as well. When that happens, Mitsubishi will be turned to the lowest ranked computer company in Japan.

According to a survey of Nikkei Industrial Newspaper in 1986, market share of mainframe computer makers in Japan is like below. The survey is based on the companies listed in the First Section of the Tokyo Stock Exchange.

Table 1.3 Mainframe Market Share

IBM	26.6%
Fujitsu	24.8%
Hitachi	21.3%
NEC	11.5%
Univac	6.4%
Burroughs	3.4%
NCR	3.1%
Others	2.9%

Brief History

In the 1970s, the Ministry of International Trade and Industry took the lead in reorganizing the six maiframe computer companies, Fujitsu, Hitachi, NEC, Toshiba, Oki and Mitsubishi, into three groups.

Later, Toshiba and Oki withdrew from the mainframe market. Mitsubishi, too, practically disappeared from it. But Fujitsu, Hitachi and NEC remained.

These three companies not only survived but strengthened their capacity to a point where they were able to produce mainframe computers comparable in performance to IBM machines.

They increased their market shares in the domestic market, competing successfully with IBM, Univac and other already established companies.

However, a gradual change is going on, with foreign computer companies mounting a vigorous price-cutting offensive, taking advantage of the the abolition of the import tax on computers in January 1986 and the steep appreciation of Yen.

IBM, whose market share has been eroded by domestic computer companies, is effectively carrying out a roll-back operation. As many users of IBM machines are banking institutions and large corporations, IBM has an edge over Japanese computer companies in the area of large capacity computers.

IBM has established a strategic marketing base in Tokyo called the A/PG (Asia/Pcific Group) to cover its marketing operations in the Pacific region. Staffed by a large number of expetriots, IBM is conducting active sales campaigns in the Japanese market.

Japanese Computer Manufacturers vs IBM

A major change is seen in Fujitsu and Hitachi, which had been mainly responsible for reducing IBM's market share in Japan. With the backing of MITI, the Japanese government, the two companies developed the M-series of IBM-compatible machines and achieved a high growth on their basis. Indications are, however, that the two companies are changing their business strategy to veer away from compatibility with IBM product lines.

The reason is the U.S. Copyright Act, which regards computer software as copyright property and makes it illegal for other companies to copy the IBM operating system (OS) without permission. The Act has placed a major obstacle in the way of developing IBM-compatible mainframe.

This was highlightened by an industrial espionage scandal, which occurred in 1982. Employees of Hitachi and Mitsubishi and their agents were arrested by FBI for allegedly stealing secret IBM technical documents.

The following year, Hitachi concluded a secret agreement with IBM on software. Hitachi was compelled to do so, as Fujitsu, following the same IBM-compatibility line, had concluded a similar agreement with IBM.

Under the agreement, Fujitsu recognized IBM's copy right in its software and agreed to develop its own software in future under certain restrictions placed by IBM.

Later, Hitachi revised this reconciliation agreement and is building up friendly relations with IBM, whereas Fujitsu is now in dispute with IBM, which charges the Japanese computer manufacturers with copying a basic operating system beyond what was specified in the agreement. (See also JEIN No. 2 and 3, LEGAL section). Thus, the relations, which the two companies have with IBM, differ widely.

Regardless of these relationships, the fate of IBM-compatible computer companies in Japan is in the hands of IBM. In these situations, Fujitsu and Hitachi turned to areas other than those covered by IBM, and began concentrating on super computers, AI (artificial intelligence), personal computers and communication networks.

As for operating system, they are moving to adopt UNIX, developed by AT&T. However, it is not only a long way to go but nobody knows if that is the right solution to the problem Japanese computer companies are trying to solve.

Personal Computer Market

In the Japanese market, persnal computer business is growing much faster than other segment of computer industries. Personal computers made their debut in 1979, an NEC's 8-bit machine dubbed PC-8001, and the market doubled every year until it reached 1.2 million units in 1985.

The dominant manufacturer of the Japanese personal computer market is NEC, which accounts for 60% of the market in terms of units. About 80% of the personal computers slod by PC retailers and other shops in Japan are are estimated to be NEC machines.

Fujitsu, IBM Japan and other manufacturers have tried in vain to boost their share of this market. The cult of NEC is very strong. The reason for NEC's unchallenged position is the richness of its software assets. For example, there are a total of 4,200 software titles for the most popular PC9800 series. NEC's software assets have doubled every year until it now enjoys an unrivaled position in the market.

Office Computer Market

Along with the mainframe and personal computers, the Japanese computer market has a third category, office computers. They corresponds roughly to the small business computers of the U.S., but are operated in the Japanese language.

Note: ALL the operator messages and ALL the screens are are in Japanese. As far as national language support is concerned, this class of computers are the most advanced ones in Japan. This is an essential consideration when we think about LXN marketing strategy for Japan. For "transaction capturing machine" operated by end-users, national language support capability would be mandatory.

In the past, mainframe computers did not use the Japanese language, and required special operators who can understand English-like operator messages. (Tandem is still at this stage, or I should say far behind other foreign computer companies in Japan. However, we are trying to catch the wave by PCLINK Japanese version (see JEIN No. 2, May issue).

Today office computers are so small, and they can be installed even in the most cramped Japanese offices. This type of machine showed an explosive growth toward the end of 1970s. In this market, Fujitsu and NEC are competing for top position, and together these two hold a nearly 50% share of the market.

According to a survey of Nikkei Industrial Newspaper in 1986, market share of office computer makers in Japan is like below. The survey is based on the companies listed in the First Section of the Tokyo Stock Exchange.

Table 1.4 Office Computer Market Share

Fujitsu	30.3%
NEC	25.2
IBM Japan	15.3
Toshiba	7.6
Hitachi	5.5
Univac Japan	2.5
Mitsubishi	2.3
Ricoh	2.1
Others	9.2

IBM Japan is making desparate efforts to regain its lost market, but it still lags far behind these two Japanese companies.

II. OLTP MARKET AND "THIRD GENERATION ON-LINE SYSTEM"

Business Environment in Financial Industry

The computerization in financial institutions in Japan are changing rapidly in face of the deregulation and liberalization of financial business, closer tie with international market, and advancement of technologies.

In addition to such traditional menus as various deposit accounts, loan, and money transfer/exchange, new type of menus are emerging in Japan as well. For example, financial commodities which are linked to varying interest rate, or "free" (from regulation of) interest rates which are up to individual institution.

Futhermore, business situations in overseas market, where Japanese financial institutions or local subsidiaries do much wider variety of busniess than that in Japan, constantly affect domestic market by introducing new type of financial commodities.

Current State of Computerization

The use of computers are changing and computer systems are getting bigger and more complex reflecting relative cost reduction of hardware with more fnctionalities.

The current state is described in a phrase "From In-door banking to Out-door banking" meaning that the computer network is not closed within the bank but is extended to outside corporations and individuals.

Total installation base of general purpose computers in the banking industry in Japan amounts to 7,964 units, and 943 billion Yen (6.7 billion USD). Whereas, securities industry 131 billion Yen (941M USD), and insurance industry 192 billion 400 Yen (1,372M USD).

The Third Generation On-Line System

The history of computerization in financial industry in Japan is described as follows.

Pre-history:	Punched Card Systems
1st Period(1959-):	Off-Line Systems
2nd Period(1965-):	1st Generation of On-Line Systems
3rd Period(1974-):	2nd Generation of On-Line Systems
4th Period(1985-):	3rd Generation of On-Line Systems

The third generation on-line systems are characterized by following features:

- Total on-line processing of all accounts; not only traditional deposit, loan, exchange (domestic and foreign), but also a balance sheet and a profit & loss statement; all processes are done on-line

- Enhanced total information systems; customer information, statistics information by branch offices, etc, supporting dat-to-day business; all accessible from terminals on-line

- Bond related business; bond dealing, trading over the counter, etc, on-line

- Enhanced total international communications network; on-line operation of overseas branch offices; dealing of foreign currencies; foreign exchange communications with overseas banks; message communications.

- External interface such as "firm banking" or "home banking"

- New systems for branch office operations; low-cost general purpose terminals; automated document processing; paper-less, electronic filing; IC cards; portable terminals, etc.

Operational Productivity Improvement

Total number of employees of top 12 banks in Japan (excluding Bank of Tokyo) as of 12/31/86 was 150,840 persons, about 15,000 persons (about 10%) down in three years before that. On the other hand, total volume of work is estimated to be increased by 30% at least.

In the future, productivity improvement will be achieved further by introducing various measures like:

- improved sales function at the window by tellers
- improved and/or automated cash disposition, chop matching, and issuance of passbooks
- robotics in branch offices
- speeding up by using enhanced low-counter-terminal
- space efficiency by eliminating hard-copy
- distributing back-office processing to "regional centers"

Enhancement of Decision Support System

The decision support systems (DSS) in financial environment have been based on the traditional management science techniques. However, DSS will be enhanced greately by introducing the expert system techniques.

Currently, following expert systems have been developed and used in the financial environment:

- Cash management
- Stock buy recommendation
- Tax consultation
- Tele message normalization
- Cash/traveller's check purchasing
- Fault diagnosis of on-line system
- Screening and evaluation of membership

Enhanced Customer Services

Various type of new customer services have been studied, experimentd, or going to be offered in the near future:

- ATM network among the entire finacial institutions
- Extended firm banking
- Multi-bank reports by cash management center
- Store automation and home shopping by POS/bank system
- Improved services and security using IC cards and laser cards
- Enhanced financial consultation and asset management

In the past few years, application of IC cards have been studied in many financial institutions already on a pilot project basis. They are shown in table 2.1.

Table 2.1 Piolot Projects for IC Cards

Type of Application	Name of Banks Involved in the Project	No. of Customers Involved	Period of Project
Cashless Shopping	-Mitsui	100	2/85-7/85
	-Sumitomo,Kyowa,Tokai,	500	5/85-
	Tomin	1600	4/86-
	-Sanwa,Ikeda	500	10/85-10/87
		700	11/86-10/87
	-Daiwa	200	10/85-11/86
	-Fuji	500	11/85-12/87
	-Taiyokobe	500	11/86-1/88
	-Mitsubishi, Mitsubishi Trust	3,000	2/86-2/88
	-Kokkaido Takushoku	200	2/86-
	-Nanto	500	3/86-3/87
	-Sumitomo,Kyowa	2,100	5/86-
	-Daiichi Kangyo, Taiyo Kobe,Saitama, Yokohama,Hokuriku, Tokyo,Japan Long Term Credit,Kyowa	1,200	6/86-5/88
	-Mitsui	30	6/86-3/87
	-Suruga	200	8/86-8/88
	-Mitsui,Yokohama, Mitsui Trust,Japan Long Term Credit, Daiichi Kangyo, Fuji,Mitsubishi, Sanwa,Sumitomo, Taiyo Kobe,Mitsubishi Trust,Yasuda Trust, Toyo Trust,Sumitomo Trust,Suruga,Japan Industrial,Tokyo Mutual,Yokohama Credit, Yokosuka Credit, Commercial/Industrial Central	400	11/86-9/87
	-Daiichi Kangyo, Fuji	3,000	2/87-2/88
Asset Management	-Toyo Trust	100	12/84-4/85
		350	8/85
Firm Banking	-Mitsui	3 corps.	12/84-7/85
	-Daiichi Kangyo	1 corp.	8/85-1/86
	-Fuji	7 coprs.	9/85-3/86
	-Tokai	5 corps.	1/86-1/87
Employee Card	-Tokai	500	3/86-
	-Kyowa	100	8/86

Market Size for Tandem

The size of market for Tandem, i.e. OLTP and Messaging, is not readily available from any source. A methodology used here is to apply information available from JIPDEC (Japan Information Promotion and DEvelopment Corporation) to the MITI's statistics shown in section I.

According to a "White Paper on Information Industry 1987" (Japanese edition) published by JIPDEC in March 1987, 76.9 percent of users, who answered to the survey, are running OLTP as of September 1986, and 34 percent of users are running message exchange application, which I refere to as "Messaging". Note that both categories are inclusive.

The reason why I use two categories is that Tandem is not necessarily sold in OLTP in Japan. Major category of Tandem user base in Japan is so-called "VAN"; Nomura, Intec, Kyodo VAN, Tokai Gas, Toshiba, to name a few all applications are "VAN". (See section III.) This fact needs to be considered. In order to provide full OLTP capability, full national language support in OLTP environment especially in database and terminal areas are needed, and Tandem is yet to provide.

Therefore market size shown as case 2 (Messaging) in Table 2.2 is more appropriate for Tandem under current product situation.

Assumptions:

Total Revenue in 1985 (LS and MS)	= 1,498,061 M Yen 10,700 M USD
Annual Revenue Growth Rate (Actual in past 5 years)	= 13 %
Percentage of OLTP (Case 1)	= 75 %
Percentage of Messaging (Case 2)	= 34 %

Table 2.2 Market Size for Tandem

Year	Case 1 (75%) OLTP	Case 2 (34%) Messaging
1985	1,123,546M Yen 8,025M USD	509,340M Yen 3,638M USD
1986	1,269,606M Yen 9,068M USD	575,554M Yen 4,111M USD
1987	1,434,654M Yen 10,248M USD	650,376M Yen 4,645M USD
1988	1,621,159M Yen 11,580M USD	734,925M Yen 5,249M USD
1989	1,831,910M Yen 13,085M USD	830,465M Yen 5,932M USD
1990	2,070,058M Yen 14,786M USD	938,425M Yen 6,703M USD

III. TANDEM'S PRESENCE IN JAPAN

Brief History

[1979] Tandem Computers Japan was establsihed back in April 1979 to provide system support services to a multi-national account, i.e. First National Bank of Chicago Tokyo office.

[1979-1982] The first system sold in Japan was a 6 CPU NonStop I for a hospital in Nagoya, called Fujita Gakuen, central part of Japan near Toyota Motor's Toyota city. It was said to be the world largest MUMPS user.

A few of NonStop systems with MUMPS applications were sold to another hospital and pharmaceutical companies through our "OEMs", such as Sumitomo Electric, and Mitsui Engineering and Shipbuilding. Characteristics of these systems are that they are relatively small and isolated in-house online systems. In this market, Tandem was viewed as an alternative to other minicomputer class systems, i.e. typically DEC where MUMPS runs also.

[1982-1984] Success in these accounts led us to a next stage of business; Tandem system as a front end to a mainframe, a typical on-line transaction processing system such as Japan Credit Bureau (JCB), an end user of one of "OEMs", i.e. Toyo Information System (TIS), and VISA, an end user of Japan Information Services (JAIS).

[1984-1985] The first opportunity and challenge in the most advanced application came in 1984 when we closed a sale to Nomura, which was the first multi-nodal networking application system in Japan. Tandem had only several S.A.s in Japan then.

This was an exciting project in terms of Tandem's role to provide custom software, such as Hitachi Network Architecture (HNA) interface based on early version of SNAX, All Japan Bank (Zengin) protocol on Sage 6100, and Japan Chainstore Association protocol on Sage 6100, etc. This was really a major undertaking of Tandem in Japan. The success of this account enabled us to get other prestigious accounts such as Toshiba and Bank of tokyo.

[1985-now] The sucess in these major accounts created a new situation; Tandem gradually emerged as one of major vendors who can supply state-of-the-art networking solutions involving foreign host mainframes. Tandem has extended its customer base in retail industry, such as M&C, a subsidiary of Marui, Seiyu, a major retail conglomerate (see JEIN No. 3 for POS terminal story "TEC Wins 53M USD POS Terminal Contract with Seiyu"), OENS, a subsidiary of Daiei which is Japan largest supermarket chain.

Tandem's Customers in Japan

Table 3.1 shows current Tandem's customers in Japan. There are total 39 customers in Japan. Classification of customers by industry shows interesting fact:

1. Service bureaus are our no.1 customers, about 1/3 of Tandem's customer base.
2. There is only one Japanese customer in banking industry, where most "prestigious" customers are.

Classification of customer by application shows that well over 1/3 of customer base are just "networking", i.e. they are refered to in such words as VAN, gateway, networking, etc.

Installed Systems

Table 3.2 shows customers and installed systems. There are total 64 customer systems installed in Japan. This figure does not include the U.S. Navy system in Yokosuka.

There are 7 VLS systems, 7 TXPs, 20 NS/II, 23 EXTs and 6 NS/I.

Geographic Distribution

Table 3.3 shows installed systems by geographic locations. It can be seen that 76% of the total installed systems are located in two major metropolitan areas, Tokyo and Osaka, and 58% in Tokyo area.

Table 3.1 Customers' Business and Application

No	Customer Name	Business	Application	Clients
1	ATI	Service Bureau	VAN	
2	BOT	Banking	Money Transfer	
3	CDS	Trading	Hospital	Tokyo Women's
4	Cycom	Service Bureau	OAG	
5	DCL	System House	Networking	NCC, Kyodo VAN, BOT, ICS
6	FNBC	Banking		
7	Fuji	Retail Chain	Credit authori.	
8	Fujita Gakuen	Hospital	Accounting	
9	ICS	Service Bureau	VAN	
10	Ines	Service Bureau	Gateway	
11	Intec	Service Bureau	VAN	
12	JAIS	Service Bureau	Credit	VISA
13	Kotobukiya	Retail Chain	Credit authori.	
14	Kyodo VAN	Service Bureau	VAN	
15	Kyoshin Service	Service Bureau	Financial	
16	M&C	Service Bureau	Retail POS	Marukyu, Sato, Fuji, Kotobukiya
17	Marukyu			
18	Mitsui E & S (MES)	System House	Toxic Lab. Hospital	Otsuka, Taiho St. Maria
19	Motorola	Manufacturing	MIS	
20	NCC	Service Bureau	VAN	
21	NSC	Secirities	Gateway	
22	Oens	Retail	Gateway	
23	Osaka Boshi Center	Hospital	Bed Side System	
24	Otsuka Seiyaku	Pharmaceutical	Toxic Lab.	
25	Quick	Service Bureau	Gateway	
26	Sato	Reatil Chain	Credit authori.	
27	Seiyu	Retail	Gateway	
28	Sony Finance	Credit	Gateway	
29	St. Maria Hospital	Hospital	Accounting, etc	
30	Sumitomo Denso	Manufacturing	Prod. planning, control, etc	
31	Taiho Yakuhin	Pharmaceutical	Toxic	
32	Takaoka	Manufacturing	Mfg. Control	
33	Tatsumi	Marine Transp.	MIS	
34	TIS	Service Bureau	Credit	JCB, Kyoshin, Sony
35	Tokai Gas	Gas Retailer	Security	
36	Tokyo Women's Univ.	Hospital	Lab.	
37	Toshiba	Manufacturing	VAN	
38	Vartecs	Software House	Soft. develop.	
39	Yakuzai Center	Pharmaceutical	Accounting, etc	

3.2 Customers and Installed Systems

No	Customer Name	"OEM" Name	System Type and Count: 1	2	T	E	V	Total
1	ATI					1		1
2	BOT	DCL			1		1	2
3	CDS		1					1
4	Cycom			1				1
5	DCL			1				1
6	FNBC				1			1
7	Fuji					1		1
8	Fujita Gakuen				1			1
9	ICS	DCL				6		6
10	Ines					1		1
11	Intec					1	1	2
12	JAIS			1	1			2
13	Kotobukiya					1		1
14	Kyodo VAN	DCL		3				3
15	Kyoshin Service	TIS				1		1
16	M&C					1	1	2
17	Marukyu					1		1
18	Mitsui E & S (MES)		1					1
19	Motorola				1			1
20	NCC	DCL		4		2	1	7
21	NSC					1	1	2
22	Oens						1	1
23	Osaka Boshi Center	Sumitomo Denko	1					1
24	Otsuka Seiyaku	MES	1					1
25	Quick			1				1
26	Sato					1		1
27	Seiyu						1	1
28	Sony Finance	TIS				1		1
29	St. Maria Hospital	MES		1				1
30	Sumitomo Denso					1		1
31	Taiho Yakuhin	MES	1					1
32	Takaoka			1				1
33	Tatsumi						1	1
34	TIS			4		1		5
35	Tokai Gas			1		1		2
36	Tokyo Women's Univ.	CDS	1					1
37	Toshiba			2	1			3
38	Vartecs					1		1
39	Yakuzai Center				1			1
			6	20	7	23	7	64

System Type:

1=NonStop I
2=NonStop II
T=TXP
E=EXT
V=VLX

Table 3.3 Installed System Status and Location

No	Sys. No.	CPU 12TEV	Customer Name	Prefecture	HK	TH	KT	CB	HR	KK	CG	SK	KS	ON
					Regional Block (*1)									
1	0593	T	FNBC	Tokyo			x							
2	1035	T	Fujita Gakuen	Aichi				x						
3	1163	1	Osaka Boshi Center	Osaka						x				
4	1307	1	Mitsui E & S (MES)	Tokyo			x							
5	1500	2T	TIS (Tokyo)	Tokyo			x							
6	1601	1	Tokyo Women's (*2)	Tokyo			x							
7	1718	1	Taiho Yakuhin	Tokushima								x		
8	1719	2	TIS (Tokyo Dev.)	Tokyo			x							
9	1743	2	JAIS (Osaka)	Osaka						x				
10	1749	2T	Takaoka	Aichi				x						
11	1774	1	Otsuka Seiyaku	Tokushima								x		
12	2017	1	CDS	Tokyo			x							
13	2062	2	TIS (Osaka)	Osaka						x				
14	2104	2	DCL	Tokyo			x							
15	2116	2	Cycom	Tokyo			x							
16	2513	2	NCC (Tokyo Dev.)	Tokyo			x							
17	2514	2	NCC (Osaka)	Osaka						x				
18	2735	2	NCC (Tokyo)	Tokyo			x							
19	2938	2	NCC (Nagoya)	Nagoya				x						
20	3025	T	Motorola	Tokyo			x							
21	3328	T	JAIS (Osaka Dev.)	Osaka						x				
22	3433	2	TIS (Osaka Dev.)	Osaka						x				
23	3497	2	Toshiba (DIS)	Tokyo			x							
24	3500	2	St. Maria Hospital	Fukuoka								x		
25	3593	2	Kyodo VAN (Dev.)	Tokyo			x							
26	3744	T	Yakuzai Center	Kyoto						x				
27	3849	2	Kyodo VAN (Osaka)	Osaka						x				
28	3850	2	Kyodo VAN (Tokyo)	Tokyo			x							
29	3974	T	BOT (Tokyo Dev.)	Tokyo			x							
30	4244	E	NCC (Yotsuya)	Tokyo			x							
31	4309	E	NCC (Nissei)	Tokyo			x							
32	4373	2	BOT (Tokyo) (*3)	Tokyo			(x)							
33	4585	2	Tokai Gas	Shizuoka				x						
34	4588	E	Kyoshin Service	Kyoto						x				
35	4614	T	Toshiba (TIS)	Tokyo			x							
36	4772	E	ICS (Tokyo Dev.)	Tokyo			x							
37	4909	E	ICS (Tokyo)	Tokyo			x							
38	4917	E	ATI	Tokyo			x							
39	5045	E	Marukyu	Yamaguchi							x			
40	5051	E	ICS (Hiroshima)	Hiroshima							x			
41	5052	E	ICS (Osaka)	Osaka						x				
42	5124	E	Intec	Tokyo			x							
43	5184	2	Toshiba (TIS Dev.)	Tokyo			x							
44	5197	E	TIS (Tokyo Dev.)	Tokyo			x							
45	5236	2	Quick	Tokyo			x							

Regional Block (*1)

No	Sys. No.	CPU 12TEV	Customer Name	Prefecture	H K	T H	K T	C B	H R	K K	C G	S K	K S	O N
46	5284	E	ICS (Fukuoka)	Fukuoka									x	
47	5291	E	ICS (Sendai)	Miyagi		x								
48	5458	V	Intec	Tokyo			x							
49	5792	E	Ines	Tokyo			x							
50	5793	V	NCC	Tokyo			x							
51	5794	E	Tokai Gas	Shizuoka				x						
52	5915	E	Sato	Kyoto						x				
53	6052	V	Tatsumi	Osaka						x				
54	6199	V	M&C	Tokyo			x							
55	6200	V	NSC	Tokyo			x							
56	6371	V	Seiyu	Tokyo			x							
57	6443	E	NSC	Tokyo			x							
58	6371	V	Seiyu	Tokyo			x							
59	6453	E	Vartecs	Tokyo			x							
60	6473	E	Fuji	Takamatsu								x		
61	6486	E	Kotobukiya	Kumamoto									x	
62	6514	E	Sony Finance	Tokyo			x							
63	6581	E	Sumitomo Denso	Aichi				x						
64	6658	V	BOT	Tokyo			x							
65	6740	E	M&C	Tokyo			x							

Note: *1 Location:

Block	Abbrev.	Prefecture	No. of Sys.
Hokkaido	HK		0
Tohoku	TO	Miyagi,...	1
Kanto	KT	Tokyo,...	37
Chubu	CB	Aichi,Shizuoka,...	6
Hokuriku	HR		0
Kinki	KK	Osaka,Kyoto,...	12
Chugoku	CG	Hiroshima,Yamaguchi,...	2
Shikoku	SK	Tokushima,	4
Kyushu	KS	Fukuoka,...	2
Okinawa	OK		0
			64

*2 Tokyo Women's University Hospital:
NonStop I system was replaced by Stratus. The system is said to reside in the University physically. It was sold by C. Itoh Data System (CDS), which is now the main distributor of Stratus in Japan.

*3 BOT:
This system is to be replaced by a VLX (sys. no. 6658).

To: Distribution

Corporate
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From: Eiichi Watanabe

Date: July 24, 1987

Subj: Japan Technology and Industry Report No. 2
(Focus on Facsimile)

This is the second issue of a series of quarterly publications "Japan Technology and Industry Report", which was started in Q3 1987. Each report is intended to be an in-depth study in a specific area.

In this report focused on Facsimile, you will see a rapidly changing facsimile market and technology in Japan. Facsimile machines are begining to be integrated with corporate networks and commercial networks (VAN) in Japan. The Facsimile Network (F-Net) of NTT is a good example. It represents the current state of use of facsimile in business environment by corporations.

This issue was planned in response to the interests of the group of people listed below who visited Tokyo during July 15 to 17.

Chris Duke	Manager, Office Information Applications, Software development
Richard Hellyer	International Product Marketing Manager, International Sales Operations
Mike Maeda	Project Manager, National Language Support, Asia Pacific Region
Marilyn Miller	Product Manager, Information Management Technology

Previously, the report (JTIR) issue no. 1 was published which focused on Tandem's business environment in Japan; 1) Overview of Computer Industry in Japan, 2) OLTP Market and the "Third Generation On-Line System", and 3) Tandem's Presence in Japan. If you missed it, I would be happy to send you a copy upon your request.

Eiichi Watanabe

JAPAN TECHNOLOGY AND INDUSTRY REPORT

Issue No. 2

Focus on Facsimile

July 24, 1987

Eiichi Watanabe

Corporate Technical Liaison

CONTENTS

REMARKS

The figures in dollar in this document are provided for the readers' convenience. They are derived from the assumed exchange rate of 150 yen per 1 US dollar.

SOURCES

The information contained in this document is based on the following sources:

* "Japan Economic Almanac 1987", Nihon Keizai Shimbun Inc.

* "Nikkei Industry Newspaper", aka "Nikkei Sangyo Shimbun", Nihon Keizai Shimbun Inc.

I. OVERVIEW OF FACSIMILE MARKET

World Marketplace

It is estimated that there are about over 2,500,000 facsimile machines in the world, and most of them are said to be "Group 3" (or G-III, refer to Technology section) mode machines which can transmit an A4 size (similar to "legal" size) document in one minute.

According to a statistics, the distribution of facsimile machines by country at the time of mid 1986 was as follows:

Table 1. Installed Facsimile Machines by Country

Ranking	Name of Country	Number of Installed Units
1	Japan	1,200,000
2	USA	650,000
3	U.K.	
4	Australia	
5	France	

Out of total 2,500,000 units in the world, 80 percent (2 million units) of facsimile machines are installed in these five countries.

The reasons for such wide acceptance in the world are;

- quick information delivery,
- transmission of image/graphics of document,
- ease of operation requiring no special training,
- low cost of equipment (200K to 400K Yen, or 1.3K to 2.7K USD),
- existence of widely prevailing telephone network that can be used for facsimile transmission.

Changing Market in Japan

Manufacturers of facsimile machines in Japan have begun shifting focus from the saturated office market to the home market by heated price-cutting competition. Prices of facsimile machines, which used to be somewhere between 500K Yen (3.3K USD) and 1,000K Yen (6.7K USD), dropped to below 300K Yen (2K USD) in the summer of 1986.

Hitachi unvailed a new model at less than 200K Yen (1.3K USD) in December 1986. In January 1987, NEC put on a sale a machine priced at 148K Yen (1K USD). In less than a year, the price of facsimile machines went down by about a half.

Facsimile machine manufacturers now know that sales for home use will jump when the price of a unit drops close to 100K Yen (670 USD).

The price of the new NEC unit was low enough to open up the home facsimile market wider. In Japan, when a manufacturer comes up with a machine in a certain price range, its competitors often immediately follow suit with cheaper products.

An intense price war among makers is expected to push the price of facsimile machines down to about 100K Yen (670 USD) during 1987.

Facsimile at Home

Facsimile machines for home use feature functions to attract users. They are equipped with copy-machine capabilities and telephone receivers with multiple functions including programmable quick dial. The copying feature is particulary sought after by users.

There are three factors that can boost the sales of home facsimile machines, according to the development staff at one manufacturer. First, price should fall to close to 100K Yen (700 USD). Second, the machine should be small enough to be placed on a desk. Third and most important, it has to be in the G-III mode, which is the most common in offices around the world, because many home users will likely use the machine for business communications.

Facsimile machines at home will enable company employees to swiftly attend to business related problems which may occur before departing for work or after coming home. One's schedule can be reported to the company when absent from the office, and important documents can be sent to the office, without need to stop by. For this reason, facsimile machines should be in the G-III mode.

Second-hand facsimile machines selling for about 300K Yen (2K USD) are very popular, particularly among executives of major corporations. The executives use facsimile machines at home to keep in close contact with their offices and avoid noisy telephone calls late at night. With a home facsimile, problems which require immediate attention can be dealt with accordingly. The machines are particularly useful for exchange of information with overseas offices where time lags exist.

The falling price of facsimile machines will eventually make possible their use by all company employees. Personal computers sell very well even at a price of 300K Yen (2K USD), but Japanese word processors priced at 100K Yen (670 USD) are even more popular. Manufacturers can use this experience to forecast at what price the sales of home facsimile machines will sharply go up.

In 1986, facsimile production was 300 billion Yen (2B USD) down by 3% from the previous year. Manufacturers are urged to develop the home market to regain prior growth of 30% a year.

Market Share by Vendors

(Note: The information contained here originally appeared in "Japan Electronic Industry Newsletter" No. 3A, July 10, 1987)

Due to a changing market situation especially rapid growth of low price home facsimile machines from the last summer, number of units manufactured in last fiscal '86 (April '86 - March '87) reached 1 million units. However, value of production stayed around a little over 300B yen (2B USD).

Market share in terms of value of production is as follows:

Table 2. Market Share of Facsimile

Ricoh	21.5%
Matsushita	21.4%
Toshiba	12.6%
NEC	12.0%
Canon	11.3%
Others	21.2%

Ricoh overtook Matsushita, the long established leader in this market, for the first time. Ricoh's success is explained by a strong business in the domestic market as well as exports to the U.S. and Europe. The strategy for Ricoh to manufacture only high value products, and OEMing low cost products from Toshiba helped Ricoh's success.

Matsushita suffered from lack of products in the low price range last year. Now it is trying to recover its position by adding low price machines to its product line.

Toshiba increased its market share to 12.6%, 2.6% up from preceeding year. Toshiba's growth is explained by a strong product dubbed "SPOT", which has been OEMed to Ricoh also.

NEC has been pushing a "system sale", i.e. a set of facsimile machines and mini computers.

II. FACSIMILE NETWORK AND SERVICES

Facsimile Network

Facsimile machines communicate with each other via communication lines. They are available in four ways:

- Regular telephone line network
- Facsimile network (NTT's "F-Net")
- Facsimile communication services in VAN
- Intra-corporation multi-media network

An individual facsimile machine can call any facsimile machine with the same "mode" (G-I, G-II, G-III or G-IV) via regular telephone line network.

Enhanced networking of facsimile machines are available from NTT's F-Net and service bureaus or common carriers who provide "VAN" (value added network) services. NTT's F-Net services are described later.

Multi-media Network

Facsimile machines are used by almost all corporations in Japan. According to an estimate in 1986, it is said that 95% of the corporations who are listed on the Stock Exchange in Japan are equipped with facsimile machines.

In these large corporations, voice, data and facsimile images are integrated in one network which is refered to as "multi-media network". It consists of high speed, digital communication lines which link corporate facilities. The benefits are cost savings in use of communication lines.

Multi-media networks are found in domestic and multi-national corporations as well. A popular configuration is one which connects Tokyo, New York and London offices.

Integration with New Technologies

There exist new types of applications which integrate new technologies such as optical discs, OCRs and mobile communications.

A company called Misawa started running a system using facsimile machines and optical discs in 1985. The system provides real estate information. Information stored in optical discs can be retrieved and printed out to facsimile machines.

Shin Nihon Seitetsu (Japan Steel) uses also facsimile machines and optical discs for storing and retrieving techincal information.

Data sent via facsimile can be read by OCR (optical character recognition) system. The Izakaya Chain is said to be running this type of data entry system.

Facsimile Machines Find New Places

Further, facsimile machines are found in many new places.

- Transportation companies already use mobile facsimile machines connected via radio.

- Some schools started communicating with their students at home via facsimile.

- Some construction companies build houses with facsimile machines installed as a value added feature.

III. NTT'S FACSIMILE NETWORK (F-NET)

The number of subscribers of NTT's facsimile network called F-Net is growing rapidly. As of March 1987, it reached about 90,000 subscribers. Out of 90,000 subscribers, 50,000 subscribers were added in one year.

The notable advantages of F-Net over regular telephone line network are efficient facsimile broadcast and economy for long distance facsimile transmission compared to regular telephone line.

Starting from February 1987, most G-III mode facsimile machines can be connected to F-Net, and it is available throughout Japan.

What is F-Net

The basic service provided by F-Net is a store-forward function, and facsimile information is transmitted over high speed digital lines.

In order to use F-Net, a one time subscription fee must be paid. It costs 800 Yen (5.3 USD). In order to communicate over F-Net, both sending and receiving facsimile machines must be hooked to F-Net. F-Net services are available in about 700 cities.

Distinction between F-Net and regular telephone line is made at the time of dialing. An unique prefix number, i.e. 161, addresses the F-Net. Dialing 161 followed by a destination facsimile number connects you to F-Net. Otherwise you just dial a destination facsimile number.

F-Net Features

- Broadcast

Maximum 100 destinations can be serviced. Broadcast transmissions are done in parallel. This is an advantage over facsimile machine's broadcast feature which handles transmission in serial.

F-Net handles multiple destinations by using "short assigned number" capability; assigning many facsimile numbers to a "short facsimile number".

- Automatic Call Retry

Up to 5 retries in 30 minutes.

- Automatic Receive

When telephone call is made, phone conversation can take place, and facsimile transmission is suspended.

- Personal

Confidential facsimile message can be handled.

- Facsimile Box

Delivered facsimile message can be stored by using buttons of a receiving facsimile machine.

- Closed Connection

An arrangement can be made so that facsimile communication can take place within a certain group only.

- Computer-to-Facsimile ("Center-to-End") Communication

Facsimile machines can be used as remote terminals.

Enhancement of F-Net

Several enhancements were made to F-Net, and they were put in services as of February 20, 1987.

- Call Signal

Previously, only those facsimile machines which use 1.3K Hz call signal were able to connect to F-Net. However, old G-III mode facsimile machines which use 16 Hz call signal can be connected to F-Net now.

- Size of Document

Previously, maximum size of document that can be transmitted without reducing it was A4 (similar to "legal" size). Now it is B4 (25 x 35 cm).

- Discount Rate

Between 19:00 in the evening and 8:00 in the morning, facsimile transmission cost is discounted by 40%.

- Facsimile Information Services

Maximum 10 pages information can be stored for an information provider in a dedicated memory in F-Net, which can be retrieved by clients afterwards. Multiple retrieval requests can be serviced in parallel.

- Certified Delivery

Once document is delivered, that fact is notified.

- Collect Call

Receiver pays for the facsimile transmission.

- Overnight Bulk Broadcast

Maximum 1,000 destinations can be specified. Sending can take place during day time. This service was started from 5/31 in Tokyo area.

Linking Computer and Facsimile

One of the F-Net features called "Center-to-End" communication allows facsimile machines to be used as remote terminals for sending and receiving information to/from computers. It can become an alternative device to a keyboard terminal for entering data to computer.

There are 20 systems exist today; Delivery of stock price information, real estate information retreival and delivery, order entry of commodities.

New Applications

Using "Facsimile Information Service", various information such as news, weather forecast, economic information, shopping information, leisure/sports information, etc, can be retrieved easily, and this type of use will explode in the future.

IV. TECHNOLOGY

Definition of Groups (I,II,III and IV)

Accroding to the recommendation of CCITT, facsimile machines are classified into four groups; Group I, II, III, and IV. The G-I and II are based on analogue techniques and G-III and IV use digital techniques.

The history of analogue techniques are fairly old. In contrast, digital techniques are relatively new. The international standards for the G-III were established in 1980 as CCITT Recommendation T.4.

Coding Techniques (MH and MR)

The principle of facsimile is to scan a paper and digitize the image in using binary values 0 and 1 corresponding to black and white. Transmission efficiency is achieved by compressing information when there is a continuous stream of bits having the same value. There are two coding techniques; MH (Modified Hoffman) and MR (Modified Read).

MH technique is a one dimensional coding technique which is applied to a single scan line. MR technique is a two dimensional coding technique which is applied to two adjacent sacn lines.

By using these compression techniques, transmission efficiency is improved compared to uncoded transmission. The coded method improves speed by a factor of as much as 8 times.

Group III Facsimile

The G-III mode facsimile machines use MH or HR coding technique and transmit information over a telephone line network. Density of scan lines is either 3.85 lines / mm or in case of "fine mode", it is 7.7 lines / mm. Transmission speed is either 2,400 bps, 4,800 bps 7,200 bps or 9,600 bps. Transmission time for sending an A4 size page (similar to "legal" size) is about 60 seconds on average.

The communication protocol between sending and receiving machines is defined in CCITT's Recommendation T.30. Currently, facsimile machines do not have error correction features. However, it is expected that CCITT will include error correction features as option for implementors.

Group IV Facsimile

The G-IV mode facsimile machines use a public data network, aiming at higher transmission speed and higher resolution of images. International standards for facsimile machine functions (Class 1, see below) were established in 1984, and they were adopted by Japan and announced by Post Office in March 1985. In December 1985, 13 manufacturers succeeded in communicating with each other via DDX packet switched network.

This group of machines uses a two dimensional coding technique, a maximum 64k bps transmission speed, and error correction techniques.

The G-IV mode machines are classified into three classes; Class 1 has a facsimile send/receive function. Class 2 has an additional capability to Class 1; Sending coded characters and receiving teletex mixed mode. Class 3 has an additional capability to Class 2; Sending teletex mixed mode functions. The Class 3 machine will look like a workstation with keyboard.

Standardization of Class 2 and 3 are now underway, and products in these classes are expected to emerge in 1990.

Class 1 machines are emerging in the market. Due to high price, it will take a while before they are widely accepted. These machines will gradually gain wide acceptance once ISDN (Integrated Services Digital Network) services (which is called "INS Net Services" by NTT of Japan) are started in the spring of 1988. Class 2 and 3 machines are in development process.

International Facsimile Network

It is said that more than half of automatic dialing connections of international telephone communications are used for data transmission including facsimile.

International facsimile transmissions are done based on current international telephone network which was designed for voice transmission and they are not suitable for facsimile transmission.

For example, failure of handshaking between facsimile machines occur not only for the reason of busy terminal, but inadequate setting of communication parameters on the terminal side. Also, communication failures occur due to noises on communication lines.

International public facsimile networks are expected to be implemented. One is a facsimlie store-and-forward system based on the MHS (message handling system) technique which is being developed by Japan's KDD (International Telegram and Telephone) for G-III mode facsimile machines. It is expected to be in service in the near future.

There exist strong demands, primarily from Japanese corporations, in the G-IV facsimile transmission between the U.S. and Japan. In response to the demands, KDD started services of 56k bps packet switched communication (called VENUS-LP) which allow extended packet size for the G-IV mode facsimile transmission.

Personal Facsimile

Recently, hot topics in the facsimile market have been centered around low priced machines, i.e. so-called "personal facsimile".

Realization of the low price without degrading functionalities was made possible by advancement of technologies in all aspects of the facsimile such as reading and writing of images, modem, data compression techniques, and inteface to communication network. It owes also to advancement of micro electronics technologies that are generally available such as larger capacity and lower price of memory, more functions in one logic chip of LSI, etc. For example, a modem normally consists of a few chips, but it will become one chip which can support higher communication speeds.

Memo Phone

As an extension to the personal facsimile, there exists a class of machines called "memo phone". It supports small size paper; A5 or A6.

The memo phone is classified into two categories depending on the type of communications. One is a facsimile type and another is a tele-writing type.

The facsimile type memo phones are further divided into two groups. One is a group of machines which are compatible with G-III. Another group is machines which are incompatible with G-III, but can communicate within the group to send and/or receive memos or documents.

The tele-writing type is a machine which has pressure sensing mechanism and senses messages or graphics which are being written on a pad, a part of the memo phone equipment.

Memo phone cost less than 50,000 Yen (333 USD). It is much smaller in size, lighter in weight, and lower in price compared to "personal facsimile". Although it is sometimes limited in functionalities and transmission speed (2400 bps), it uses advanced technologies such as contact sensor for "reading", one-chip modem, special LSI for image processing.

Standardization of memo phones which use G-III compatible communication technique is being worked on by CCITT. Once standardized, it is expected to be used more widely as a handy terminal.

Automatic Switching and Voice Response

Personal facsimile machines and memo phones are likely to be used as telephone equipment as well. Therefore functions such as an automatic switching function between telephone mode and facsimile mode, and a voice response function become more important and are required.

As to an automatic switching function, there are a few techniques already in use now; Counting call ring, detecting a signal as part of facsimile communication protocol, analysis of frequency of response to recognize if it is human voice or not.

Voice response is already implemented in some machines. It is conceptually a combination of an answering phone with a facsimile machine. It has a collection of simple phrases stored in read-only memory (ROM) chips such as "Please call again later" etc.

Examples are Matsushita's Panafax UF-32, Ricoh's RIFAX L30/L60, Toshiba's COPIX TF-230/330.

Color Facsimile

Most of office documents do not require multi-color print on facsimile machines. However, in some application such as schooling via facsimile communication, a black and red two-color print capability is appreciated and there are such machine available today.

Two-color facsimile machines have a two-color scanner by which red and black signals are sensed and coded. On the receiving side, two-color thermal paper is printed by a two-color thermal plotter. The thermal paper deveops differnt colors depending on different energy level.

There are a few methods in color printing; 1) multi-color thermal printing, 2) multi-nozzle ink jet printing, 3) thermal transfer printing, and 4) laser printing. Some of the methods are implemented in commercially available facsimile machines. Example is Ricoh's RIFAX 810SR.

Standardization of color information coding and transmission are now under way by CCITT.

High Performance Facsimile

A high performance facsimile machine which is sometimes refered to as a "central machine" is characterized by a quality picture and high speed. In order to achieve a high quality picture, improvement of overall technologies for reading, writing and processing of image need to be addressed.

For small characters such as those in newspapers, it is required to have four times denser scan lines than the "fine mode" of existing facsimile machines. Currently multi-bit CCD to read 16 pixels per mm is implemented. However, it is expected that better performance can be achieved.

ACKNOWLEDGEMENT

Bill Horne was kind enough to spend his time to review the draft and helped improve it.

FYI: CONTENTS OF JTIR ISSUE NO. 1

To: Distribution

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From: Eiichi Watanabe

Date: August 25, 1987

Subj: Japan Technology and Industry Report No. 3
(Focus on Fault Tolerant Computing in Japan)

In this issue, Japanese efforts on fault tolerant computing are reported. This report describes failures of on-line systems as experienced by users, and activities in fault tolerant computing research, etc. The contents are as follows:

- A report on on-line systems' failures
- Approach to reliable systems by Japanese vendors
- Efforts in setting standards for FT Techniques
- Efforts by Academia: Technical groups on FT Systems

This series, Japan Technology and Industry Report, is intended to be published quarterly, and two reports were published in the past. The report #1 focused on computer industry and market in Japan including Tandem's general business environment, and the report #2, a special issue focused on facsimile. I would appreciate your input as to the area of your interests in Japan technology and industry.

Eiichi Watanabe

JAPAN TECHNOLOGY AND INDUSTRY REPORT

Issue No.3

Focus on Fault Tolerant Computing in Japan

August 25, 1987

Eiichi Watanabe

Corporate Technical Liaison

CONTENTS

REMARKS

The figures in dollar in this document are provided for the readers' convenience. They are derived from the assumed exchange rate of 140 yen per 1 US dollar.

SOURCES

The information contained in this document is based on the following sources:

(1) "A Survey on Computer Security," JIPDEC (Japan Information Development Corporation), March 1986

(2) "Strategy for Fault Tolerant Systems by Vendors in Japan," Shohei Kurita, "Bit" magazine Vol.18, No.11, October 1986, Kyoritsu Shuppan

(3) "JIS Draft Proposal for Highly Reliable Systems," Appendix of "Fault Tolerant System," Eiichi Watanabe, McGraw-Hill Book Japan, October 1986.

(4) "Papers of The Technical Group on Fault Tolerant Systems," Quarterly journal published by IEICE (Institute of Electronic, Information and Communication Engineers)

I. A Report on On-Line Systems' Failure

Product quality of Japanese electronics components and computers are said to be very high. However, computer systems working in Japan do fail as described below, and computer outages are becoming increasingly important issues to be resolved.

JIPDEC Report

A report on computer security tells us interesting facts about system failures of on-line systems in Japan. The report was published in March 1986 based on a surevey conducted by Japan Information Development Center (JIPDEC), a non-proit organization, in 1985 (Refer to Sources No. 1).

The data reflect the facts, as responded by those who answered, during a period of July 1984 through June 1985. The selected users were those who run on-line transaction processing systems.

Out of a total 1,383 institutions responded to the survey, 978 institutions answered to the question No. 230 (There were total 265 questions).

1) How many times have you experienced system down in the past one year (July 1984 - June 1985) ?
2) What was the mean time between down (MTBD) ?
3) Waht was the mean down time (MDT) ?

The term "system down" means a total system failure or similar conditions.

System Down and Causes

Following table shows total counts and causes of system down.

Cause	Count	Percentage
Hardware & O.S.	3,155	42.0%
Appl. software	1,846	24.6%
Comm. line	917	12.2%
Operation	702	9.3%
Power equipment	428	5.7%
Air conditioner	281	3.7%
Others	188	2.5%
Total	7,517	100.0%

System Size and System Down

Following table shows system size in terms of Yen value and count of system down by causes per company. It can be seen that a user experiences a system down about once for every two months on average. (LT means "less than" and GE means "greater than" in the table.)

System Size in Yen (USD)	No. of Company	HW or O.S.	SW	Comm. line	Op.	Power Eq.	Air Con.	Other
LT 50M (.4M)	38	2.4	0.8	0.2	0.8	0.5	0.2	0.1
GE 50M LT 100M (.4M) (.7M)	72	2.5	1.0	0.6	0.8	0.5	0.3	0.1
GE 100M LT 1B (.7M) (7M)	454	2.6	1.5	1.0	0.8	0.5	0.3	0.2
GE 1B LT 3B (7B) (21M)	213	3.5	2.4	0.9	0.7	0.4	0.3	0.2
GE 3B LT 5B (21M) (36M)	80	4.2	2.3	2.2	0.6	0.3	0.2	0.1
GE 5B LT 10B (36M) (71M)	63	5.7	3.1	1.0	0.6	0.5	0.3	0.2
GE 10B (71M)	58	4.6	3.3	0.1	0.5	0.2	0.0	0.2
Total	978							
Average		3.2	1.9	0.9	0.7	0.4	0.3	0.2

Total 7.6 times

Mean Time Between Down, Mean Down Time

A mean time between down (MTBD) and a mean down time (MDT) were as follows)

Mean Time Between Down (MTBD)

Government	2,161.0 hours
Retail	2,417.0 hours
Service bureau	2,398.0 hours
Local government	
. . .	
Average (704 institutions)	1,770.0 hours

Mean Down Time (MDT)

Financial	28.0 minutes
Utility	39.0 minutes
Government	58.0 minutes
Service bureau	60.0 minutes
. . .	
Average (911 institutions)	87.0 munites

II. Approach to Reliable Systems by Japanese Vendors

There are three major Japanese mainframe manufacturers; Fujitsu, NEC and Hitachi. As far as computer architecture is concerned, Japanese mainframe manufacturers seem to be in the similar situation where IBM is in. They have no choice but to stick to the current architecture and implement various fault-tolerance features.

Fault tolerant architecture has been developed by some Japanese companies in such areas as frontend or backend processors. NEC has developed fault-tolerant communication multiplexor, and Mistubishi has developed an integrated communication controller which tolerate failures in two locations.

We will examine below the product strategy of Japanese mainframe manufacturers (Refer to Sources No. 2).

Fujitsu

Fujitsu believes that it has many years of experience in highly reliable systems in commercial filed such as race track accounting systems and electronic switching systems for telephone company (KDD, i.e. Japanese international telephone service), and it can meet with customers' needs for fault tolerance.

There are four types in system configuration to achieve high reliability:

1) General purpose multi-processor system

   Two or more processors run under a single copy of operating system. In the event of one processor failure, the system continues to operate with the rest of the system.

2) Duplex system

   One system runs on-line, and another system performs other jobs, typically off-line batch processing jobs.

3) Load sharing system

   Two or more systems participate in an on-line application processing in a distributed manner and share the processing load. In the event of one system failure, application processing can continue.

4) Dual system

   All the equipment are redundant and duplicated. Two outputs are compared, and one output is employed.

A highly reliable system can be built as a combination of various types of hardware equipment like below based on above system configuration approaches;

- Mainframes only,
- Mainframes and mini's
- Mini's only

Fujitsu released a new series of mainframe computers dubbed M780 in the fall of 1985. In contrast to conventional structure of a processor such as a model called M380 which comprises 12 printed circuit boards (PCBs), the new M780 is a single board mainframe, first in the world. It has 336 components of very high speed LSIs on a multi-layered 54 x 49 cm sized PCB, achieving much higher density in packaging components by a factor of 7 times.

Fujitsu emphasizes that a reliability of M780 is increased substantially compared to its predecessors; Even a uni-processor configuration can provide satisfactory reliability. Further, a duplex configuration can achieve an extreme reliability.

Although basic architecture is not changed from conventional design, the high reliability in an single board processor alleviates the necessity to have duplicate files and programs, resulting in ease of development and maintenance. It means that quality of overall system is improved and productivity is improved.

Fujitsu defines a concept of "No down system," meaning that the system is always available to end users. Various techinques are available to implement of this concept;

- a system is configured in a load sharing manner,
- software supports a shared database configuration between two systems and mirrored volumes,
- a "global processor" and a "super processor" monitor the status of host computers and provide automatic switching between them,
- hot stand-by control by the global processor,
- remote backup centers for disaster recovery
- backup of a branch office by a peer branch office

Fujitsu thinks that system performance should be evaluated in terms of transaction per unit time rather than a MIPS (million instructions per second). The top end model M780/40 can process 1 million transactions per hour (i.e. 278 transactions per second, TPS) in banking environment.

In fact, a Fujitsu user who has implemented so-called the third generation on-line banking system runs a system that handles 800,000 transactions per hour (i.e. 222 TPS). It is the top class performance in the world. In a real business environment where a system has to run 24 hours a day, the system has such challenges as;

- Daily batch processing should be able to run concurrently during on-line processing,
- On some scheduled day in a month, a monthly batch processing must be done concurrently with on-line processing.

These factors bring up an issue; Can a multiprocessor architecure based on minicomputer class processors, such as NCR 9800, do the job ?

NEC

NEC used to implement highly reliable systems in duplex configuration, and later in dual configuration, both based on a conventional uni-processors.

However, with the advent of the ACOS 900 system, NEC started to offer tightly coupled multi-processor with fault tolerance. In 1985, NEC began to offer loosely coupled multi-processor configuration as well.

In this system, multiple sets of a processor and associated operationg system run in parallel. In the event of a single processor failure, a processing in the failed processor can be switched to any hot stand-by processor. In the past, restarting a processor took long by a factor of a quarter hour. However, it takes now only 30 seconds.

ACOS 1500 and 2000 series, which are aimed to compete with and perform better than IBM 3090 series, feature such fault tolerance. The ACOS series is designed as functionally distributed system, and because of this design concept, it is easy to ensure RAS (reliability, availability, serviceability) and security.

ACOS 1500

As to RAS capability, ACOS 1500 system provides following features:

- Automatic error correction
- Processor relief function; Processes in a failed processor are transfered to surviving processors to continue processing.
- Dynamic reconfiguration
- Automatic reloading and restart at software level; In the event of operating system crash, reloading of operating system takes place automatically.
- Automatic reconfiguration and reloading at hardware level; In the event of system failure due to hardware malfunction, the system can be restarted automatically at "boot" level.
- Hot stand-by configuration; A system can be configured such that a backup processor is ready to takeover a current processor in the event of failure.
- Built-in diagnostics; A replacement component can be identified by using error log and by consulting a failure dictionary.

ACOS 2000

The central design concept for ACOS 2000 system was high reliability and ease of use. In order to achieve a high reliability for on-line systems in loosely coupled multiprocessor architecture, the system has a "Multi-System RAS Facility" (MSRF) as a standard feature.

Under the hot backup arrangement of on-line system, a processing in a failed processor can be switched to a backup processor in a short period of time with end user not knowing outage of the system.

In order to achieve ease of use, NEC has developed five Expert Systems based on its own "EXCORE" shell;

- Performance analysis
- JCL
- Network failure analysis
- FORTRAN advisor
- Database design and diagnosis

Monitoring of a failure and switching between current and backup systems are controlled by a software component called "hot stand-by controller" (HSC). The HSC begins the monitoring once current and backup processors start operation.

When an on-line application system is configured using two computer systems, one system can hold jobs A and B', whereas another system holds jobs A' and B. (The apostrophe ['] means that the job runs in a backup mode). In the event of one system failure, another system will takeover the processing load.

In order to avoid a situation where a failure of memory becomes the cause of single point of failure, memory is divided into two separate modules.

The entire system is characterised as a loosely coupled multi-processor system. Each processing system can be comprised of multiple processors, achieving the best cost / performance.

When one computer system fails, communication lines are switched to a backup computer system, and integrity of data files are ensured by roleback operation to the last checkpoint.

Hitachi

Hitachi has been offering systems which keep running 24 hours a day. Examples are the systems for Japan Steel, Nomura Securities and Japan Air Lines. Nomura uses Hitachi's packet switching gear which has a redundant processor architecture.

On-line systems in securities and banking customers are very large and complex, and can not afford outage. In the event of system failure, system can be restarted in a few minutes, and end users are rarely aware of the outage.

Hitachi thinks that large scale on-line systems will be built on mainframe computers. However, in other field like process control, appropriate approach to fault tolerant systems should be taken.

Fault tolerant techniques fall into a catogory of RAS (reliability, availability, serviceability) in the mainframe field. In Japan, the word "NonStop" would be taken literally as a word guarantying 100% reliability.

The RAS capabilities of Hitachi's high end model of mainframe computer M-68X are as follows:

- Automatic retry of instruction; In the event of execution failure of an instruction, retry is done automatically,
- Error detection and automatic correction of main memory and control store,
- RAS features handled by software; Recovery and isolation of main memory, retry of I/O commands via alternate path, isolation of failed component,
- Automatic isolation of failed components; high speed buffer memory, buffer address array, address translation buffer,
- Storage tracer for recording internal state of processor,
- Maintenance functions in service processor,
- Remote maintenance facility.

One chief engineer says "System reliability is largely dependent on the stability of software. If there is a bug in software, system could possibly fail. I guess the reason for Tandem's success can be attributed to the quality of software."

According to the engineer, reliability of products have been substantially increased by various measures including a system simulation tester (SST). The quality program covers several stages;

- Component test
- Component function test
- Subsystem test
- System test
- System simulation test

Hitachi developed a concept called "Self-controlling distributed system". Hitachi started research project in 1977 on this theme. A paper on this subject was awarded by IEEE in 1984.

The concept is described briefly like this. A system consists of subsystems. A subsystem is either active or inactive. Each subsystem has a controller in it. A controller has a domain of control. In the event of a failure of a controller, each remaining controllers is able to control its domain and cooperate with the rest.

This concept has been applied to a subway system in Tokyo. A controller is installed in each subway station, and they are tied together via self-controlling distributed loop communication system. The system survives double failures.

III. Efforts to Standardize Fault Tolerant Techniques

Background

As evidensed by the JIPDEC report which was introduced briefly in the first section of this report, on-line systems do fail. In section two, you saw that current state of fault tolerant techniques implemented in commercial systems in Japan are premature. Users have always asked for reliable on-line systems, and people are in need of common words to communicate ideas in this field.

This is why user community, industry, academia and the Japanese government (MITI) have been working on standardization of techniques to achieve high reliability for OLTP systems.

It was back in 1985 when Tandem got a phone call from an official of MITI who was trying to set up a tour to the U.S. for a group that was studying standards for super reliable systems. The group was planning to join in a conference; The IEEE Technical Committee on Fault Tolerant Computing had an annual international symposium in Chicago. On the way back, they were planning to see other people also.

As fault tolerant techniques and resultant products are new in the history, there is no standard in this field yet. They were not confident in what they were doing then, and wanted to visit Tandem, among others, and exchange thoughts on the draft proposal of the standards.

One year later, final draft came out with much revisions. This revised draft proposal is contained in my book "Fault Tolerant System" in Japanese (Refer to Sources No. 3). It is my feeling that it will take a while before it becomes official.

Any industry standard normally has one thing in common. They start with defining the words used. So is the case of the this draft proposal on reliable systems. It has the following contents:

- Scope
- Definition of Technical Terms
- Level of Requirements for Reliability
- Classification of Reliability Technique
- Reliability Technique

The value of this efforts, in my opinion, is its effect in facilitating discussions; people from different areas can understand each other, and users can evaluate products by consulting the standards.

Japan Industry Standard: Draft Proposal on Highly Reliable Systems

(NOTE: In the description below, I have listed headings from the proposed document, because it could take a volume of complete book if each topic were to be discussed.)

1. Scope

This standard specifies denifintion of technical terms and various techniques used for higly reliable on-line transaction processing systems.

2. Definition of Technical Terms

(1) Gerneal

fault-tolerance
fail-soft
fail-safe

(2) Fault

fault
design fault
permanent fault
transient fault
intermittent fault
error
latency
defect
bug
system failure
failure
dead lock
hazard

(3) Detection of errors

error detection
error
duplication and comparison
error-detecting code
parity-check code
residue code
cyclic code
M-out-of-N code
watchdog timer
N-version programming
recovery blcok scheme

(4) Diagnosis

diagnosis
test
test & maintenance program
test program
diagnostic program
fault locating test
microdiagnostics
built-in diagnostics
log out analisys (LOA)
easily testable design, or design for testability
scan design

(5) Techniques to avoid malfunction

active redundancy (paralell redundancy)
stand-by redundancy
hot stand-by
cold stand-by
triple modular redundancy (TMR)
load share
fault masking
error recovery
error correcting code (ECC)
retry
coverage
rollback
rollforward
data integrity
storage protection
robustness

(6) System reconfiguration

(automatic) system reconfiguration
checkpoint restart
file restore

(7) Evaluation

availability
reliability
maintenability
performability
serviceability
testability
mean time to failure (MTTF)
mean time between failure (MTBF)
mean down time (MDT)
mean time to repair (MTTR)
computational reliability

3. Level of Requirements for Reliability

3.1 Classification by reaction to fault

(1) level of fault masking

(2) level of recovery of system functionality

(a) complete recovery
(b) partial recovery (fail-soft)

(3) level of technique to lead to safe situation after malfunction

(a) aviodance of critical situation (fail-safe)

(4) level of assuring data integrity

(a) assuring data integrity

3.2 Classification by length of stopped time

(1) instant recovery

(2) recovery of second order

(3) recovery of minute order

4. Classification of Reliability Techniques

The reliability techniques are divided into two :

. fault-aviodance techniques

. fault-tolerance techniques

Fault-tolerance techniques are further classified into three:

. configuration and recovery techniques

. fault detection techniques

. diagnosis and repair techniques

5. Reliability Techniques

Categories of computer systems where reliability techniques are relevant :

(1) System

Refer to table 5-1.

(2) Network

Refer to table 5-2.

(3) Software

Refer to table 5-3.

(4) Hardware

Refer to table 5-4.

Table 5-1 System

(1) Horizontal distribution

(2) Vertical distribution

(3) Geographical distribution

(4) Tightly coupled multi-processing

(5) Loosely coupled multi-processing

(6) Hot stand-by

(7) Cold stand-by

(8) 1-to-1 redundancy

(9) M-to-N redundancy

(10) Dual system

(11) Redundancy using voter

(12) Dual file

(13) Resource management

(14) Automated operation

(15) Automatic switching

(16) Stand-alone diagnosis, in-line diagnosis, on-line diagnosis

(17) Health check

(18) Remote diagnostic

(19) Preventative maintenance

Table 5-2 Network

(1) Error Correction Technique

(2) Recovery by protocol

(3) Duplex operation of communication control processor (CCP) and modem

(4) Stand-by backup operation of CCP and modem

(5) Fallback operation with lower transmission speed

(6) Paralell link/multi-link

(7) Routing control

(8) Degraded operation of CCP

(9) Disconnection of failed portion of CCP and modem

(10) Alternate terminal for receiveng output

(11) Loopback testing

(12) Remote dump, remote initial program load (IPL)

(13) Logging

(14) Line monitoring/testing

(15) On-line remote testing

Table 5-3 Software

(1) Automatic recovery of Task by forcefully aborting Task

(2) Automatic recovery by retry of intermittent failure

(3) Reconfiguration of faild devices by switching or disconnection

(4) Avioding total failure by load distribution

(5) Retry/fallback operation

(6) Backout recovery of database

(7) Checkpoint restart

(8) Automatic program load (quick IPL)

(9) Scheduled backup copy operation

(10) Version control of programs

(11) File recovery

(12) Automatic reallocation of failed file

(13) Logging of data exchange between layers

(14) Avioding failure propagation of failed file

(15) Robust database

(16) Detection of illegal data (including instruction or command)

(17) Watchdog timer

(18) Detection of deadlock

(19) Output of logging information

(20) Checkpoint dump

Table 5-4 Hardware

(1) Redundant circuit with voter

(2) Error correction techinque

(3) Soft-error protecton circuit

(4) Replicated components

(5) Hazard-free circuit

(6) Hardware error recovery (retry, automatic correction)

(7) Automatic system reconfiguration

(8) Asymmetric error logic circuit

(9) Fault secure function

(10) Protection function

(11) Error detectin function

(12) Selfchecking function

(13) Checking circuit for logical correctness

(14) Checking between layers

(15) Information gathering for later analysis (diagnostics, sense information, log, memory dump)

(16) Self diagnostic function

IV. Efforts in Academia: Technical Groups on FTS

Who's Who: Leaders in FTS in Japan

If I were to name a few leaders in the academic research field of fault-tolerant computing in Japan, they are

Dr. Yoshihiro Tohma, Professor of Tokyo Institute of Technology,
Dr. Kozo Kinoshita, Professor of Hiroshima University, and
Dr. Yoshisuke Koga, Professor of National Defense Academy.

Dr. Tohma has been the chairman of a technical group on FTS of Institute of Electronic, Information and Communication Engineers (IEICE) since the group's foundation in 1985, and the group holds conferences once in every quarter. Since the IEICE is a sister organization of IEEE of the U.S., the conferences of this group have been co-sponsored by the IEEE Computer Society Tokyo Chapter. Dr. Tohma visited Tandem headquarters in 1986.

Dr. Kinoshita has been the chairman of a technical group on FTS which has been active for longer period of years, and the group holds conferences twice a year. Dr. Kinoshita visited Tandem headquarters in 1985.

Dr. Koga chaired a workshop on fault-tolerant computing in Spring this year. He is also active in above groups.

Activities of IEICE in Fault Tolerant-Computing

The Institute of Electronic, Information and Communication Engineers (IEICE) started organized activities by establishing a group called "Technical Group on Fault Tolerant Systems" specilized in studying fault tolerant techinques in April 1985. The group's conferences have been chaired by Dr. Tohma.

The group has been holding quarterly conferences since April 1985. Duration of a conference is one day. There are about eight presentations by researchers in academia, Japanese computer and technology companies, and sometimes computer users such as Japan Air Lines.

Most of the presentations have been hardware related, as you can see in the list of titles of the presentations shown at the end. Most of the technical papers are written in Japanese. There are a few exceptions, which are written in English. They are marked with an (E) on the left most column in the list.

Tandem was asked to talk about fault-tolerance of Guardian opreating system, and Mike Lisenbee and self worked together, and did presentation at Tohoku University in November 1986 (FTS86-24).

Dr. Tohma introduced my book "Fault Tolerant System" to the audience as "the first complete book on fault-tolerant systems published in Japan." According to the publisher, McGraw-Hill Book Japan, more than 1,500 copies of the book were sold as of June 1987 in 8 months.

The 18th International Symposium on Fault-Tolearant Computing

The 18th international simposium on fault-tolerant computing dubbed FTCS-18 is scheduled in Tokyo in June 1988. This symposium is organized by IEICE and IEEE jointly. Originally, IEEE Technical Committee on Fault-Tolerant Computing started this symposium in the U.S. back in 1971, and it has been extended to overseas in 1975 when the 5th FTCS was held in Paris, France.

Right after 10th FTCS that was held in Tokyo, Japan FTCS Committee was organized to prepare for the future international symposium to be held in Japan again. It was decided in Mirano, Italy, in 1983 that the 18th symposium is in Tokyo.

A fact to be noted here is a list of members, as shown in the next page, who are participating in the organization committee for the 18th symposium. The list shows who and which institutions are interested in the fault-toleranct computing and systems. They are from both academia and industry. You will notice popular names of corporations in computer and electronics industries.

Members of Organization Committee for 18th Int'l FTC Symposium

Chairman	Yasuo Komamiya, Meiji University
Vice chairman	Yoshihiro Tohma, Tokyo Institute of Technology
Vice chairman	Shuzo Yajima, Kyoto University
Supervisor	Hideo Aiso, Keio University
	Shoichi Noguchi, Tohoku University
Advisor	Kenji Kawanishi, Nihon University
	Hisashi Mine, Kansai University
Member	Toshimi Toyoda, Matsushita Electric
	Osamu Ishii, Nihon Technology Insitute
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Papers Presented at IEICE Fault Tolerant Systems Conference

FTS85-1 "New Frontier on Fault-Tolerant Computing," Y. Tohma (Tokyo Institute of Technology)

FTS85-2 "Exception Handling in Distributed Operating System," S. Fujita (Tokyo Institute of Technology)

FTS85-3 "On-Line Error Detectable High Speed Multiplier by Redundant Binary Three-Rail Logic," N. Takagi, S. Yajima (Kyoto Univ.)

FTS85-4 "An Encoder and a Decoder with Ternary BCH Code," N. Muranaka, S. Imanishi (Kansai Univ.)

FTS85-5 "A Design Method of Main Memory Self-Checking ECC Circuits," M. Hoda, S. Shinmori, Y. Koga (The National Defense Academy)

FTS85-6 "An Approach to Built-In Testing of Programmable Logic Array," H. Fujiwara (Meiji Univ.), Robert Treuer, Vinod K Agarwal (McGil Univ.)

FTS85-7 "Test Generation for Combinational Logic Circuits Using Structured Test Table," M. Nakamichi (Chiba Univ.)

FTS85-8 "An Application of Ranking Theory to Self-Diagnosis System - An Algorithm of Syndrome Decoding," Y. Inoue (Sumitomo Bank), Y. Ishida, H. Tokumaru (Kyoto Univ.)

FTS85-9 "On an Error Detection Rate Theory for Software Reliability Growth Models," S. Yamada (Okayama Univ.), S. Osaki (Hiroshima Univ.)

FTS85-10 "A Construction of Self-Checking nMOS Circuits for 2-Rail Code," H. Itoh, R. Shinohara (Chiba Univ.)

FTS85-11 "Designing Method of Self-Checking Fault Locater," Y. Namiki, Y. Koga (The National Defense Academy)

FTS85-12 "Politonic Fault Free Combinational Circuits for Alternate-Data-Retry," O. Fujiwara M. Tsunoyama, S. Naito (The Techonlogical Univ. of Nagaoka)

FTS85-13 "A Study on Combinational Circuits Tests Based on Structured Test Table," M. Nakamichi (Chiba Univ.)

FTS85-14 "Optimal Redundancy of Multi-Valued Output Systems," K. Nakashima, K. Yamato (Himeji Insitute of Technology)

FTS85-15 "The Output Interface of Triplicated Systems with Loose Synchronization," D. S. Chang Y. Tohma, T. Yoneda, T. Suzuoka (Tokyo Institute of Technology), M. Nishimura (Nippon Signal)

FTS85-16 "Analysis of Self-Diagnosable System by Means of Petri-Net Model," H. Douzono, Y. Ishida, H. Tokumaru (Kyoto Univ.)

FTS85-17 "Application of Knowledge Engineering to E.S.S. Fault Recovery Design," H. Ono, H. Watanabe (NTT)

FTS85-18 "A Report on FTCS-15," Y. Koga (The National Defense Academy)

FTS85-19 "Evaluating Signal and Fail-Safe Reliabilities of Logic Networks," M. Mukaidono (Meiji Univ.), K. Moriya (Nippon Signal)

FTS85-20 "A Note on Strongly Fault Secure Sequential Circuits," T. Nanya (TIT), T. Kawamura (Hitachi)

FTS85-21 "Quick-Reconfigurable Parallel Processing System," M. Tsunoyama, S. Naito (The Technological University of Nagaoka)

FTS85-22 "Algorithmic Generation of Test Patterns for Circiuts with Tri-State Modules," N. Itazaki, K. Kinoshita (Hiroshima Univ.)

FTS85-23 "Fault Detection Method by Use of Cross-correlation," H. Kashiwagi, T. Araki (Kumamoto Univ.), I. Takahashi (Terenix Inc.)

FTS85-24 "Speedup of Logic Design Verification and Test Pattern Generation by Using Temporal Logic and Cover Expressions," M. Fujita, A. Nakashima, N. Kawato (Fujitsu)

FTS85-25 "Effective Application of the Instruction Sequence-Test to Computer Design Verification," K. Okumura, H. Nishioka (NEC)

FTS85-26 "Variance of Malfunctions Caused by Metastable Operation in a Daisy Chained Arbiter," T. Okamoto, S. Okamoto (Okayama Univ.), Y. Sato (Toshiba)

FTS85-27 "On Test-Effort Dependent Software Reliability Growth Models," S. Yamada (Okayama Univ.)

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FTS85-30 "A Specilization Language for Hardware Design Verification," A. Takahara, T. Nanya (Tokyo Institute of Techmnology)

FTS85-31 "Optimum Inspection Policies for A Computer System with Imperfect Maintenance," T. Nakagawa (Meijo Univ.), K. Yasui (Chubu Electric Power Inc.)

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FTS85-35 "Reliable Token-Driven Synchronization Algorithm," S. Hasegawa (NEC), Jane W.S. Liu (Univ. of Illinois)

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FTS86-5 "Performance Evaluation of RFSIM," T. Nishida, S. Miyamoto, T. Kozawa (Hitachi).

Note: RFSIM stands for Reduced Fault SIMulator

FTS86-6 "Synchronization of Sensors on Redundant System," T. Ishifuji, M. Higashiguchi (Tokyo Univ.)

FTS86-7 "Multi-System Contorol Processor for Fault Tolerant System," T. Masai, M. Tajima, S. Nomiyama, M. Araki, K. Bando (NEC)

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(E)
FTS86-12 "A Study of Defect-Tolerant Technologies in Wafer-Scale Integranted ROMs," (English). H. Kikuchi, K. Matsuzawa, S. Kohda (NTT)

FTS86-13 "A Construction Method for Fault Tolerant FFT System," M. Uenoyama, M. Tsunoyama, S. Naito (Technological University of Nagaoka)

(E)
FTS86-14 "A Model for Estimating the Number of Sortware Faults," (English), Y. Tohma, K. Tokunaga (Tokyo Institute of Technology)

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(E)
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FTS86-23 "Structural Approach to Software Reliability Growth Model Based on the Hyper-Geometric Distribution," (English), Y. Tohma, Y. Murata (Tokyo Institute of Technology)

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FTS86-24 "GUARDIAN Operating System: Fault Tolerant Design," (English), M. Lisenbee, E. Watanabe (Tandem Computers Inc.)

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FTS86-31 "A Model for Estimating the Number of Software Faults Considering the Progress of Test," Y. Murata, Y. Tohma (Tokyo Institute of Technology)

FTS86-32 "Recent Trends on Software Reliability Technology," K. Torii (Osaka Univ.), Y. Urano (KDD)

(E)
FTS87-1 "Anti-Code-Disjoint Mapping for Excepřion Handling in Self-Checking Systems Hierarchy," (English), T. Nanya (Stanford Univ.), S. Asano (Toshiba)

(E)
FTS87-2 "Modular Approach to the Test Generation for Large Combinatorial Circuits," (English), Y. Tohma, K. Goto (Tokyo Institute of Technology)

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FTS87-5 "A New Model for Intermittent Faults and an Optimal Design of t-Intermittent-Fault Diagnosable Systems," T. Kohda, O. Andoh (Kyushu Univ.)

FTS87-6 "Self-Organizing Distributed Operating System (III)," S. Fujita (Tokyo Institute of Technology)

FTS87-7 "Verification of Combinatorial Circuits Utilizing Set Concepts on Inputs and Outputs," K. Kosaka, M. Tsunoyama (Technological Univ. of Nogaoka)

STANDARD & POOR'S

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computers & office equipment

BASIC ANALYSIS

OUTLOOK

Industry expanding in size, scope, importance

 USPS No. 517-780. Photo courtesy of *Xerox Corp*
This issue of Standard & Poor's Industry Surveys includes 1 section.
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As giant IBM closes its grip on every major market, the 'also-rans' are scrambling to find the means to compete. Computer prices are declining rapidly, new products are being introduced at a dizzying speed, and distinctions across all product classes are blurring. After the 1984 boom, a slowing economy could mean a tough year ahead for most vendors in 1985.

Computers are the small beige boxes sitting on office desks used for spreadsheet analysis. Computers are also massive systems in environment-controlled back rooms, orchestrating the manufacture of automobiles. And there is a complete spectrum in between.

Simply put, computers are electronic machines that manipulate text and numbers at high speeds using prewritten sets of instructions. These machines improve productivity in service industries by aiding the preparation, analysis, and flow of information and provide a competitive edge to manufacturers through automation, which reduces manufacturing costs while increasing product quality.

Computer hardware shipments reached $53 billion worldwide in 1984, according to estimates by International Data Corp. (IDC), a market research firm. That excludes any revenues from service, software, and maintenance. IDC expects sales to grow at an annual rate of 18.1% over the next five years, to $122 billion in 1989.

IBM taking a broader view of its market, estimates the information processing industry generated more than $260 billion in revenues worldwide in 1984. IBM dominates many of the major markets in the information processing industry. In its view, the information processing industry is actually a convergence of the computer, communications, and content businesses. (By content, IBM means databases, software, user languages, and directories.) Communications deals with the transfer of information by such means as the telephone and electronic mail and the transmission of instructions and data to such equipment as workstations, printers, and copier machines. Any major player in the information processing industry must address all these issues. IBM estimates that the information industry represented about 3.9% of U.S. gross national product (GNP) in 1984. The company projects the industry will grow by 15% annually, to reach $300 billion in revenues worldwide in 1985 and a trillion dollars by the early 1990s. The information processing industry is likely to be the largest in the world by the end of the century and to affect the daily life of every person.

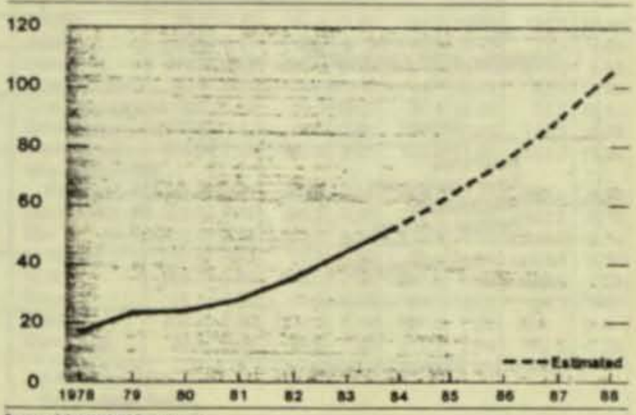
Melanie McCrossen, Computers Analyst

Price/performance drives market expansion

Continued improvement in price/performance levels of available equipment is the driving force behind the growth of the industry. As the performance level at each price point continues to improve (or, conversely, as the price for a given level of performance falls), more customers are willing to buy computing power. The industry has improved price/performance by approximately 20%-25% per year. This trend is expected to continue for at least the next decade and correlates with annual revenue growth of 15%-20%.

Several classes of computers are available to solve a wide range of computing problems and price/performance improvements are expected to be effected across all classes.

VALUE OF COMPUTER SHIPMENTS DELIVERED IN U.S.
(In Billions of Dollars)



Source: International Data Corp.

Large-scale systems are needed as central data repositories, as communications controllers, and for batch processing by large businesses and institutions. Mid-size systems perform similar functions for smaller businesses and departments and provide optimal solutions for real-time, interactive computing. Microcomputers provide inexpensive local computing power and act as communications terminals; their capabilities will continue to increase, enabling them to perform a larger number of functions. Microprocessor-based computers will evolve from single-tasking machines into multi-tasking workstations.

Large-, medium-, and small-scale refers primarily to processing power, not actual size. The physical size of all computers has been shrinking over the past decade with advances in semiconductor technology.

Throughout this discussion, MIPS (millions of instructions per second) will be used to evaluate and compare computer performance levels. MIPS is not recognized as a valid measure of performance by many computer manufacturers, including IBM, with justification. MIPS ratings can be misleading, as instructions used to execute commands vary in length. In addition, the efficiency of the operating system and hardware architecture also contribute to a computer's performance. However, MIPS is the best standard of comparison available and is widely used by analysts and market researchers.

The boundaries separating product classes have become blurred as performance gaps between product categories have been filled in and new technologies overtake the old. Consequently, customers have a broader array of solutions for their processing needs. Vendors must offer a vast selection of integrated products to compete effectively. Carrying a growing number of products has had an adverse effect on profits. An increased number of products reduces the volume of each product, increases inventories, often necessitates larger marketing expenditures, and lengthens order cycles, as customers require more time to evaluate all the alternatives.

Because of the crossover between superminis and mainframes, between minis and micros, and in all other categories of computers, the traditional divisions—mainframes, minicomputers, and microcomputers—are being replaced by the terms large-, medium-, and small-scale systems and personal computers.

As important as the blurring of product categories is the reversal of the traditional price/performance relationship across product type. In the past, the rule of thumb was that

IBM's 1984 market share in various product markets

Category	Market share (in percent)	Category	Market share (in percent)
Large-scale	72	Small-scale	'22
Medium-scale	30	Personal computers	33

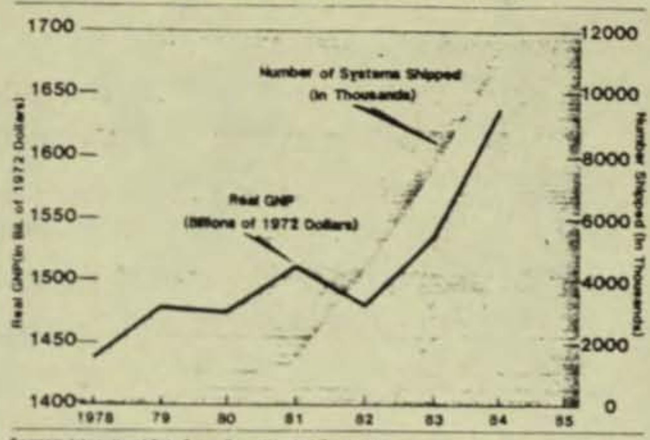
'1983 latest available.
Source: International Data Corp, S&P estimates.

Computer cost per MIPS*—1984

Category	Price per MIPS (in thousands)
Mainframes	500-1,000
Superminicomputers	150-350
Minicomputers	50-100
Personal computers	25-40

*Millions of instructions per second.
Source: NCR.

REAL GNP VS. TOTAL COMPUTER SHIPMENTS



Sources: International Data Corp., Department of Commerce

for twice the price one could buy four times the performance. Today, all else remaining equal, a dollar will buy more processing power at the low end of the performance range than at the high end. According to Charles E. Exely Jr., chairman and president of NCR CORP., a typical mainframe, with peripherals, cost $500,000–$1 million per MIPS in 1984. Superminicomputers were priced at $150,000–$350,000 per MIPS, minicomputers cost $50,000–$100,000 per MIPS, and personal computers cost $25,000–$40,000 per MIPS. The smallest computer had a cost per MIPS about one-twentieth that of the large-scale systems.

This phenomenon was brought about by the development of the microprocessor, used in the smaller systems. The price differentials should narrow as new semiconductor technologies are applied to the larger systems. In the meantime, the cost advantage of the smaller systems has contributed to the trend toward decentralized data processing. Twenty years ago, it was cost-effective for firms to have a data processing center to justify the purchase of the largest system possible in order to get the lowest cost per job. The minicomputer made it possible to buy computing power in smaller increments for departmental use. Microcomputers brought this one step further by providing systems dedicated to one user, at a fraction of the cost of large-scale processing. However, microcomputers cannot perform all the tasks larger systems can. Personal computers compete more with the calculator, the typewriter, and other desktop utensils than with larger computers.

No one ever got fired for buying IBM

IBM is expanding its dominance in almost every major market. In 1984, IBM had revenues of $46 billion and net income of $6.6 billion. By contrast, DIGITAL EQUIPMENT CORP. (DEC), the second-largest computer company, would have shown revenues of only $6.2 billion and net income of $487 million for calendar year 1984 (DIGITAL EQUIPMENT has a June fiscal year). According to a user survey conducted by *Datamation*, most IBM customers say they assume they will continue to buy most of their equipment from IBM over the next five years, not only for the safety of buying from the market leader, but also because of IBM's superior record for service and support.

IBM's stated goal is to grow at or above the rate of growth in every segment in which it competes, or at or above the estimated 15% growth rate for the overall industry. Gains of this magnitude would result in revenues in excess of $100 billion by 1990. At that size, IBM would probably be the largest corporation in the U.S.

By virtue of its enormity, IBM is the price leader for almost every category of computer. In the past IBM has provided a pricing umbrella under which most competitors could live while leaving IBM with healthy margins. The picture changed in early 1982, when the U.S. government dropped its 13-year-old antitrust suit against the company. Since then IBM has made aggressive price cuts, introduced a steady stream of new products on the leading edge of technology, and sued competitors allegedly infringing on its copyrights.

Although IBM has a virtual monopoly in the large-scale systems market and is rapidly gaining share in the personal-computer market, the government will probably not renew any action, particularly in the current political climate. Given the strategic importance of the industry and Japan's recent advances in technological know-how, it might even be argued that IBM's size and resources are the U.S.'s best weapons in defense of its current supremacy in the computer industry. By IBM's estimate, it currently holds no more than 30% of the computer systems market. IDC, however, estimated IBM's share at 38.5% in 1983 and slightly below that in 1984. In all likelihood, serious antitrust action would not be taken against IBM unless predatory pricing (pricing below average cost) could be proven. This would not be easy, as IBM does not break out cost information by product line.

Due to economies of scale, IBM is the low-cost producer in many cases. The company has enlarged this advantage by investing in automated facilities. Between 1980 and 1984, IBM spent $16.5 billion in plant and other property ($4.6 billion in 1984 alone). No other U.S. computer company can match IBM's plant modernization and expansion programs. IBM takes pains to design such high-volume products as microcomputers, typewriters, and printers, with as few parts as possible so they may easily be manufactured in automated facilities.

IBM is a firm believer in the price elasticity of demand and has historically priced carefully down its cost curve. With gross margins of about 40% in 1984, the company has plenty of room for price cuts.

Competition fuels technology advances

As IBM lowered its pricing umbrella, it increased its flow of new products to the market. In 1980–84, IBM spent $15.5 billion on research, development, and engineering. IBM spent $4.2 billion (9.1% of revenues) in 1984 alone, compared with $631 million (11.3%) by second-ranked DIGITAL EQUIPMENT CORP. during its fiscal year ended June 30, 1984.

IBM's competitors, particularly the plug-compatible manufacturers (PCMs), who make computers or peripherals that can be plugged into and operated with IBM equipment, thrive only when they can provide a price/performance advantage over IBM. Now competitors must play technology catch-up with an ever-increasing number of IBM products just to stay even, let alone provide superior products. The result has been an industrywide acceleration of R&D expenditures in the face of severe pricing pressures.

In 1984, IBM introduced new products with estimated program revenues totaling $40 billion over their lifetimes. IBM plans to introduce new products in 1985 expected to generate total program revenues of $80 billion. This phenomenal rate of new product introductions is likely to continue.

As the speed with which new products are introduced increases, product life cycles shrink. The margin for error is small, as exemplified by the experience of STORAGE TECHNOLOGY, which was one of the 10 largest computer companies in 1983. In late 1981, IBM introduced a new high-performance disk storage subsystem, the 3380, for use with large-scale systems. STORAGE TECHNOLOGY, whose main products are IBM-plug-compatible high-performance storage products, began developing a comparable product. Plagued with delays and technological problems, the company operated at a loss for four straight quarters (ended June 1984). Finally the company began gearing up for volume production of its 8380 disk storage subsystem. The company projected that it would break even in the third quarter of 1984. At that time, however, IBM cut prices on its existing product line in preparation for the announcement of a new generation of high-performance storage devices. In October 1984, STORAGE TECHNOLOGY announced it would report yet another loss and filed for protection under Chapter 11 of the Federal Bankruptcy Code.

STORAGE's prospects do not look good. IBM plans to begin volume shipments of its new-generation storage device in late 1985. A competitive product from STORAGE TECHNOLOGY will not be available before late 1986. It takes a lot of cash, which STORAGE does not have, to bring a new product to market. Moreover, customers are likely to be leery of buying such expensive items as high-performance storage subsystems from a company that could disappear.

Some vendors find temporarily safe harbors in market niches where IBM is not yet strong. INTERGRAPH CORP. found such a niche in the computer-aided design and computer-aided manufacturing (CAD/CAM) market, and DAISY SYSTEMS found one in the computer-aided engineering (CAE) workstation market. But no niche that offers potentially large revenues or an entre into another large market will ever be safe from IBM.

In summary, IBM's competitors survive only by offering products with significant advantages over those of IBM, usually a lower price or higher performance for comparable equipment. As the technology involved in IBM's products becomes more complex and the rate at which IBM introduces new product into the market accelerates, it gets more difficult to develop competitive products and bring them to market on a timely basis. And as IBM lowers its prices, it gets harder to offer a price advantage and remain profitable. The net margins and returns on equity of most computer vendors that compete with IBM have been declining for the past few years.

R&D expenditures as a % of sales—selected computer manufacturers

	1981		1982		1983		1984	
Company	R&D (mil. $)	R&D as % sales	R&D (mil. $)	R&D as % sales	R&D (mil. $)	R&D as % sales	R&D (mil. $)	R&D as % sales
Amdahl	75.1	16.95	81.3	17.60	101.7	13.07	126.9	20.86
Apple	21.0	6.27	38.0	6.52	60.0	6.10	71.1	4.69
Burroughs	176.0	5.30	220.6	5.39	248.2	5.78	274.6	5.63
Computervision	27.1	10.0	36.3	11.16	43.7	10.92	60.9	10.95
Cray Research	16.3	15.98	28.3	20.07	25.5	15.00	37.5	16.41
Data General	74.6	10.12	84.5	13.94	84.7	10.22	101.5	8.75
Digital Equip.	251.2	7.85	349.8	9.01	472.4	11.06	630.7	11.29
Hewlett-Packard	347.0	9.70	424.0	9.97	493.0	10.47	592.0	9.79
Honeywell	368.8	6.89	396.9	7.23	428.6	7.45	422.0	6.75
IBM	1,612.0	5.56	2,053.0	5.97	2,514.0	6.26	4,200.0	9.14
Intergraph	12.0	13.1	17.6	11.30	25.4	10.06	37.1	9.20
NCR	229.2	6.68	248.6	7.05	257.5	6.90	288.9	7.09
Prime	27.5	7.53	37.0	8.49	52.1	10.08	64.1	9.97
Sperry	336.5	6.20	397.6	7.14	397.1	7.82	N.A.	N.A.
Wang Labs.	68.9	8.06	86.9	7.50	117.5	7.64	160.5	7.35

N.A.—Not available

Source: *Annual Reports.*

IBM sets the standards

As long as IBM remains near the leading edge of technology, it will maintain its product leadership position. Its size and large customer base assure that its products will set the standards for the industry and that IBM compatibility will remain a strong selling point. Everyone wants standards, for they insure the availability of software and peripherals and make networking easier.

Many vendors and customers would like to see a second industry standard emerge. The most likely candidate is AT&T's *UNIX* operating system, which is popular in multi-user environments and widely used in the scientific and technical markets. Several non-IBM-compatible computer vendors have embraced *UNIX* as a way to compete with the giant. Commercial applications have not been widely developed, but the fact that IBM now offers a version of *UNIX* for its new mainframe line and its PC *AT* suggest that software applications will become more widely available in 1985.

One might suppose that AT&T offers the most serious threat to IBM with its *UNIX* operating system, substantial resources, and large customer base. Yet 1984, its first year of operations as a computer vendor, was less than spectacular. It is still uncertain whether AT&T can successfully make the transition from regulated utility to marketing-oriented computer company. In addition, IBM will likely introduce a multi-user operating system of its own that offers equal or superior performance in office environments.

Communications a future priority

With all the emphasis on IBM compatibility, one might assume that IBM's products are compatible across product lines. They aren't. Developed separately for different purposes, the company's computer families have different hardware and operating systems. In other words, its systems cannot talk to each other. Connectivity provides the key to two of the fastest growing markets in the industry—office automation and factory automation—and is a top priority for IBM. Automation does not mean putting a microcomputer in every office or providing every engineer with a workstation. It often means the application of communications networking. Automation facilitates the flow of information between data processing mainframes, word processors, workstations, robots, printers, copiers, storage devices, and any other electronic machine that manipulates text or data.

Not surprisingly, IBM dominates both factory and office automation. Since the federal antitrust suit against it was dropped in 1982, IBM has been making its presence more strongly felt with a bevy of new products for both environments. Vendors who had established market niches are finding their lives a lot more difficult these days. For instance, after years of growth in excess of 40%, WANG LABORATORIES, once the premier office automation company, reported a 66% decline in earnings on a revenue gain of only 21% in the quarter ended March 31, 1985. It is known for its stand-alone word processing equipment and is having trouble penetrating the full-line office automation market. COMPUTERVISION CORP., once the leader in factory automation, is now faced with formidable competition from IBM and INTERGRAPH CORP. It is in a product line transition, from systems that automate specific aspects of production to those that automate the whole product process, from conception and design to sales and service. Customers apparently aren't quite ready for such complete automation. The company reported a loss of $19 million on a decline in revenues of 13% in the first quarter.

Local area network (LAN) technology, the means by which all this equipment is connected, is not nearly as advanced as the press would have it. IBM's own LAN won't be available until 1986. Until then, many customers will take a break from their rush to purchase processing power to consider how best to connect all their various systems. ■

MAINFRAMES

Large-scale systems will power LAN technology

International Data Corp. (IDC), a market research firm, defines large-scale or mainframe computers as systems designed to support more than 128 users in commercial environments. They sell for an average of more than $1 million. IDC estimated worldwide shipments of large-scale systems in 1984 at $16 billion, up 11% over 1983, and representing some 30% of total computer shipments. IBM's share was put at about 72%, with IBM plug-compatible manufacturers (PCMs) accounting for an additional 10%, according to IDC. Five-year growth rate estimates for this class of computer range from 9% to 18%. Our estimate calls for 10% revenue gains in 1985, and growth averaging 15%–16% over the next five years.

The boom in personal computer sales in 1982 led many prognosticators to forecast the demise of the mainframe and minicomputer. Clearly the limits and possibilities of all these machines were not fully understood. Distributed data processing has brought computing power to the desk. However, connectivity—the ability of desktop computers to communicate with each other and share information—is needed to maximize the power of these machines. This requires connection with a larger central computer. Consequently, if the microcomputer has had any effect on the large-scale computer market, it has spurred demand, as companies strive to automate both factory and office.

Although growth in the value of shipments of large-scale computers will be healthy, it will be slower than that of smaller, newer systems. By 1986 the value of shipments of microcomputers should exceed that of mainframes. By the early 1990's, the total value of microcomputers installed should exceed that of large-scale systems.

IBM's stronghold

IBM's share of this important market has been increasing since 1981; not coincidentally, the U.S. government dropped its 13-year antitrust suit against the company in 1982. IBM has a considerable investment in its large installed customer base, which it uses to leverage sales into new markets. With IBM's increasingly aggressive pricing and technology, it should continue to increase market share. IBM will benefit most from the projected growth in this market.

The five companies known as the BUNCH—BURROUGHS CORP., SPERRY CORP. (formerly Univac), NCR CORP., CONTROL DATA, and HONEYWELL, INC.— manufacture large-scale computers, using non-IBM-compatible operating systems that are proprietary to each vendor. These are IBM's oldest competitors. With IBM's stranglehold on the market, this group will at best maintain their customer bases over the next five years, but are unlikely to add many new accounts. Existing customers are reluctant to change vendors due to the high cost of switching software and peripherals to processors with different operating systems. However, IBM compatability is almost a necessity for adding new customers. According to IDC, the BUNCH actually managed to increase their total share of the in large-scale systems to 14% in 1984, from 12% in the previous year, primarily due to a jump in BURROUGHS' share to 5.2% from 3.6%. This increase places BURROUGHS in second place, behind IBM, in that sector.

The BUNCH companies have adopted several strategies to defend their customer bases. One has been to seek out niches in which they can offer superior products, better service, or some other advantage. For example, HONEYWELL uses its expertise in controls and computer systems in the factory-automation and building-security markets. BURROUGHS has targeted several markets, such as the financial industry, in which it already had a strong position.

Most of these companies have adopted the *UNIX* operating system to some degree, usually at the lower end of their product offerings, but also in some mainframe products. In a world that demands standards, this approach might offer a strong offensive weapon against IBM if a standard *UNIX* is determined and enough commercial applications are developed for the *UNIX* environment. Customers don't always choose IBM systems because they are better, but often because they are the standard.

Most of the BUNCH companies have diversified to some degree, but usually into related businesses. CONTROL DATA has probably strayed the farthest. In 1984, financial services, including leasing and insurance businesses, provided 25% of revenues and 59% of operating profits. Overall corporate profitability in the last few years has been less than satisfactory, and in late 1984 it announced it would sell its finance subsidiary to refocus its resources on the computer businesses.

Plug-compatible manufacturers (PCMs) make systems and peripherals that are compatible with IBM equipment. They have made a market in the past by providing some advantage over IBM products, such as improved price/performance, faster delivery, smaller physical size, or better support. However, this has become more difficult as IBM has increased efforts to improve in these areas.

AMDAHL CORP. is currently the only major PCM vendor of large-scale systems based in the U.S. By IDC's estimate, AMDAHL, with about a 4.7% share of the market, is in third place, behind IBM and BURROUGHS. AMDAHL has been having trouble keeping up in the PCM market in recent years. As the technology of large-scale computers gets more complex, it has become more difficult to engineer computer products comparable to those of another manufacturer and offer a price advantage. It is even more difficult to independently develop technology that provides an edge over IBM within the ever-shortening life span of computer products. At present, only Japanese manufacturers appear to have the resources to succeed in the PCM market.

Japan will be IBM's strongest competitor in the mainframe arena in the future. Fujitsu Ltd. and HITACHI LTD. market PCM equipment ranging from large-scale systems and peripheral devices to lap-size personal computers. Fujitsu owns about 49% of AMDAHL CORP., through which it plans to market its supercomputers. HITACHI has a marketing arrangement with the NAS (National Advanced Systems) division of NATIONAL SEMICONDUCTOR. NEC CORP. provides non-IBM compatible equipment, but has adopted the *UNIX* operating system. HONEYWELL has a cross-licensing agreement with NEC.

IBM is now shipping its *308X* series of large-scale mainframe computers. The *3083 CX* entry level system, introduced in October 1984, operates at about 3.3 MIPS and has 8 to 32 megabytes of control storage. The entry-level systems sell for $635,000–$1,025,000. This system is really in the medium-scale class, illustrating the overlap in classes of computers. It offers inferior price/performance to certain models of the medium-scale *IBM 4300* family computers, but offers upgrade capabilities within the *308X* class. Therein lies the only apparent rationale for its existence. Prior to its introduction, the low end of the family was the *3083 EX* at 4.4 MIPS. At the high end is the *3084*. Using four processors working at about 7.5 MIPS each, which share the same pool of data and instructions, the *3084* achieves a performance level of 27–28 MIPS at system prices that range between $5.21 million–6.41 million.

IBM unveils *Sierra* line

Probably the most significant product launch of 1985 occurred in February, when IBM introduced the first of its next-generation high-end computers. Code-named the *Sierra* series while in development, the machine will be shipped as the *3090* series.

The first system to become available will be the *3090-200*. Volume shipments are set to begin in November 1985. The *3090-200* entry-level system will employ two processors, each capable of operating at about 15 MIPS in commercial applications, for an overall performance level of about 27–28 MIPS, roughly equivalent to that of the *3084*. However, in order to better penetrate the scientific and engineering markets, the *3090-200* is designed to offer up to 41 MIPS in scientific and engineering applications through high-speed multiplication, faster add/subtract instructions, special circuitry for loop control, 64-bit data flow, and other improvements. The system has new 256k memory chips to provide shared resource storage of 64 megabytes. Up to 128 megabytes of storage is optional in 64 megabyte increments. System prices range from $5 million to $6.09 million.

The second member of the family, the four-processor *3090-400*, will not be available until the second quarter of 1987 and will be available only as an upgrade from a *3090-200*. The *3090-400* will offer estimated performance levels of 46–51 MIPS for general-purpose use and up to 78 MIPS for scientific/engineering applications. The systems will be available with 128 megabytes of shared central storage, plus up to 256 megabytes of expanded storage in 128-megabyte increments. The upgrade will cost $4.3 million.

The *3090* family is not truly compatible with the *308X* series because IBM has gone back to the use of high speed emitter-coupled logic (ECL) chips with three times as many logic circuits per chip as the transistor-to-transistor logic chips used in the *308X* series and in most existing mainframes. The intense heat generated by the high density of circuits is dissipated through advances in thermal conduction module packaging. Because of the hardware incompatability, the *308X* series is software-compatible but can not be field-upgraded to a *3090-400*.

The idea of field upgradability came about as life cycles of large-scale systems shortened. In the past, customers scrapped or resold expensive systems at substantially reduced prices and bought new ones when they needed increased computing power. Field upgradability allows customers to increase their processing power on-site and in increments. However, new technology is required to get boosts in speed with each generation of computer. At some point, incompatibilities brought about by the new technologies prevent field upgradability.

The long lead time between the introduction of the *3090-400* and future availability came as some surprise, but is not out of line with past gaps between IBM announcements and delivery schedules. IBM has said that the length of delay is necessary to give its customers adequate planning time and to make sure all bugs have been worked out of the processors. Customers will need time to make buying decisions, given the system's incompatability with the older IBM systems in their data-processing centers. It is also likely that IBM feels there are still a lot of revenues to be garnered from the *308X* series. The customers that are unhappiest, of course, are those at the limit of their *3084* processing capacity; they may be forced to purchase a second *308X* processor, which cannot be upgraded, in the interim. The delay should give IBM's competitors time to get viable alternatives to market.

IBM competitors rush to fill the gap

As of April 1985, BURROUGHS, HITACHI, and HONEYWELL had all announced new mainframe computers roughly comparable to the *3090* models, but with earlier availability dates. BURROUGHS announced eight models of its *A15* line, using one to four processors. Initial deliveries are scheduled for the third quarter of 1985 through the first quarter of 1986. HONEYWELL will offer five models using one to four processors, all available in late 1985. Japan's NEC CORP. is manufacturing the processor HONEYWELL will sell. HONEYWELL will provide the operating system software; the peripheral equipment will come from IBM. HITACHI has also announced an IBM-compatible processor in the U.S. to be sold by the National Advanced Systems Corp. (NAS) *AS/XL* line. Whether these delivery dates are actually met remains to be seen. The computer industry has a long history of product delays, particularly when leading-edge technology is involved.

SPERRY is the remaining BUNCH company most likely to offer a response to the *Sierra*. AMDAHL-Fujitsu should also be a candidate.

Mainframe shipments should be strong in the second half of 1985 and into 1986, particulary for IBM, BURROUGHS, and other vendors with fairly new product lines. Longer term, IBM will continue to dominate the market. BURROUGHS could remain a very distant but strong second, particularly if it is the only U.S. manufacturer producing a *Sierra*-type processor. The positions of the other BUNCH companies are likely to weaken further. The Japanese, who have the size and resources to offer the price/performance advantage needed to compete with IBM, should experience gains in market share, largely at the expense of AMDAHL.

Comparison of supercomputer performance

Model	MFLOPS	Model	MFLOPS
Cray-1 (original model)	160	*Hitachi S801/20*	400
Cray X-MP/48	1,000	*Hitachi S810/20*	800
Cray 2	1,200	*Fujitsu VP-100*	267
Cray 3	16,000	*Fujitsu VP-200*	533
CDC Cyber 205	800	*NEC SX-1*	570
ETA GF-10	10,000	*NEC SX-2*	1,300

Source: Electronic Business, Cray Research.

Supercomputers: the ultimate number crunchers

Supercomputers are, by definition, the fastest processors at any time. This definition suggests rightly that the parameters defining supercomputers are constantly revised to accommodate new technological developments that increase performance. Supercomputers are generally used for applications that require huge quantities of computations, such as the simulation of physical phenomena. Typical examples are measuring the movement of air over an airplane wing, or the flow of water through an oil reservoir. IDC includes supercomputers in its large-scale computer category.

At year-end 1984, about 130 supercomputers were in place worldwide. CRAY RESEARCH supplied 88 of these. In 1985, an estimated 45 machines are to be installed, at least 30 of which will be CRAY computers. Today's estimated market of some \$300 million in annual revenues is expected to grow more than 30% compounded annually, to \$1.5 billion by 1990. In 1972, when Seymour Cray established CRAY RESEARCH, the company projected a total market for its machines at 80–100 potential customers (those who would be technically and financially qualified to order CRAY machines). CRAY now puts its potential customer base at more than 500. As with any class of computer, the market continues to expand with each improvement of the price/performance level.

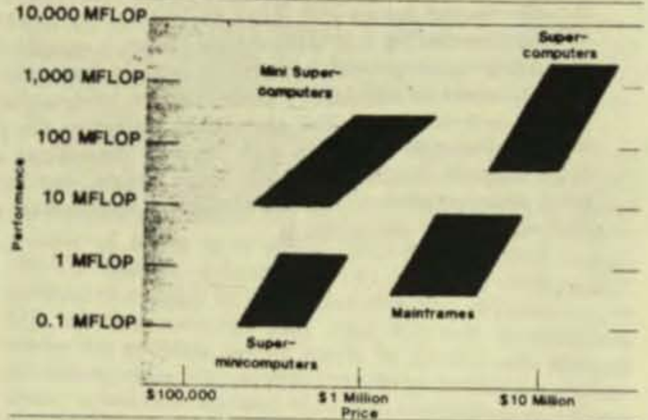
Performance of supercomputers is most often measured in terms of millions of floating-point operations per second (megaFLOPS or MFLOPS), as opposed to MIPS, the standard performance measurement for large- and medium-scale computers. Floating-point operations are addition, subtraction, multiplication, and division. The performance of these processors is generally measured in terms of hundreds of MFLOPS, whereas very large IBM mainframe performance reaches only four to five MFLOPS, and microcomputers work at about one-thousandth of one floating point operation per second, or 0.1 MFLOPs. Because of the dominance of CRAY machines, the company is often used as a market proxy, and CRAY machines are commonly used for comparative purposes. Other vendors often compare the performance of their machines to that of the *Cray 1* machine, introduced in 1976 and no longer produced.

Supercomputer processors are designed for large-scale scientific and engineering computing. These applications usually involve both vector and scalar operations. Vector operations entail a few calculations performed on vectors, or strings of numbers. Scalar operations involve single numbers or pairs of numbers which cannot be treated as vectors. Supercomputers achieve their superior number crunching ability through use of *parallel processing* and *pipelining*. Parallel processing involves either the concurrent execution of more than one program or subprogram or the concurrent operation of more than one hardware element, either a complete processor or a specialized hardware unit. Pipelining, on the other hand, permits manipulation of data in assembly-line fashion. Usually scalar arithmetic performance is no better on a supercomputer than on a general-purpose mainframe or minicomputer. Hence, reliance on vector, or MFLOPs, performance for comparing computer performance can be misleading because the time the processor takes to solve a given problem depends on its vector and scalar speeds, the proportion of each type of operation in the problem, and machine memory size and input/output speeds.

Cray Research sets the benchmarks

The *CRAY X-MP* series, announced in 1982, is designed to offer balanced scalar and vector performance. The unipro-

SCIENTIFIC COMPUTING PRICE/PERFORMANCE



Source: Floating Point Systems

cessor *X-MP/12*, priced at about $5 million, provides peak performance of up to 250 MFLOPS. The dual processor *X-MP/24* provides peak performance of 500 MFLOPS at prices ranging from $9 million—$11 million. The four-processor version, the *X-MP/48*, available as of the first quarter of 1985, operates at peak performance rates of about 1,000 MFLOPS, or one gigaFLOPS, and sells for about $14 million. Memory sizes range from only one to eight million 64-bit words, which limits performance.

Initial shipments of the company's second-generation model, the *CRAY 2*, are to commence in mid-1985. The *CRAY 2*, a four-processor *UNIX*-based system, is expected to offer performance of 600 to 1,200 MIPS with 256 million words of memory at a price of $17.6 million. CRAY's growth is currently limited by its production capacity.

In the table on page 78 are current and future offerings of CRAY and other supercomputer vendors. CRAY's competition in the U.S. is less than formidable.

With a peak performance limited to 800 MFLOPS, CONTROL DATA's *CYBER 205* is marketed generally to the government and education markets where price is an important factor. About eight systems are sold per year. In 1983, supercomputer development activities were spun off to 90%-owned ETA Systems. ETA is developing the *GF-10* system, which is to incorporate up to eight processors, a very large memory and high-speed peripherals to attain peak performance of 10,000 MFLOPS for a price of $20 million. The system is scheduled to be available in 1987.

A potentially greater threat to CRAY's supremacy is the introduction of supercomputers by the Japanese. HITACHI, which had installed one system at a Japanese university at year-end 1984 and had another on order, recently said it had no plans to market its computers in the U.S. Fujitsu, on the other hand, entered a marketing arrangement in 1984 with 49%-owned AMDAHL CORP. to sell Fujitsu supercomputers in North America and Europe. However, although AMDAHL has announced plans to sell six to 12 Fujitsu machines in 1985, it had not received any orders as of May 1985. Fujitsu had two installations at Japanese universities in 1984 and two more machines on order from the Japanese government. Both HITACHI and Fujitsu have provided a degree of IBM compatibility in an attempt to make their machines more attractive to the large installed base of IBM and plug-compatible mainframe users. NEC CORP. had two university orders in 1984 for its *SX* series, which was clocked at up to 1,300 MFLOPS, similar to the performance of the *Cray X-MP/48*. No installations of the *SX-2* have yet been reported.

All three Japanese vendors have stated goals of selling about 30 computers to the Japanese market by 1988, and CRAY has said it planned to sell at least 10 machines in Japan during the next five years. The total Japanese market is put at about 80 machines.

Despite the apparent gains made by the Japanese, it is unlikely that CRAY, and therefore the U.S., will lose its supercomputer lead in the near future. CRAY plans on shipping three of its second-generation *CRAY 2* computers in 1985. The company feels that the *UNIX* operating system utilized by the *CRAY 2* will provide the communications capabilities necessary in commercial markets without impairing its computational powers as could an IBM-compatible operating system. IBM operating systems are designed for general-purpose machines, and may not optimize the speed of the computer. In addition, Seymour Cray, the company's founder and developer of the original *CRAY 1* and *CRAY 2*, has left the *CRAY 2* in the hands of the production people and has begun work on developing the *CRAY 3*, which is expected to be about 100 times faster than the *CRAY 1*, have an even larger addressable memory than the *CRAY 2*, use a *UNIX* operating system, and incorporate gallium arsenide semiconductor technology to increase processing speed.

IBM has entered the supercomputer arena (to a limited extent) with an off-the-shelf design for parallel processing. Currently in operation is an *IBM 4381* mid-size computer hooked up to seven of FLOATING POINT SYSTEMS's (FPS) array processors for computational work, which are attached to an *IBM 4341* and three FPS array processors, for program development, and another *4341* and a graphics station. With the addition of two FPS *164/MAX* boards to each processor, the system achieves 550 MFLOPS. Up to 15 boards will be added to each array processor to achieve a maximum capacity of 3,410 MFLOPS. The two companies first signed a joint marketing agreement in 1981, and this system appears to be the logical progression from that agreement.

Although the U.S. is well-positioned currently, the importance of maintaining that lead is not lost on the U.S. government. In late Februrary 1985, the National Science Foundation said it would provide $200 million in funding over the next five years to set up supercomputer centers at four universities. State governments and industry are to provide an additional $200 million. Cornell University will

The blossoming "baby super" market

The burgeoning interest in supercomputing power for commercial applications has interested many vendors in developing low-priced entry-level systems that bridge the gap between general-purpose mainframes and supercomputers. These machines are labeled "baby supercomputers," "mini supercomputers" (as opposed to super minicomputers), and the more creative "Quarter Crays" and "Crayettes."

Timesharing preceded the mini- and microcomputer booms; about 30,000 users currently timeshare CRAY supercomputers. A potential market appears to exist for smaller machines offering reduced MFLOPS performance at a lower price. There are several contenders and potential contenders in this market, including FLOATING POINT SYSTEMS, Scientific Computer Systems (SCS), Convex, Encore, and ELXSI. These companies rely, or will rely, on offering price/performance advantages over mainframes and superminis while providing a fraction of a true supercomputer's performance. ■

use an *IBM 3084QX* mainframe connected with five of FLOATING POINT SYSTEMS's *FPS 264* and one *164/MAX* scientific computer. A consortium of 12 universities is setting up a center near Princeton which will install a CONTROL DATA's *CYBER 205* computer, later to be upgraded to an ETA SYSTEMS's *GF-10* when the system becomes available. CRAY will install an *X-MP/24* at the University of Illinois and an *X-MP/48* at the University of California-San Diego. The University of Illinois is expected to upgrade to an *X-MP/48*. Any technology developed at the centers will not be considered proprietary to the manufacturers. The centers are expected to aid research and development of new supercomputer technologies and to provide a fertile training ground for future professionals for the supercomputer industry.

Supercomputers have extensive uses, both military and industrial. Roughly half of the supercomputers now sold are for commercial use. The three largest automobile manufacturers have had supercomputers installed to test designs without building expensive prototypes. Other applications include reactor design and other nuclear energy research, weather forecasting and meteorologic research, geophysical and petroleum exploration, including seismic data processing and reservoir simulation, aerodynamics, computational physics and chemistry, film animations, including the generation of special effects in such films as *Star Wars*, and other graphics applications, electronic design, and structural analysis, primarily in the aerospace, automotive, and civil engineering industries. ■

MEDIUM-SCALE MARKET

Medium-scale market battleground: IBM vs. DEC

Medium-scale computers, according to International Data Corp. (IDC), a market research firm, are systems supporting 17–128 users in normal commercial environments and costing from $100,000 to $1 million. This category comprises superminis and the lower range of general-purpose mainframes. Most current systems are in the one- to five-MIPS range. Total worldwide shipments of medium-scale systems in 1984 were estimated at $13 billion, up 40% from those of 1983, and represented about 25% of total shipments. Because 1984 was a recovery year for many of these companies, less favorable comparisons are likely in 1985. We expect shipments to be up only about 10% in 1985, but five-year growth should average some 15%.

According to IDC's preliminary census, IBM, with an estimated 30% share in 1984, stole the lead in this market from DIGITAL EQUIPMENT CORP. (DEC), which maintained a 20% share. The other half of the market is split up among a dozen or so vendors, including the BUNCH companies (BURROUGHS CORP., SPERRY CORP. (formerly Univac), NCR CORP., CONTROL DATA CORP., and HONEYWELL, INC.), with low-end general purpose machines, and fast-growing supermini vendors such as DATA GENERAL, PRIME COMPUTER, GOULD, and WANG LABORATORIES.

The supermini sector is in transition. Vendors are trying to defend their positions in their traditional scientific/engineering, industrial, and government markets from mainframes at the high end and the workstation at the low end. At the same time, they are trying to make further headway in the faster-growing commercial markets, particularly office automation. Moreover, most of the vendors in this market are in product-line transitions as their product bases shift from 16-bit minicomputer (small-scale) technology, to the faster 32-bit superminicomputer (medium-scale) technology. All of this is occurring while the firms try to manage very fast, but variable, growth. Revenues are expected to increase about 20%–25% annually over the next five years.

With supermini performance levels continuing to improve, supermini vendors find themselves increasingly in competition with mainframe vendors. Just as with large-scale computers, switching vendors in the medium-scale market is a costly proposition due to the substantial investments in software and peripherals. Market shares are more volatile, though, in this higher-growth market. The market is shaping up as a shoot-out between IBM and DIGITAL EQUIPMENT as they defend their respective strongholds in the commercial and scientific/engineering markets. As in the large-scale market, the lesser players must search for specific niches.

DEC's leadership has eroded

In the past, DEC was clearly the leader in medium-scale computers, but this is no longer the case. DEC's line of *VAX* 32-bit superminis, introduced in the 1970s, were the standard of comparison, as were their 16-bit *PDP 11* minicomputers before that. Superminis use 32-bit technology to increase their speed, whereas minicomputers use 16-bit technology. However, DEC's to long delays in bringing out a new top-of-the line model, the *8600*, have given DATA GENERAL and PRIME time to launch highly competitive systems. In addition, IBM's *43XX* systems compete head-to-head with the *8600* in terms of performance. The BUNCH companies tend to offer slower-growth low-end mainframe products, but have begun remarketing *UNIX*-based 32-bit systems, which might prove quite competitive in the future.

The *DEC 8600*, code-named *Venus* while in development, was introduced in October 1984 after years of delay. The entry-level system, priced at $576,000–$970,000 with 12 to 32 megabytes of storage, operates at a rating of 4.6 MIPS. The *8600* utilizes 256k memory chips, so that although the new processor offers 4.2 times the performance of an older *VAX 780*, it is the same size.

The *IBM 4381-3*, introduced a week before the *8600*, is rated at 5 MIPS and is priced from $825,000 for 8 megabytes of central storage to $1,065,000 for 32. Although the *4381-3* is more expensive than other medium-scale offerings, it provides a clear price/performance advantage over IBM's own entry-level mainframe, the *3083 CX*, rated at 3.3 MIPS. On the other hand, the *3083 CX* can be upgraded to more powerful large-scale systems, while the *4381* cannot. The *4381* combines minicomputer and mainframe technology to achieve its performance, adding to product-line confusion.

PRIME COMPUTER's response to the *8600* was the *9955*, which offers performance of 4.0 MIPS for a typical configuration price of $371,000. DATA GENERAL's *MV/10000 SX* offers lower performance, 3.6 MIPS, for a lower price of $223,000. Both PRIME and DATA GENERAL claim price/performance superiority over the *8600*.

In addition to competing with other supermini vendors, DEC offers a unique alternative to mainframes through *VAX Clusters*. When the *8600* was introduced, it was compared with an IBM mainframe, not other superminis. DEC claimed a cluster of seven *8600s* could outperform a then top-of-the-line *IBM 3084* (about 27 MIPS) for a cost of about $6.7 million, or roughly 65% the cost of a *3084*. Whether or not this solution succeeds, only time will tell. In situations where the problem cannot easily be divided into discrete processing units, such as with large batch processing, performance is less than optimal. However, the modularity offered by *VAX Cluster* is extremely attractive to customers, since it provides a simple means of upgrading performance.

Clearly, large-scale systems are facing competition from superminis at the low end of the large-scale performance range on a pure, stand-alone basis, and from clustered and networked solutions at the high end. However, IBM's new *3090-200* mainframe outperforms the standalone *DEC 8600* by six to nine times, and the *3090-400* provides a minimum 10- to 20-fold advantage. Theoretically, it would take 14 clustered *8600's* to get comparable *3090-400* performance, and that is a room full of computers.

Many customers are performance-hungry, as strong sales of high-end processors indicates, and it is only in terms of price/performance that superminicomputers have an advantage, not in raw computing power. Mainframes are feeling the heat from superminis, but superminis also face mainframe competition as price/performance levels in the large-scale market continue to extend down into supermini terrain, providing clear upgrade paths to higher-performance, large-scale machines.

Nonstop processing: a wave of the future

TANDEM COMPUTERS established an interesting niche in the supermini market in 1976 with its so-called fault-tolerant systems. Several smaller competitors have since entered the market. Fault-tolerant systems use redundant processors, back-up memory, and other duplication in hardware and software so that if a failure is detected, processing is switched to an alternative processor. Fault tolerance is desirable in applications that require a high degree of processor availability, such as in on-line transaction processing (OLTP) applications. Examples of OLTP applications are airline reservation systems and automatic teller networks.

Another emerging market with outstanding growth potential for fault-tolerant systems is "work group" servers, which act as database and communications centers for a large number of personal computers or workstations. Currently, when a work group server fails, many users can be idled for hours.

The potential market for fault-tolerant systems is expected to exceed $7 billion by 1988. However, the OLTP market is dominated by IBM mainframes with some $17 billion in sales. In addition, IBM recently agreed to market STRATUS COMPUTER's fault-tolerant systems, to stem further inroads into the OLTP market by the fault-tolerant vendors. As traditional computers become more reliable, the more-expensive redundant solution will be less attractive.

'85 will be difficult for vendors

In the last few months, many medium-scale manufacturers have announced a slowdown in orders and plummeting earnings. Although some of this can be explained by economic sluggishness following a year of strong recovery and growth, it also reflects the growing complexity of the market. With increased competition comes an acceleration of product announcements. This, and the confusion arising from the overlapping of product lines, have made the buying decision more difficult. The current uncertain economic outlook is further muddying the waters. Vendors in this market may be more vulnerable to short-term economic fluctuations than manufacturers of other classes of computers. Large-scale systems have very long sales cycles, and after a couple of years of planning, buyers are unlikely to cancel orders quickly. Medium-scale computer purchases are more easily postponed, and the cancellation of a medium-scale computer can represent real cost savings.

Another factor affecting sales is the dominance of IBM and the adverse effect its increased aggressiveness has had on competitors. These factors have made buyers cautious. They are taking more time to evaluate new products, vendors' financial stability, and their own needs. The end result will be a less-than-spectacular year for medium-scale vendors. Revenues in this segment are likely to be up only 10% in 1985, and profitability will be under pressure for many players.

Just as large-scale computer vendors are feeling the heat from below, medium-scale makers are feeling the breath of lower-end competitors. Competition is particularly fierce in their traditional stronghold, the scientific/engineering market. In the past, engineers have had to share a central processing unit. Such companies as MENTOR GRAPHICS and DAISY SYSTEMS are now offering dedicated engineering workstation with advanced graphics and networking capabilities. Some supermini sales will obviously be lost. DEC has responded by bringing out its own 32-bit workstation product, the *MicroVAX II*. IBM and other companies are likely to follow soon. ■

The competition continues

Small-scale systems, as defined by International Data Corporation (IDC), a market research firm, generally accommodate two to 16 users in commercial applications. Prices typically range from $10,000 to $100,000. At year-end 1984, small-scale systems were estimated to represent about 18% of the total installed base. Worldwide shipments of these systems were estimated at $10 million in 1984, up about 20% over 1983 and representing some 18% of total shipments. Again, IBM and DEC are the leaders with market shares of 22% and 16%, respectively, in 1983 (latest available), by IDC's estimate. Countless smaller firms are fighting it out for the rest of the market, and relative positions are extremely volatile. Five-year growth is expected to be at a 20% rate.

This classification includes the older, slower-growing minicomputers and the newer, faster growing small-business systems. Performance is generally less than one MIPS.

As in superminicomputers, DEC has long set the standard in minicomputers with its *PDP-11* series. The *PDP-11* has a large installed customer base in the scientific and engineering markets, as well as with government agencies. IBM's strong product in this market is the *System 36*, the centerpiece of its office automation thrust. Other vendors include DATA GENERAL, HEWLETT-PACKARD, and WANG.

Minicomputer vendors are an often-cited example of companies being squeezed from above and below by newer products. Sales of the 16-bit minicomputers have peaked, but noting that the performance of the superminis is coming down and that networked personal computers are becoming widespread presents only part of the story. The technology on which these 16-bit machines are based is being replaced by 32-bit architecture. Demand for performance in this range is still extremely strong and growing, but it is increasingly being supplied in different forms. An analogy can be found in the market for personal computers following the shift from 8-bit microprocessors to 16-bit microprocessors. Obviously, the shift didn't kill the personal computer industry; it simply altered demand within the industry. The confusion arises here with the prevailing use of minicomputer to mean both 16-bit and 32-bit computers. Most suppliers of 16-bit machines, the "minicomputer vendors," also supply superminis. Only vendors who have not made the transition to 32-bit architecture are hurting.

HEWLETT PACKARD, a leading minicomputer manufacturer, does not currently have a 32-bit product. It is developing a so-called reduced instruction set computer (RISC), code-named Spectrum, based on 64-bit technology. Its date of availability has not been announced. RISC computers theoretically offer higher speed through simplified architecture.

Despite the dire predictions, minicomputer sales are expected to expand by a healthy 10%-15% in 1985, albeit at a slower pace than in the past. Customers are reluctant to shift products, and most of the demand will come from the large installed base in the commercial and industrial markets. Most minicomputers are sold to original equipment manufacturers (OEMs) for resale to specialized markets. They are often used in factories and laboratories for process control and data acquisition, and in scientific and medical instruments. Commercial markets include insurance, real estate, law, and finance. These machines are seldom general-purpose; most are built to solve specific problems. Because of this, cost, rather than performance, is often the major selling factor. In many cases, the power of a superminicomputer is unnecessary, and a minicomputer offers a lower-cost alternative to networked PCs.

Supermicros vs. networked PCs

Although supermicros, like PCs, are based on microprocessor technology, they are able to support several users. Multi-user systems—microprocessor-based processors capable of supporting two or more terminals and sharing common storage devices—allow users to send and receive messages and share data files.

As yet, neither networked PCs nor multi-user systems dominate the two- to 20-user market. According to *Electronic Business*, end-users prefer the networked PC solution because they can retain local processing capabilities while sharing data and other resources, whereas corporate data processing managers prefer the multi-user solution because it is easier to install and monitor.

The multi-user market is crowded. ALTOS COMPUTER SYSTEMS, TELEVIDEO, and FORTUNE SYSTEMS are the most widely known vendors. IBM entered the market, which it surely intends to dominate, with its October 1984 announcement of the *IBM AT*. While this machine set a new performance level for personal computers, it is obviously intended to be more than a stand-alone personal computer. The *AT* will be the frame on which IBM hangs its multi-user strategy. Eighty-four of 100 *Fortune 1000* companies surveyed by Newton Evans Co. planned to buy an *AT*. Among the companies planning to buy a multi-user system, the *AT* was mentioned twice as often as all competitive products put together. The machine is discussed further on page 00.

Multi-user systems manufacturers have been the most eager of all computer companies to embrace AT&T's *UNIX* operating system, which was developed for multi-user environments. IBM will offer *Xenix*, its version of *UNIX*, as an option for the *AT*. This will undoubtedly result in a tidal wave of applications software packages developed for *UNIX*.

As with most types of computers, small business computer performance is improving fast, testing the lower limits of supermini performance. ALTOS COMPUTER was the leading money-maker in the supermicro arena in 1984, according to International Data Corp., with some 7.2% of worldwide shipments. On April 17, 1985, ALTOS announced its new multi-user system, the 3086, which uses a modified *UNIX V* operating system. It can support up to 30 terminals and has 1 to 16 megabytes of main storage and a high-speed 32-bit bus for transporting data. An entry-level system will sell for about $7,000. Incorporation of a very high speed 17 megahertz chip will permit a performance level of about 3 MIPS beginning in late 1985.

Customer demand for computing power in this price/performance range should be exceptionally strong over the next five years. As with most growing markets, however, competition is fierce, particularly with IBM participating. Consolidations, joint ventures, and exits from this very crowded market during the year are likely. Unit volume growth could exceed 35% annually, but price competition will cause the value of shipments to increase only about 25%. ■

Temporary saturation approaching

The microcomputer (or personal-computer) market is entirely different from the medium- and large-scale markets. Microcomputers are more user-oriented. Personal computers are sold not only to the home market, which gets much of the press, but also to the business/professional, educational, and scientific markets.

Microcomputers are very small computers with microprocessors as central processing units, and usually sell for less than $15,000. Current market value of shipments is put at some $17 billion by IDC, representing about 28% of all shipments. The spectacular growth in unit sales appears to be moderating; some submarkets, particularly the home market, may be temporarily saturated. Yankee Group, a market research firm, estimates that the value of 1984 shipments rose 72% on a doubling of unit volume. They anticipate unit growth of 30% over the next year but an increase in shipment value of only 13% due to falling prices. Unit growth over the next five years should be about 20%-25%, much closer to the industry average than originally anticipated.

Once again, IBM dominates

The history of the microcomputer market has traced a familiar pattern. IBM was late entering the market and did not introduce its 16-bit *IBM Personal Computer* until 1981. Despite what was considered an unexciting product, IBM managed to take the market leadership position away from APPLE COMPUTER and TANDY in 1982. IBM now has about a third of the total market in terms of dollar sales. Plug-compatibles have another 30% share, and APPLE COMPUTER has some 10%. There are dozens of minor players in the field.

IBM's line of personal computers set the standards for the industry. The original *PC*, introduced in 1981, had 64k of memory, which was sufficient to run the then-most-popular spreadsheet package, *VisiCalc*. It had one disk drive and cost $2,235 (it currently sells for $1,995). In 1983 the *PC XT* was announced. The basic model, with 128k of user memory, expandable to 256k, one floppy disc drive, and a 10-megabyte hard disc drive, retailed for $4,995 (it currently sells for $3895). In 1984, IBM introduced its next-generation, high-speed *PC AT*. The standard *PC AT* has 256k memory and a 1.2 megabyte floppy disc drive, and sells for $3,995. The enhanced model has 512k user memory, expandable to 3 megabytes, a 1.2 megabyte floppy, and a 20 megabyte hard disc drive, and sells for $5,795.

The *PC AT* has more than twice the speed of most personal computers. It is six times faster than the original *PC* and nearly three times as fast as the *XT*. Despite its speed, it is compatible with most previous hardware and software for the *IBM PC* line.

The *AT* is IBM's personal-computer centerpiece. *AT*, short for advanced technology, is no misnomer. The *AT* is not only fast, but it is also designed to operate in stand-alone, multi-user, and networked environments. As a single-user, single-tasking machine, the *AT* will run under a new release of IBM's *PC-DOS* operating system, but it will also support the *IBM Xenix* multi-user operating system, priced at $395. The *AT* can currently support up to three users with IBM hardware and software. Computone Systems Inc., an IBM value-added reseller, has introduced a controller board that allows the *AT* to support up to eight terminals, including *IBM PCs*.

Personal computer manufacturers are rushing to market with competitive *AT*-like products, just as they rushed *PC* clones to market a couple of years ago when the *IBM PC* was fast becoming the industry standard. Much of the microcomputer software written over the next two years will be for the *AT*.

Chances of success for *AT* clone slim

Since the *AT* has been the de facto standard almost from the day of its introduction, personal computer vendors had little choice but to offer a similar product. However, the chances of success for an *AT* "clone" are slim. The potential market for the higher-priced *AT* is substantially smaller than the market for the original *PC*. Shelf space at the retail level is pretty well sewed up by IBM, APPLE, and COMPAQ COMPUTERS. And IBM is more aggressive in taking legal action against its competitors for alleged software copying.

Although clone manufacturers can exploit current *AT* shortages, IBM is gearing up for volume production by September 1985. Some vendors hope to garner sales by offering *AT* compatibility, plus features not found in the *AT*. Other vendors hope to develop sales to value-added resellers (VARs) which sell to specific vertical markets, such as the insurance and construction industries.

Recent price cuts by IBM and the termination of production of the low-end *PC Jr* suggest that IBM is repositioning its product line for new product announcements. Most speculation centers on the possibility of a fall introduction of a new low-end *AT* computer. If this occurs, the price of the *PC* could drop to about $1,000.

Second-ranked APPLE COMPUTER sells machines that are not compatible with IBM software. Its older 8-bit *Apple II* product line is sold mainly to the home, education, and small business markets. Its newer 32-bit *Macintosh* line is being positioned for the office. APPLE has had a tough time since IBM entered the personal computer market and, in May 1985, announced a reorganization, as well as plant consolidations, layoffs, and reduced advertising expenditures. APPLE was the instigator of the marketing wars that resulted in skyrocketing advertising expenditures. APPLE tries to appeal to potential customers who dislike the idea of buying from the colossus, IBM.

Most minicomputer and mainframe companies have entered the personal computer market. None of these vendors, other than IBM, has been terrifically successful. The concept of a mass-produced, end-user oriented product is antithetical to their approach of building one machine at a time to be sold to a MIS manager. Moreover, personal computers tend to have lower margins than larger systems, putting pressure on profitability. Several have given up the retail market, including DEC, and will focus on supplying their own customers with machines that will work with their other computers. Many are purchasing their microcomputers from other vendors that sell exclusively to the OEM market, such as CONVERGENT TECHNOLOGIES.

Software drives PC market

It is common industry wisdom that the publication of *VisiCalc*, a spreadsheet software package, was the catalyst for the microcomputer boom. It was the first practical use developed for personal computers. The expansion of the personal computer market is driven by applications as well as by price/performance. Microcomputer sales will expand with the machines' capabilities, in terms of both local computing and communication with larger data bases in other systems. Applications software availability is a major consideration when buying a personal computer.

MS-DOS, the operating system for IBM's *PC* family, is standard for personal computers. Any company offering a personal computer with a different operating system—APPLE COMPUTER is the prime example—must convince independent software firms to write for their machines. Unless there is the possibility for high-volume sales, the independents have no incentive to do so. Of course, this serves to further solidify IBM's dominance in the market, and to a lesser extent, APPLE's.

Limited software availability can cripple a machine's sales. APPLE's *Macintosh* computer offered advanced technology and ease of use, yet sales were slow in 1984 due to a lack of software, particularly for business applications. APPLE was depending on the LOTUS DEVELOPMENT's *Jazz* integrated business software to spur *Macintosh* sales. In April 1985, LOTUS announced that *Jazz* would be delivered May 27, nearly two months later than originally planned. The delay will surely hurt *Macintosh* sales.

Retail shelf space a valuable commodity

IBM and other vendors that traditionally sold only through their own sales force have had to develop new marketing methods for personal computers, which are generally marketed to less-sophisticated users. Roughly 10% of IBM sales now come from sources other than its in-house sale force. These sources include value-added resellers and dealers (VARs and VADs) and independently owned retail stores. Manufacturers must use these outlets to generate enough sales to achieve profitability in personal computers, as well as to compete effectively with single-product-line, mass-market-oriented companies, such as APPLE COMPUTER.

It is difficult for vendors other than IBM, APPLE, or COMPAQ to convince dealers to carry their products. Even such firms as AT&T, ITT, and HEWLETT PACKARD are having trouble. Not only is physical space a limitation, so is "mind space"; salespeople can only learn so many machines. Inventory costs are also high, particularly for product lines that do not move. Add to this the huge cost of introducing a new product—including the price of a floor demo, a machine in stock, a service kit, and training—and it becomes a matter of practicality for retailers to shy away from new and untried products, even those from established vendors. This perpetuates the positions of IBM and APPLE. COMPAQ's position is more tenuous. The company cannot afford a new-product mistake, and not all their new products will be readily picked up by the major dealers.

The new AT&T *UNIX PC*, which is both a personal computer and a multi-user system, will have to prove itself before it gets much shelf space. It is untried, not very price-competitive with the IBM *AT*, and is handicapped by the limited amount of *UNIX* software available.

Retailers are suffering. Serious overbuilding of outlets accompanied the boom in microcomputer sales. The competition forced retailers to discount prices and raise advertising outlays. Then came a series of manufacturer's price cuts, led by IBM and a slowdown in unit sales. Substantial consolidation can be expected in 1985.

IBM wins desktop battle

About one out of 10 office workers in the U.S. has access to a PC, and not surprisingly, about 60% of those PCs are made by IBM. That share is expected to exceed 75% in 1985. IBM has leveraged its substantial presence in the data processing departments of corporate America to penetrate the front offices. In addition, IBM's superior record for service and support is important to that client base.

APPLE COMPUTER is attempting to penetrate this lucrative market with its 128k and 512k *Macintosh* computers, a low-cost local area network that can link up to 72 computers and peripherals, and a laser printer. APPLE stresses the *Macintosh's* ease of use and graphics capabilities, but in an IBM world, these may not be enough to sell their machines. Moreover, APPLE cannot supply the larger computers needed to control company-wide communications. APPLE has finally conceded the need to offer communication capabilities with IBM products, but much of the hardware and software to accomplish this won't be available until 1986. Most likely, *Macintoshes* will be purchased as graphics nodes in largely IBM departmental networks.

The commercial market is nearing temporary saturation. For the first time in years, funds allocated for the purchase of microcomputers declined as a percentage of average data processing budgets in 1985, according to a survey by *Datamation*. It will take new applications, like truly integrated voice-data capabilities, to create another boom. Unit volume growth in the commercial market will be in the 20% range in 1985.

IBM also leads the nascent industrial and scientific/engineering markets. Penetration of these markets has been less spectacular since the performance of available micros has been insufficient to perform many useful tasks. In addition, engineers used to working on large computers are reluctant to give up the ability to tap into that power.

There's no place like home

The "home computer" is a product in search of a market. By late 1984, it was apparent that consumers were abandoning the low-end, $200 machines, such as *Commodore 64* and the *Atari 80XL*, which could do little more than run game programs. Buyers figured out that it was easier to balance their checkbooks with a pencil and a $10 calculator and to store their recipes on file cards than to use a computer for these tasks.

The higher end of the market (over $1,000) has always been APPLE's stronghold. The company pioneered this market in 1976 with its original *Apple* computer. But competition is getting fierce. Both COMMODORE and ATARI CORP. intend to bring computers of comparable performance to market at lower prices this year. IBM's discontinuance of the *PCJr* removes some of the pressure, but widespread discounting of the orphaned machine might lead to price wars.

The *IBM PCJr* story provides insight into the transition under way in this market. Introduced in 1983, the *Jr* appeared ill thought-out. Priced at $999 for only 64k of memory, it was positioned to limit cannibalization of the *IBM PC*. However, the machine could not run PC software, had an extremely unpopular keyboard, and sold poorly. In 1984, IBM increased the memory to 128k, added a disk drive, and replaced the keyboard with a typewriter-style keyboard, for the same system price of $999, and offered as options memory expansion modules to up to 512k. Moreover, the enhanced *Jr* could run much of the software written for the PC, and the best-selling business software package, *Lotus 1-2-3*, was available in ROM cartridge form. IBM attempted to reposition the *Jr* as a home business computer for those who had PCs in the office. Still, the machine did not sell well until, in an aggressive Christmas season promotion, IBM bundled the system with a color monitor, which retailed for $429, and two software packages, for a list price of $999. Retailers sold it for as low as $795. IBM outsold APPLE during the season, but when the promotion was over and the system price returned to over $1,400 at the end of January, sales dried up. In March, IBM announced that it would cease production of the *Jr*.

This move has serious implications for the home market. It is likely that IBM determined that the market simply isn't there at this time, and won't be until more useful applications are developed. The market is temporarily saturated. Hobbyists already have their machines, and the number of professionals who need PCs to work at home is limited. Electronic mail and information services like Compuserve are too expensive to sell machines.

The education market is still extremely important. Children who learn on a particular brand of computer are likely to retain some brand loyalty when grown up. Hence APPLE and, to a lesser extent, COMMODORE INTERNATIONAL, have catered to this segment through discounts and educational software offerings. IBM got into the game rather late, but adopted the same tactics with the introduction of its enhanced *PCJr*. IBM will undoubtedly position a new *IBM PC* product for this market, but may have trouble selling to educators who feel they got burned with the *Jr*.

PC sales are expected to slow considerably in 1985, reflecting the temporary saturation of certain markets after a spectacular 1984. With prices falling, dollar sales could increase less than 15%, but over the five-year period through 1989 growth should average 20%-25% annually. ■

SOFTWARE

Hardware companies, independents vie for market

Nearly everyone knows something about software: it tells a computer what to do. Software is a series of coded instructions, written in programming language, that control the internal workings of a machine and enable communication with the end user. Software tailors a computer for specific applications, be it numerical computations by large corporations or game-playing by home users.

Today's software market can be defined in a variety of ways. Two broad categories are systems and applications. Systems software includes both the operating systems that control the management of a computer's resources and other products that help to organize data, assist with the programming of applications, and measure a computer's performance. Applications software provides specific functions for the end user, such as financial analysis, word processing, or learning tools for children.

A second way to view the market is according to the type of machine on which a piece of software will run. The processing power and memory capacity of computers determine the range of software they can use. Mainframe and minicomputers have traditionally been able to handle more complex tasks, hence more sophisticated software, than microcomputers, although the evolution of more powerful smaller machines is blurring the distinctions. Mainframe products may cost upwards of $100,000, while most micro software packages cost $600–$700, or less.

Software may also be categorized as packaged or custom-designed. Custom software is more likely to be developed by a company for its internal use to meet specific requirements. Packaged software, the area in which most commercial efforts are targeted, has broader applications and a far greater potential audience. International Data Corp. (IDC), a market research firm, estimates that worldwide packaged software revenues of U.S.-based suppliers will total $15.2 billion in 1985, up from $11.1 billion in 1984.

Developments in computer hardware have had important implications for the software market. Advances in electronic technology have enabled the prices of hardware to decline steadily, making computers more affordable to businesses and personal users. As the installed base of machines has mushroomed, so, too, has the demand for software. And whereas hardware is a one-time sale unless the user outgrows his machine, software is a potential source of recurring revenues as users seek additional applications. Also, with a host of machines offering similar computing capability, software becomes the chief value-added feature distinguishing one computer system from another.

The computer industry's premier company, IBM, has acknowledged the great potential of the software market by aiming for future software revenue growth of 35% annually. In 1984, IBM's applications and systems software revenues totaled $3.197 billion, up 39% from 1983 and far above that of any other company. IBM is particularly dominant in mainframe systems software, aided by its 72% share of the worldwide mainframe hardware market. Even in the micro software market, where IBM has only recently become a major presence, the company's estimated $150 million in sales in 1984 was topped only by LOTUS DEVELOPMENT.

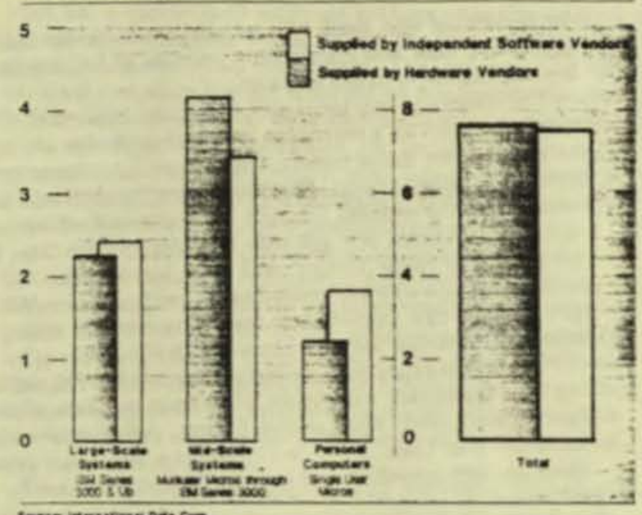
Because of the difference in products and industry participants, a discussion of packaged software is best segmented between the market for large computers, such as mainframes and minis, and the market for micros. Both are high-growth areas, but strategies for success differ.

This section prepared by Tom Graves

Mainframe and mini software

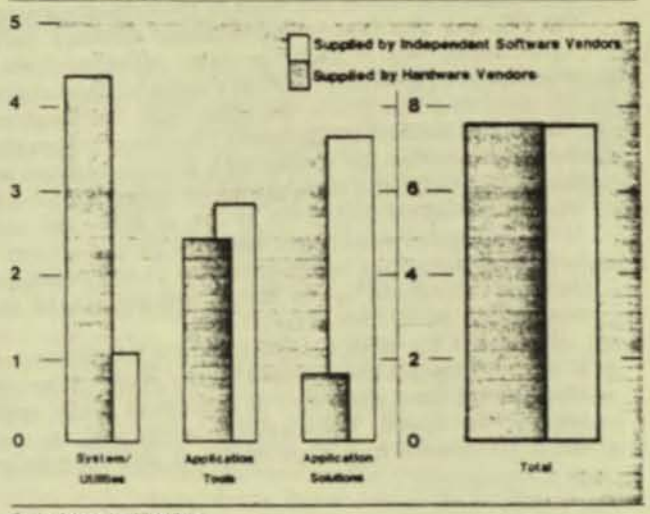
In dollar-volume terms, expenditures for mainframes and minicomputers continue to dominate the software industry. Shipments by U.S. companies of software for medium- and large-scale machines will total an estimated $12.2 billion in 1985, up more than 80% from just two years earlier, according to InfoCorp., a market research firm. What accounts for this strong growth is the greater number of installed machines and the successful efforts of software developers to create applications that improve user productivity.

1985 WORLDWIDE REVENUES OF U.S.-BASED MULTI-USE SOFTWARE SUPPLIERS BY TYPE OF HARDWARE
(In Billions of Dollars)



Source: International Data Corp.

1985 WORLDWIDE REVENUES OF U.S.-BASED PACKAGED SOFTWARE SUPPLIERS BY TYPE OF SOFTWARE
(In Billions of Dollars)



Source: International Data Corp.

The market for software to run on mainframe and minicomputers is shared by the companies who make the machines and independent software firms. The hardware companies dominate the operating systems area, while the independents have made rapid gains in applications and specialized systems software.

Independent software firms sell or license their products in several ways. In the mainframe market, the independents typically have little to do with the sale of the hardware. Software packages are sold to a customer who has already bought or is about to buy a computer from another company. With less expensive minicomputers, however, a number of software vendors have become resellers of machines, enhancing their value through the addition of software. Examples of such turnkey-system companies include ASK COMPUTER SYSTEMS, which adds manufacturing software to minicomputers made by HEWLETT-PACKARD and DIGITAL EQUIPMENT, and MENTOR GRAPHICS, which combines software with 32-bit machines from APOLLO COMPUTER to provide workstations for engineers.

A customer who buys an IBM mainframe is likely to have an IBM operating system. While there are several available, IBM is pushing its *MVS* system, featuring greater processing power than the company's *DOS* product. Systems aren't cheap; the top-of-the line *MVS/XA* costs up to $12,000, plus monthly charges of about $4,000.

The growth of multi-user systems, whereby a number of terminals are connected to a host computer, has generated increased interest in an operating system called *UNIX*, developed by AT&T and licensed to software manufacturers. *UNIX* is thought to have advantages over other systems, both for developing software and for transporting applications from one machine to another. Its acceptance, however, has been restricted by confusion over the many different versions of *UNIX* currently being offered and by the limited amount of applications software available to run with it. *UNIX* is expected to make inroads in the supermicro and minicomputer markets, but IBM's proprietary products are likely to continue their dominance among mainframes.

IBM's lead in database management shrinking

An operating system, however, is only the first step. A customer may also require a database management system costing $400,000 or more to manipulate large amounts of information. Other systems software includes library products and packages to help programmers develop applications. Input, a market research firm, estimates that the systems software market for IBM-compatible mainframes totaled $4.6 billion in 1984, and predicts annual growth of 29% through 1989.

The choice of vendors widens when a customer moves beyond the operating system. In database management products, for example, IBM is again a major force, with about 50% of the market, but its share appears to be shrinking. According to an IDC survey, primarily of commercial IBM mainframe users, IBM's installed base of *IMS* and *DL/1* products had a 62.8% market share in 1983. In 1984, however, independent software firms were making headway, as IBM, even with the introduction of its new *DB2* product, was expected to get only 44.7% of the new database system purchases, according to the IDC survey.

Major companies among the independents include CULLINET SOFTWARE, which parlayed success with its *IDMS* database products and other software into annual revenue growth exceeding 50% over the past four years. CULLINET had an estimated 10.3% of the database system installations in 1983 and was expected to receive 18.7% of purchases in 1984. APPLIED DATA RESEARCH, INC., was bursting into the market even more dramatically in 1984. Its *Datacom/DB* product also was expected to get 18.7% of database system purchases, compared with only 4.9% of the installed base the year before. Both companies are expecting continued revenue growth of at least 30% in the year ahead.

Other independent firms in the database management area include SOFTWARE AG OF NORTH AMERICA and Cincom Systems, both of which have other systems products as well.

PANSOPHIC SYSTEMS has grown rapidly without offering a database management product. Its information-retrieval and library-control systems offer such functions as enabling non-technical personnel to access data files easily and protecting programs against accidental or intentional destruction. PANSOPHIC's revenues for the 12 months ended January 31, 1985, were up nearly 29% over the year-earlier period.

Other fast-growing systems firms include COMPUTER ASSOCIATES and UCCEL. COMPUTER ASSOCIATES' products provide library functions, storage allocation, data sorting, and tools for making programming easier, while UCCEL emphasizes software that makes large data processing centers more productive.

UCCEL and CULLINET are among the more diversified independent mainframe systems software companies. UCCEL sells applications products to the financial services industry, offers microcomputer business packages, and operates data processing centers. CULLINET is seeking to leverage its strength in database management systems into an increased presence in the applications market. The company offers financial and human-resources applications packages and is expected to have products for the banking industry next year. In late 1984 it introduced a communications link between micro- and mainframe computers and an integrated package for microcomputers, in moves to position itself as more of a single-source supplier to corporate software customers.

Some applications software products can be used by a wide variety of customers; others are specific to the needs of a single industry. To date, the market leader in mainframe applications products is MANAGEMENT SCIENCE AMERICA, which has had more than 10,500 packages installed worldwide. Its products focus primarily on three areas—financial management, human resources, and manufacturing—and its customers are located in a broad spectrum of industries. MANAGEMENT SCIENCE attempted in 1981 to diversify into retail microcomputer software through its Peachtree subsidiary, but the company elected in 1984 to discontinue this segment.

In contrast to MANAGEMENT SCIENCE, which serves a variety of industries, POLICY MANAGEMENT SYSTEMS has chosen to be industry-specific. By serving the property and casualty insurance industry with products to automate such back-office functions as policy processing and claims handling, the company nearly doubled its revenues in the past two years to $84.8 million in 1984. Other industry-specific firms in the mainframe and minicomputer software markets include HBO & CO. and SHARED MEDICAL SYSTEMS, which serve the health care industry, and HOGAN SYSTEMS, which markets software to financial institutions. HBO, which recently acquired two other companies, Amherst Associates and Mediflex Systems, in the health information area, estimates that total expenditures for health-care information systems and services exceeded $2.3 billion in 1984 and have been growing 20%-25% annually. According to Input, a market research firm, commercial bank spending for applications software to run on mainframe or minicomputers should rise from an estimated $473 million in 1984, to $670 million in 1985 and to $2.5 billion by 1989.

Micro software

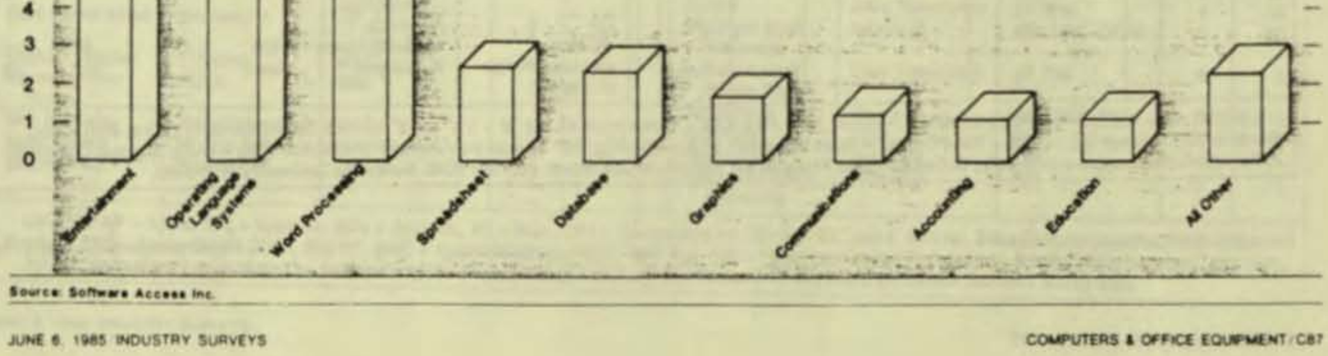
The microcomputer software industry is characterized by enormous fragmentation, a high degree of product similarity, and reliance on the technological innovation and marketing efforts of hardware manufacturers. Estimates vary, but micro software revenues probably were close to $3 billion in 1984, with most of it in the applications area. Revenues in 1985 should approach $4 billion.

The micro software market is sometimes compared to the book and music industries, where companies also compete to generate best-selling products. The software market is so new, however, that although companies may offer dozens of products, firms can become visible and successful through only one or two major hits. Hundreds of companies now offer upwards of 20,000 products to home and business users, and an industry consolidation is under way.

Micro software is evolving into a mass consumer market, and as greater marketing muscle is required to sell products, the barriers to entry are rising. From its start as a cottage industry, with a plethora of computer aficionados designing programs in their homes, the market is moving toward increasing domination by large companies.

Today, however, no single company has even a 10% market share, and a consumer may easily be overwhelmed by the bevy of software products available to entertain, educate, or increase productivity. Ranging in price from less than $20 to $695, micro software may be acquired on disks, cartridges, and chips and be bought everywhere from discount department stores to computer specialty stores. In the home market, which suffered in the past 12 months from slowing demand for hardware, games are still the most popular application, but demand is expected to shift toward education and record-keeping products. The business software market, which features higher-priced, more sophisticated products, has moved toward integrated packages, which enable a user to meld a variety of functions, such as computation and graphic presentation of data on a spread-

PROJECTED 1985 UNIT SALES OF MICROCOMPUTER SOFTWARE-TOTAL U.S. MARKET
(In Millions of Dollars)



Source: Software Access Inc.

sheet. These products contrast with other software, which has more limited applications, such as only word processing.

The creation and popularity of integrated packages was made possible by developments in computer hardware. The widespread introduction of 16-bit machines, particularly the *IBM PC*, has given software developers and users a faster, more powerful tool. Further advances in software are likely when microcomputers get 32-bit processing power.

While some computer manufacturers, notably IBM, have recently expanded their efforts in micro software sales, the hardware and software industries are still largely separate, though interdependent. Prominent software firms such as LOTUS DEVELOPMENT and ASHTON-TATE do not make the machines on which their products run.

Much depends on success of microcomputers

The growth of the overall software market depends on how many microcomputers have been sold to homes and offices. The penetration is still relatively low, according to Future Computing, a market research firm, which estimates that less than 15% of office workers and U.S. households had personal computers at year-end 1984. And even the installed base may be misleading, as many of the lower-priced machines sold to the home market may have been discarded when purchasers became frustrated by their limitations. In addition, software piracy is a major problem, creating millions of dollars in lost revenues (see box).

Hardware companies need software makers, too. In both industries there has been a great flurry of start-ups over the

"SOFTSEL HOTLIST" for week of May 6, 1985

Software	Producer	System	Week of May 6, 1985	Weeks on Chart
BUSINESS SOFTWARE				
1-2-3	Lotus	IBM, PCjr, DG, DEC, TIP, WNG	1	117
dBase III	Ashton-Tate	IBM	2	44
Multimate	Multimate Int'l.	IBM, TIP	3	94
Sidekick	Borland Int'l.	IMB, PCjr	4	28
PFS:File	Software Pub.	AP, APe, IBM, MAC, C64, DEC, TIP	5	138
Microsoft Multiplan	Microsoft	AP, IBM, MAC, CP/M	6	132
Microsoft Word	Microsoft	IBM, MAC	7	76
Symphony	Lotus	IBM, DEC	8	43
PFS:Write	Software Publishing	APe, IBM	9	94
ThinkTank	Living Videotext	AP, APe, IBM, MAC	10	54
PFS:Report	Software Pub.	AP, APe, IBM, MAC, C64, DEC, TIP	11	137
Wordstar	Micropro Int'l.	AP, IBM, PCjr, CP/M, DEC, TIP	12	136
Microsoft File	Microsoft	MAC	13	15
Word Perfect	Satellite Software	IBM	14	53
Microsoft Chart	Microsoft	IBM, MAC	15	34
Hayden Speller	Hayden Software	MAC	16	21
Harvard Project Manager	Harvard Software	IBM	17	31
Wordstar 2000	Micropro Int'l.	IBM	18	20
Volkswriter Deluxe	Lifetree Software	IBM, DG, TIP	19	46
Helix	Odesta	MAC	20	15
SuperCalc 3	Sorcim/I.U.S.	AP, IBM, PCjr, TIP	21	45
PFS:Graph	Software Publishing	AP, APe, IBM, TIP	22	132
PFS:Proof	Software Publishing	IBM	23	21
Back to Basics Gen. Ledger	Peachtree	AP, APe, MAC, C64	24	17
R:Base 4000	Microrim	IBM, DEC, TIP	25	68
Megaworks	Megahaus	APe	26	5
Reflex	Analytica	IBM	27	2
Framework	Ashton-Tate	IBM	28	36
Back to Basics Acct. System	Peachtree	AP, APe, IBM, C64	29	10
Symphony Spelling Checker	Lotus	IBM	30	3

Software	Producer	System	Week of May 6, 1985	Weeks on Chart
PERIPHERALS				
Video 310A Monitor	Amdek	...	1	13
MSP-10 Dot Matrix Printer	Citizen America	...	2	15
A2 Disk Drive	Microsci	...	3	4
Color 300 Monitor	Amdek	...	4	15
Video 300A Monitor	Amdek	...	5	15
122 Hi-Res Amber TTL Monitor	Taxan	...	6	4
Color 600 Monitor	Amdek	...	7	14
440 RGB Monitor	Taxan	...	8	6
115 Composite Green Monitor	Taxan	...	9	5
Color 700 Monitor	Amdek	...	10	4
COMPONENTS				
Six Pak Plus	AST Research	IBM	1	70
Smartmoden 1200B	Hayes	IBM	2	85
Hercules Graphic Card	Hercules	IBM	3	80
Smartmodem 1200	Hayes		4	103
Hercules Color Card	Hercules	IBM	5	28
Expanded Quadboard	Quadram	IBM	6	21
Modular Graphics Card	Paradise Systems	IBM	7	9
Advantage	AST Research	IBM/AT	8	5
Grappler +	Orange Micro	AP	9	28
PC Modem Halfcard	Ven-Tel	IBM	10	4
ACCESSORIES				
Mach III	CH Products	AP, APe, IBM, PCjr	1	31
Lemon	Electronic Protection Device		2	47
Microsoft Mouse	Microsoft	IBM	3	15
Joystick	Kraft Systems	AP, IBM	4	93
MasterPiece	Kensington	IBM	5	15
System Saver	Kensington	AP	6	137
PC Mouse/PC Paint Bundle	Mouse Systems	IBM	7	24
Lime	Electronic Protection Device		8	2
PC Mouse	Mouse Systems	IBM	9	12
Universal Printer Stand	Kensington	MAC	10	12

LEGEND: **AP** – Apple, **APc** – Apple IIc, **APe** – Apple IIe, **AT** – Atari, **C64** – Commodore 64, **CP/M** – 5¼" and 8" formats, DG – Data General One, **DEC** – DEC Rainbow, **EPS** – Epson QX-10, **IBM** – IBM-PC, **MAC** – Apple Macintosh, **PCjr** – IBM PCjr, **TIP** – Texas Instruments Professional, **WNG** – Wang Personal Computer.
Source: *Softsel Hot List* published by Softsel Computer Products, Inc., 546 North Oak Street, P.O. Box 6080, Inglewood California 90312-6080.

past four years, producing a fiercely competitive marketplace. Critical to the success of a new machine is the availability of software for it, which causes equipment makers to solicit the development of compatible software from programmers. A machine's design and operating system will determine what applications programs can be run on it, but software firms commonly modify their packages to different specifications. Many of today's best-selling software packages are available for a variety of otherwise incompatible machines.

The cost structure of the software industry differs from that of hardware makers. The cost of producing disks on which software is generally stored is low compared to the expense of manufacturing a machine. As a percentage of 1984 revenues, manufacturing-related costs were only 16% for LOTUS DEVELOPMENT, while for APPLE COMPUTER, such costs came to 58% of revenues in fiscal 1984 (ending September). Such numbers depend partly on the size of a company's revenue base, but the point is that software is not manufacturing-intensive.

Instead, marketing is assuming increasingly greater importance to the software industry. Companies seeking to differentiate their products compete for the attention of distributors, retailers, and end users. National television advertising was used in the summer of 1984 for LOTUS's new *Symphony* product and ASHTON-TATE's *Framework*. LOTUS, which has launched a monthly magazine for users of its software, had sales and marketing costs amounting to 27% of revenues in 1984.

Research and development is another major expense for

"SOFTSEL HOTLIST" for week of May 6, 1985

Software	Producer	System	Week of May 6, 1985	Weeks on Chart
RECREATIONAL SOFTWARE				
Microsoft Flight Simulator	Microsoft	IBM	1	118
Flight Simulator II	Sublogic	AP, C64, AT	2	122
Hitchhiker's Guide to the Galaxy	Infocom	AP, IBM, MAC, C64, AT	3	25
Saragon III	Hayden Software	AP, IBM, MAC, C64	4	74
Gato	Spectrum Holobyte	AP, IBM, PCjr	5	26
Lode Runner	Broderbund	AP, IBM, MAC, C64, AT	6	91
Karateka	Broderbund	AP	7	7
Wizardry	Sir-Tech Software	AP, IBM	8	138
Zork I	Infocom	AP, IBM, MAC, AT, CP/M, DEC, TIP	9	138
Ultima III	Origin Systems	AP, IBM, C64, AT	10	75
Ultima II	Sierra On-Line	AP, IBM, MAC, PCjr, C64, AT	11	84
King's Quest	Sierra On-Line	APe, IBM	12	26
Millionaire	Bluechip Software	AP, IBM, MAC, C64	13	80
Snooper Troops #1	Spinnaker	AP, IBM, C64	14	83
F-15 Strike Eagle	Microprose Software	AP, C64	15	8
Ancient Art of War	Broderbund	IBM	16	1
MacAttack	Miles Computing	MAC	17	22
Summer Games	Epyx	AP, C64, AT	18	51
Zork II	Infocom	AP, IBM, MAC, AT, CP/M, DEC, TRS	19	133
Bruce Lee	Datasoft	AP, IBM, C64, AT	20	32
HOME SOFTWARE				
Print Shop	Broderbund	AP, C64, AT	1	43
Print Shop Graphics Library	Broderbund	AP, C64	2	22
Newsroom	Springboard	AP	3	10
Dollars & Sense	Monogram	AP, APc, IBM, MAC, TIP	4	85
Bank Street Writer	Broderbund	AP, APc, IBM, C64, AT	5	122
ClickArt Effects	T/Maker	MAC	6	5
Managing Your Money	MECA	IBM	7	38
Mac the Knife	Miles Computing	MAC	8	41
Music Works	Hayden Software	MAC	9	21
Dazzle Draw	Broderbund	APe	10	21

Software	Producer	System	Week of May 6, 1985	Weeks on Chart
HOME SOFTWARE				
Home Acct.	Arrays/Cont.	AP, APc, IBM, MAC, PCjr, C64, AT, EPS	11	137
Micro Cookbook	Virtual Combinatics	AP, APc, APe, IBM	12	58
Homeword	Sierra On-Line	AP, IBM, C64, AT	13	77
Click-On Worksheet	T/Maker	MAC	14	1
Mac the Knife II	Miles Computing	MAC	15	18
EDUCATIONAL SOFTWARE				
Mastertype	Scarborough	AP, IBM, MAC, C64, AT	1	133
Typing Tutor III	Simon & Schuster	AP, IBM, MAC, PCjr, C64	2	37
Math Blaster!	Davidson & Assoc.	AP, IBM, C64	3	78
Turbo Tutor	Borland Int'l.	AP, IBM	4	12
E. G. for Young Children	Springboard	AP, IBM, C64, AT	5	64
Mind Prober	Human Edge	AP, IBM, MAC, PCjr, C64	6	29
Word Attack!	Davidson & Assoc.	AP, IBM, C64	7	66
Kids on Keys	Spinnaker	AP, IBM, C64	8	11
Reader Rabbit	The Learning Company	AP, IBM, PCjr, C64	9	12
Spell It!	Davidson & Assoc.	AP, IBM, C64	10	24
Study Program for the S.A.T.	Barron's	AP, IBM, PCjr, C64	11	51
Typing Instructor	Individual Software	IBM, TIP, WNG	12	1
Kindercomp	Spinnaker	AP, IBM, PCjr	13	65
Chipwits	Brainpower	MAC	14	8
Kidwriter	Spinnaker	AP, IBM, C64	15	2
SYSTEM & UTILITY SOFTWARE				
Turbo Pascal	Borland Int'l.	AP, IBM, PCjr, CP/M	1	24
Crosstalk	Microstuf	AP, IBM, PCjr, CP/M, DG, TIP	2	82
Sideways	Funk Software	AP, IBM	3	55
Fontrix	Data Transforms	AP, IBM	4	13
Microsoft Basic Interpreter	Microsoft	IBM, MAC, CP/M	5	60
Letter Forms & Poster Sets	Data Transforms	AP, IBM	6	2
Smartcom II	Hayes	IBM, MAC, DEC	7	14
Fast Load	Epyx	C64	8	18
Printworks	SoftStyle	IBM	9	14
Microsoft Macro Assembler	Microsoft	IBM	10	13

LEGEND: **AP** – Apple, **APc** – Apple IIc, **APe** – Apple IIe, **AT** – Atari, **C64** – Commodore 64, **CP/M** – 5¼" and 8" formats, **DG** – Data General One, **DEC** – DEC Rainbow, **EPS** – Epson QX-10, **IBM** – IBM-PC, **MAC** – Apple Macintosh, **PCjr** – IBM PCjr, **TIP** – Texas Instruments Professional, **WNG** – Wang Personal Computer.
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software companies, as it is for most technology-related industries. Product life cycles can be short, as former hit products are eclipsed due to technological developments or successful marketing by competitors.

Products can be created internally or acquired from others. When IBM elected to follow its enormous success in microcomputer hardware sales with an increased software presence, it introduced packages developed by other companies in 1984. IBM's *Assistant Series*, which features filing, spreadsheet, and reporting functions, was licensed from SOFTWARE PUBLISHING, a fast-growing company that also markets its products independently. IBM's *Personal Decision* and *Business Management* software series were developed by Information Programming Services, a Connecticut-based firm.

Acquisition pace to quicken

The pace of acquisitions, not only through licensing agreements, but of whole companies, is likely to accelerate in the year ahead. Smaller firms will increasingly find themselves lacking the financial clout to compete successfully against larger competitors. According to a survey by Broadview Associates, a merger and acquisition consultant, some 30 microcomputer software companies were acquired during 1984. Broadview, which calls the overall computer services group "one of the most acquisition prone industries of the last 10 years," says that micro software firms were vulnerable because traditional sources of funding became unavailable in 1984. "Venture capitalists shied away from that sector and the window for public offerings was slammed shut." Exceptions include SOFTWARE PUBLISHING and MICROPRO INTERNATIONAL, which went public in November and March, respectively. According to Broadview, getting acquired was the primary source of financing available to cash-poor firms and should continue to be in 1985, as they see an "ample supply of potential sellers with a smaller number of selective buyers."

One of the most visible software businesses on the selling block has been MANAGEMENT SCIENCE AMERICA's Peachtree unit, which the parent company had acquired in 1981 in order to expand beyond its core mainframe software business. In May 1985, MANAGEMENT SCIENCE announced the sale of Peachtree to INTELLIGENT SYSTEMS for an undisclosed sum, completing the company's exodus from the retail micro segment after its decision to discontinue the segment in late 1984. MANAGEMENT SCIENCE's micro division, of which Peachtree was a prominent part, roughly broke even on rising sales in 1982 and 1983, but 1984 revenues dipped 38% to $13.5 million.

Unit sales of Peachtree's accounting and productivity-enhancing packages are estimated at more than 200,000 since 1981, but the company never had a big hit on the scale of LOTUS's *1-2-3*, the industry's all-time best-seller, with unit sales of close to 800,000. MANAGEMENT SCIENCE remains active in mainframe-to-micro communications, but says the micro retail software division had become incompatible with its remaining businesses, in part because of the market's emphasis on merchandising rather than technology or service.

LOTUS DEVELOPMENT, currently the premier independent micro software company, has prospered through internal development of a very few products. LOTUS rose to eminence with the January 1983 introduction of *1-2-3*, an integrated package combining a spreadsheet with database and graphics capabilities. Its *Symphony* product, which also includes word processing, debuted in June 1984, and a third integrated product, *Jazz*, hit the market in late May 1985. LOTUS has grown from no sales in 1982 to revenues of $157 million in 1984, but even this constitutes a market share of only about 6%.

LOTUS is joining the move toward industry consolidation, having announced its intention in April 1985 to acquire the assets of Software Arts, one of the early leaders in the software industry. Software Arts was the developer of *VisiCalc*, a best-selling spreadsheet product prior to the widespread success of integrated packages, such as *Lotus 1-2-3*. In addition to *VisiCalc*, LOTUS will gain rights to several other products, including a problem-solving program for the engineering and scientific markets.

Both LOTUS and rival ASHTON-TATE, whose 1984–85 revenues totaled $82 million, have been successful largely through sales to business and professional users. ASHTON-TATE's *dBASE* family of products has been a leader in the database management area, and its *Framework* product is similar to LOTUS' *Symphony*. Both companies expect overseas sales to be important contributors to continued growth. ASHTON-TATE's *dBASE II* has been translated into 11 languages, and foreign versions of *Framework* and *dBASE III* have been prepared. LOTUS, meanwhile, has French, German, and Italian versions of *Symphony*; more translations are expected.

The presence of a hit product, however, does not guarantee long-term financial success. MICROPRO INTERNATIONAL has had a product, *WordStar*, on Softsel Computer Products' list of best-selling business programs for more than 130 weeks, but the company's overall sales and earnings have slumped since peaking in early fiscal 1984 (ended August). MICROPRO, which failed to turn a profit for the three quarters through February 1985, has been hurt by slowing growth in the personal computer market and increased competition among word processing products.

Education market large

While companies serving the business and professional markets get the most attention, a host of other firms are offering products for educational and recreational use. General weakness in home computer sales and pricing pressures are among the problems they face. Privately owned Spinnaker Software has been a leader in the educational field, but revenue projections for fiscal-year 1985 (ended January) have dwindled from $50 million, to less than $20 million. Spinnaker's products include a *Fisher-Price* line of early-learning games and science-related products that are linked to *Nova*, a Public Broadcasting Service series.

Other participants in the educational market include CBS Software, which has learning programs for youngsters featuring *Sesame Street* characters, and products to help high-school students with math and college admission exams. Book publishers, such as Random House and Prentice-Hall, also offer educational software, along with Scholastic Software, which has built upon the longtime presence of its parent company's reading materials in U.S. schools. The best-selling piece of educational software may be Scarborough System's *Mastertype*, a typing tutorial that has had unit sales of close to 500,000.

Games introduced many people to home computers, and although the home computer markets appears to be turning toward other applications, there is still demand for products seeking to test users' agility and wits. Companies with leading recreational products include Microsoft, which is also prominent in operating system and applications software, Sublogic, Infocom, and Broderbund. Three of Infocom's interactive fiction packages, which challenge the user to participate in a computerized adventure, are on Softsel's list of top 20 recreational packages, and the company expects to sell its millionth adventure game in June 1985.

Infocom also recently diversified with the introduction of a database management product called *Cornerstone*.

Two vendors dominate operating systems market

While users are most concerned with the myriad applications products, all microcomputers must also have an operating system. Two companies, DIGITAL RESEARCH and closely held Microsoft, have dominated the sale and licensing of such software to hardware manufacturers. DIGITAL RESEARCH's *CP/M* system was the favorite for early 8-bit computers, while Microsoft is the leader in the 16-bit market with its *MS/DOS* system, which is used in the *IBM PC*. The *UNIX* operating system, developed by AT&T, is attracting considerable interest, particularly for multi-user office environments. There are, however, a number of *UNIX* versions, with a standard yet to emerge. AT&T, for example, offers a *UNIX System V*, while Microsoft has a *Xenix* version, which IBM has supported for its *AT* personal computer. Another Microsoft operating system, *MSX*, has made inroads among Japanese manufacturers of 8-bit computers.

Both Microsoft and DIGITAL RESEARCH are coming out with new products designed to enhance the ability of users to do several tasks simultaneously. DIGITAL RESEARCH has an operating system extension called *GEM* (graphics environment manager) which, by using a mouse, will enable IBM-compatible machines to have windowing ability (the ability to view two or more functions at the same time) similar to that of APPLE COMPUTER's *Macintosh*. Microsoft was expected to start shipping a similar product, *Windows*, in June 1985. Microsoft and DIGITAL RESEARCH, however, face the increased software presence of IBM, which, in August 1984, introduced *TopView*, a product with windowing and multitasking features.

Overall micro software market to do well in '85

In the year ahead, we expect micro software sales of both existing and new product areas to grow. According to David Wagman, chairman of Softsel, the following categories are likely to increase their overall market share: business software that improves productivity and can thus be economically justified, such as word processing, database and spreadsheet packages; software that is targeted toward specific industries, or vertical markets; and graphics software. Speaking in May 1985 at COMDEX, a semiannual computer trade show, Wagman predicted a more stable market share for general accounting software and home productivity packages. He saw a loss of interest in recreational and educational software, although he expected intellectual games to do better than other recreational packages.

The increased emphasis on vertical markets reflects several forces. The drop in hardware prices has expanded the market for machines, and the rapid introduction of similar general-applications products has caused companies to search for market niches. Medical practices, construction businesses, and real estate firms are among those targeted by developers of industry-specific software.

New-product categories Wagman expects to show explosive growth include communications packages and artificial intelligence. Software that enables micro-to-mainframe access is a hot area. Communication is available in several forms already, but the preferred method would appear to be integrated links that enable a microcomputer to manipulate data after it has been obtained from a mainframe, in contrast to the microcomputer being largely limited to serving as a dumb terminal. International Data Corp. estimates the market for integrated link software will grow from

Software piracy

"Make me a copy" has been said countless times in countless offices, and sounds innocent. But for the micro software industry, it has been a costly refrain. Future Computing, a market research firm, estimates that unauthorized and illegal packages account for 50% of the business software in use today and that this cost software companies at least $1.3 billion in lost revenues between 1981 and 1984.

The difficulty involved in copying software varies. At its simplest level, a user with two disk drives inserts a blank diskette into one drive and the program to be copied into the other and types an instruction for two; a product that may have cost up $600 originally is then duplicated for practically no expense. Software firms have attempted to combat this by encoding some protection on the original disk, but the results have been mixed. Users are sometimes able to circumvent the protection; sometimes such anti-copying measures make using the product more difficult.

What else can be done to halt software piracy? One approach is lawsuits, since software, like books, comes under copyright protection as intellectual property. Earlier this year, MICROPRO INTERNATIONAL, along with an industry group, the Association of Data Processing Service Organization (ADAPSO), filed suit against AMERICAN BRANDS, alleging illegal software copying and distribution.

Going to court, however, is a limited remedy. Unearthing software piracy is not easy, and even when a case can be made, a software vendor risks straining relationships with potential customers. Potentially better and longer-term solutions include licensing software to users' sites, enabling unlimited product use at particular locations, or development of hardware-based protection devices that make copying more difficult.

ADAPSO is working to gain industry approval for a protection system that would be attached to computer hardware. To run a piece of software, a user would have to insert a key encoded with a serial number matching that of the software into a ring attached to the computer. Some software users regard this system as potentially disruptive or inconvenient.

Large corporate users are now calling for licensing agreements from software vendors, but the response has been mixed. Allowing software to be copied and used on a limited number of sites could ease concern over copyright violations, but the economics and distribution channels of the software business would likely change. The revenue mix would move away from outright sales of individual software packages, and vendors may put a greater emphasis on dealing directly with corporate accounts, potentially bypassing distributors and retailers.

The role of dealers in site licensing agreements will depend largely on how much training and support customers require for a particular product and whether the software vendors consider it more economical for the dealers to provide it.

Volume discounts to large software users are another alternative, but whether discounts can stem the pressure for a change to site licensing is yet unclear. ■

$20 million in 1984, to $1.4 billion by 1990. Mainframe software companies, such as MANAGEMENT SCIENCE, CULLINET, and ON-LINE SOFTWARE INTERNATIONAL, are among the companies with such products available, and several joint agreements have been reached between mainframe and micro firms. Demand should also be strong for communications software that facilitates networking between microcomputers.

Artificial Intelligence a growth area

Artificial intelligence (AI) involves getting a computer to think like a human being. Long a gleam in the eyes of scientists, this ability, including the inference of solutions from incomplete or inconsistent data, has evolved toward commercial applications as the hardware to run such software has become more powerful and less expensive. The computing power and memory space required to process programs written in *LISP*, the dominant symbolic computing language in the field, currently puts artificial intelligence more in the province of minicomputers than of microcomputers, but a number of micro software firms are promoting or working on AI-related products. The most publicized application of artificial intelligence to date is called expert systems, whereby a computer can make choices and conclusions based on knowledge in its memory. Expert systems have been developed for such tasks as medical diagnosis and geological exploration.

Artificial intelligence is still a fledgling product area, but early leaders in the sales of AI machines include SYMBOLICS INC., Lisp Machine, Inc., and XEROX. The related software market will include operating systems from the manufacturers and applications developed by machine customers, plus hardware and software firms. ■

DISK DRIVES

An industry in disarray

The disk drive industry, which furnishes memory devices on which data can be stored, has been among the most volatile sectors of the computer industry in the past four years. In the early 1980s, disk drive companies had revenues and earnings growth of more than 100% annually as they filled burgeoning orders for newly introduced microcomputers. Investors rewarded these companies with lofty stock prices, reflecting high expectations.

But in 1983–84, the microcomputer market became glutted with too many companies selling similar products, IBM swamped smaller competitors with its best-selling *IBM PC*, and troubles mounted for the independent drive makers. Customers, such as Victor Technology and Osborne Computer went into bankruptcy, and disk drive companies found themselves with excess manufacturing capacity. Prices tumbled as companies sought to keep unit production at profitable levels, and the threat of inventory obsolesence increased as computers moved toward new generations of products.

Worldwide shipments of disk drives for all types of computers totaled an estimated $16 billion in 1984 and should approach $20 billion in 1985, but the industry is clearly in disarray. IBM dominates the drive market for large computers, and STORAGE TECHNOLOGY was a recent victim of IBM's technological and marketing muscle there. In the micro area, IBM is the drive makers' biggest customer, making order rates of even the largest vendors highly vulnerable to IBM's product needs. In addition IBM is manufacturing more micro drives itself. Companies selling memory storage devices are facing continued high spending requirements for research and development and severe pricing pressures as they attempt to survive an industry shakeout.

What are they?

Disk drives are needed to supplement the limited memory capacity of a computer's central processing unit. The drive is a device that writes information on to a disk and is able to read information from it, providing the user with the ability to input instructions and data, in the form of software, and to store the information a computer generates. Disks are typically characterized as either flexible or hard, with further product differentiation based on physical size and storage capacity.

Microcomputer users are most acquainted with the flexible-disk drives and the record-like platters (disks) that are inserted into them. Microcomputer purchases typically include one or two such drives, since they are required to use software pacakges. Flexible disks and drives are less expensive than their hard-disk counterparts, but have less memory capacity.

Flexible disks are removable from the machine. Hard disks, by contrast, are sealed in air-tight environments. In addition to storing more data than flexible disks, a hard-disk drive enables faster access to information. Hard disks are based on the so-called Winchester technology introduced by IBM in 1956. Their high cost initially confined their use to large computers, but as prices have dropped and the microcomputer market has both grown and demanded more memory for sophisticated applications, hard-disk drive sales for small computers have mushroomed. Disks come in a variety of sizes, with a 5¼-inch diameter the current standard. However, as technology improves, the hard-disk market is expected to move increasingly toward 3½-inch devices. Use of 3½-inch flexible disks and drives should also grow, but more slowly, due to the large base of 5¼-inch software currently in use.

The worldwide market for flexible disk drives, estimated at $4 billion in 1985, is dominated by Japanese producers. U.S. companies such as Shugart Associates, now a subsidiary of XEROX, and TANDON CORP. were early technological leaders in flexible drives, but aggressive pricing by the Japanese has cut into their market share. TANDON has accused three Japanese companies of illegally infringing on one of its drive patents, a charge that the International Trade Commission has agreed to investigate.

The market for the actual disks, which consumers typically buy separately, as they would records or tapes to play music, is also highly competitive. Sales totaled more than $2 billion in 1984, but the balance of power appears to be shifting away from independent disk producers and toward larger, mass-consumer product companies. EASTMAN KODAK, for example, in May 1985 acquired Verbatim, which had

This section prepared by Tom Graves

reflecting expanding demand and lack of competition. Earnings gains in 1986 could also be difficult, reflecting continuing weakness in the economy and increased competition in almost every market sector.

High expected growth rates, coupled with high levels of sustained expenditures needed to maintain that growth means that a decline in the rate of revenue increase can be as devastating for a computer company as an absolute decline in sales for a traditional manufacturer. As became evident in 1981 and 1983, mainframe and minicomputer makers are vulnerable to capital spending fluctuations. As market penetration for microcomputer products progresses, their sales will also become susceptible to economic trends. A firm's product life cycle positions and new product introductions, along with those of its competitors, also affect its revenues. Early in a product's life, pent-up demand for a product at that price/performance level boosts revenues. As the product ages, demand dries up; customers are willing to wait for the next generation before they purchase, or they lease instead of buy to reduce the risk of obsolesence. The precipitous drop in sales of the *Commodore 64* in 1985, after years of spectacular growth, occurred because IBM and APPLE had introduced products with vastly superior capabilities. COMMODORE was late getting into the 128k market, and demand, as well as technology, passed them by. Prices of the *Commodore 64* were drastically reduced, but the end result was losses for the company, not increased sales.

The current industrywide sluggishness in orders is evidence of vendor vulnerability to economic slowdowns and of the proliferation of a vast array of new products. This has resulted in a longer sales cycle as customers seek to sort out the plethora of solutions for their data processing needs.

U.S. imports of computers, related equipment, and parts—1984

Rank	Country	Billions of dollars	Rank	Country	Billions of dollars
1.	Japan	3.185	4.	Hong Kong	0.651
2.	Singapore	0.937	5.	China-Taiwan	0.645
3.	Canada	0.708	6.	Mexico	0.247

Source: Computer and Business Equipment Manufacturers Association.

U.S. exports of computers, related equipment, and parts—1984

Rank	Country	Billions of dollars	Rank	Country	Billions of dollars
1.	Canada	2.139	4.	Japan	1.140
2.	United Kingdom	1.967	5.	France	0.829
3.	FR Germany	1.276	6.	Netherlands	0.754

Source: Computer and Business Equipment Manufacturers Association.

Percentage of 1984 data processing revenues derived from foreign sources—selected computer manufacturers

Company	Percent	Company	Percent
Apple	22	Honeywell	26
Burroughs	40	IBM	40
Control data	27	NCR	45
Cray Research	42	Prime Computer	39
Digital Equipment	35	Wang	29
Hewlett-Packard	42		

Source: *Annual Reports.*

Since the demand for software and components is largely derived from how many machines are being sold, the increased cyclicality of the hardware manufacturers is having a spillover effect on software and memory storage suppliers. Even niche participants such as ASK COMPUTER (software for manufacturers) and market leaders such as CIPHER DATA PRODUCTS (tape drives) appear vulnerable to broad shifts in the economy and the overall computer industry. Also, during the early stages of development in technology-based industries, front-running companies often experience phenomenal growth rates. Substantial year-to-year increases in revenues and profits are typically unsustainable, however, as more competitors join the fray and the market share fight intensifies. Growth rates are also, in part, a function of size: large percentage gains become more difficult to achieve as a company becomes bigger.

Financing growth

Although a high debt level can leverage earnings for a company with a high return on investment during a time of rising sales, it can exacerbate profitability problems should the sales for a company stall unexpectedly. Consequently, well-managed computer manufacturers tend to rely more on equity offerings and cash flow from operations to finance growth than on debt. This minimizes earnings volatility. However, over the last two years, the stocks of technology companies have generally underpreformed the market, despite their superior growth potential. The cause has likely been the declining net margins and returns on equity brought by increased competition. With the poor market for computer stocks and the adverse effect of competition on cash flow, some increase in the use of debt financing in 1985.

The days of assembling computers in a garage are gone forever. Over the past five years manufacturers have spent roughly twice their depreciation charges on capital expenditures each year. Smaller growth companies often spend four to six times their depreciation charges. Since capital expenditures often exceed cash flow after dividend, access to the capital markets is essential for growth. Survivors in the computer industry will be companies with strong, conservative balance sheets and experienced managements.

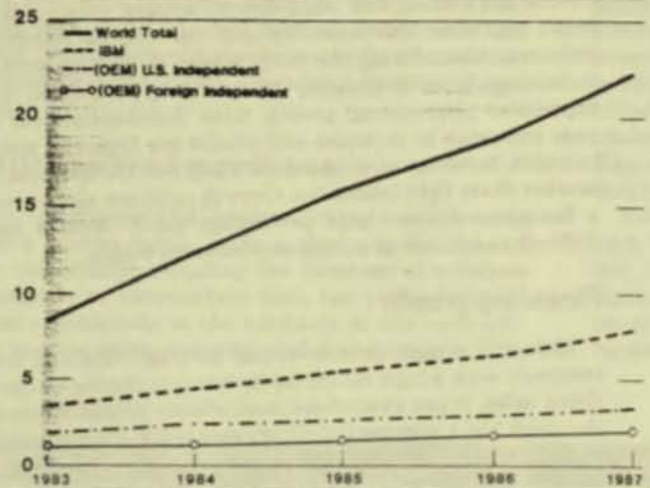
Costs rising

Price/performance is the basis of competition in the computer industry. The price side of this equation puts the squeeze on margins and underscores the need to invest in automated facilities to reduce manufacturing costs. The performance side leads to shortened life cycles, which contribute to the uncertainty in planning and the need for heavy commitments to R&D. Added to this is a relatively new aspect for the computer makers brought about by the fray in the microcomputer arena- the need to invest heavily in advertising and marketing.

As product life cycles shorten and competition from IBM and the Japanese heats up, the trend toward higher dollar spending on R&D should continue. The sluggish revenue growth expected for 1985 should result in higher R&D as a percent of revenues. R&D spending levels for an individual company also depends on the company's product life cycle. For example, DIGITAL EQUIPMENT was in the process of developing new products in 1983 and 1984 and R&D spending as a percentage of revenues grew to 11.29%, from 9.01% in 1982. APPLE, on the other hand, introduced several new products in early fiscal 1984, and R&D as a percent of sales declined to 4.69% in fiscal 1984, from 6.10% a year earlier.

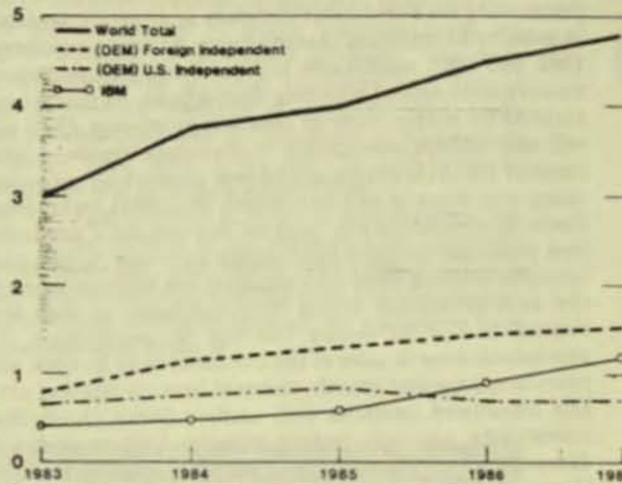
IBM's massive spending on research dwarfs the expendi-

SALES OF HARD DISKS
(In Billions of Dollars)



Source: Disk/Trend as published in Financial World

SHIPMENTS OF FLOPPY DISKS
(In Billions of Dollars)



Source: Disk/Trend as published in Financial World

been losing money in recent quarters after being one of the early success stories in the disk industry. Polaroid is also moving into the disk market, joining audio and photo companies such as 3M, MAXELL, and FUJI PHOTO FILM. With the 5¼-inch disk in particular becoming a commodity product, success in the marketplace depends increasingly on high volume, low-cost production, and marketing muscle. Further evidence of industry consolidation is Xidex's recent acquisition of Dysan, another major disk maker that had fallen on hard times.

The worldwide hard disk drive market, estimated at $15.6 billion in 1985, has seen swift technological change in recent years, as storage capacities have increased and the drives have become smaller in size. Drives with capacities of 500 megabytes or more for large computers are about 40% of the market, while at the low end, drives with 30 megabytes or less will garner about 15%, or $2.6 billion, according to James Porter, publisher of the *Disk/Trend Report*, an industry newsletter.

Japanese companies have not forged into the hard drive micro market with the aggressiveness they have shown with flexible drives, in part because the short product life cycles of hard drives are less suited to the Japanese's expertise in high-volume production of electronic goods. This has not, however, ensured easy times for U.S. drive makers. Slowing order rates from IBM in the past 18 months have hurt several major vendors, and prices in general have deteriorated as product development costs have remained high.

The profitability of major disk drive makers, such as SEAGATE TECHNOLOGY and MINISCRIBE, has shrunk to break-even or lower in recent quarters, and their hopes for a strong rebound rely on the introduction of new products. The market is turning increasingly toward drives with 20 megabytes and above of storage capacity, in contrast to the old 10-megabyte standard, and drives with 3½-inch-diameter disks. Pricing should be stronger for the new products, enabling the companies to better cover their high research and development costs.

Magnetic disks are not the only means of storing computer data. Prior to disks, tape was the standard medium, but its appeal diminished as disks proved to provide faster access to information. Although tape drives are used primarily today as back-up systems for disk drives, the market for them is growing.

Users storing large amounts of data do not want to risk losing it if a hard disk proves defective, and such companies as CIPHER DATA PRODUCTS, which grew to $116 million in revenues in fiscal 1984 (ended June), from $55 million two years earlier, and ARCHIVE CORP. have moved to fill this niche. CIPHER's growth has stalled since year-end 1984 due to weakness in minicomputer sales and slower-than-expected demand for microcomputer storage backup, but the long-term prospects for the tape drive market remain good.

Future generations of memory storage devices will likely use laser beams and light, rather than magnetism, to write information onto disks or tape. This technology, known as optical memory, enables data to be condensed into a smaller space than can be done with magnetic disks. However, unlike magnetic disks, optical storage devices are typically not erasable, making the user unable to change or diskard outdated information. Until this limitation is resolved, applications for optical disks and tapes will be restricted. ■

FINANCIAL

'85 earnings will be flat

Earnings for the computer manufacturers are expected to be relatively flat in 1985, reflecting slowing demand following a strong recovery year. Individual companies' earnings, as usual, should vary widely, however. COMPUTERVISION CORP.'s earnings are expected to decline to break-even levels due to a product-line transition during a time of industry wide weakness in orders. CRAY RESEARCH, on the other hand, could show a gain of 45% in earnings from operations, tures of its competitors, illustrating the need for non-IBM manufacturers to find alternative methods of investing in research. Such methods include customer-sponsored projects, particularly by the government, R&D partnerships and joint ventures like the Microelectronics & Computers Technology Corporation (MCTC), a research consortium formed by 20 companies: and licensing and marketing agreements with other firms, including the Japanese, such as the arrangements between AMDAHL and FUJITSU, or AT&T and CONVERGENT TECHNOLOGIES. Both Japan and the European community have substantial joint research programs.

The advent of the personal computer has given marketing new importance. Manufacturers are increasing advertising outlays, expanding in-house sales forces, and cultivating alternative methods of selling products, such as through value-added-resellers and dealers (VARs and VADs) and retail outlets. Makers of microcomputer memory storage systems are also expected to be seeking to expand their distribution channels, with an increased emphasis on selling directly to end users.

Advertising expenditures related to computer products was estimated at a billion dollars in 1984, and the recent upward trend is likely to continue. Manufacturers are realizing that advertising must be used to establish awareness of their products and to point out the sometimes subtle differences between their offerings and those of their competitors. WANG LABS, for instance, has developed a substantial campaign around the rather provocative slogan "We're gunning for IBM." Some of the smaller, more leveraged, or lower-margined firms will be unable to maintain the pace of spending being set by the most aggressive competitors.

International operations

Many computer hardware manufacturers derive a substantial portion of their sales and profits from overseas operations and considerable untapped demand remains in foreign markets. But while the recovery in worldwide economies contributes to volume sales growth in 1984, the strong U.S. dollar constrained profitability in the latter part of the year and first quarter of 1985. A strong dollar makes the U.S. computers more expensive in local currencies. A decline in the dollar would be a boon to these companies.

According to the Computer & Business Equipment Manufacturers Association, exports of computer and related equipment and parts rose 27% in 1984, to $13.865 billion. However, imports of computer and related equipment and parts advanced 75%, to $7.687 billion. The positive balance of trade in the computer industry has been declining since 1981. However, a positive balance of trade was maintained with all major world markets except the Far East. In 1984 the U.S. manufacturers exported $1.140 billion to Japan, while imports from Japan totaled $3.185 billion, an increase of 79%. The trade deficit with Japan is likely to continue to widen as Japanese imports gain further acceptance here. ■

COMPOSITE INDUSTRY DATA

*Per share data based on Standard & Poor's group stock price indexes

COMPUTER SERVICES: This group was not included in the 400 Industrials prior to May 13, 1981. The companies used for this series are: Automatic Data; Computer Sciences; Electronic Data Systems (added 6-24-81); Tymshare (deleted 5-2-84).

	1978	1979	1980	1981	1982	1983
Sales	11.17	14.03	17.29	16.46	17.97	19.73
Operating Income	2.07	2.62	2.97	2.55	2.72	2.98
Profit Margins %	18.53	18.67	17.18	15.49	15.14	15.10
Depreciation	0.54	0.72	0.88	0.80	0.91	1.10
Taxes	0.70	0.87	0.99	0.78	0.79	0.87
Earnings	0.88	0.97	1.11	1.02	1.10	1.16
Dividends	0.09	0.12	0.14	0.24	0.27	0.30
Earnings as a % of Sales	7.88	6.91	6.42	6.20	6.12	5.88
Dividends as a % of Earnings	10.23	12.37	12.61	23.53	24.55	25.86
Price (1941-43 - 10)—High	12.36	14.58	20.49	24.34	27.02	36.34
—Low	7.95	9.99	13.13	17.00	16.19	24.92
Price-Earnings Ratios—High	14.05	15.03	18.46	23.86	24.56	31.33
—Low	9.03	10.30	11.83	16.67	13.81	21.48
Dividend Yield % —High	1.13	1.20	1.07	1.41	1.78	1.20
—Low	0.73	0.82	0.68	0.99	1.00	0.83
Book Value	2.88	3.61	5.14	5.46	6.12	7.23
Return on Book Value %	30.56	26.87	21.60	18.68	17.97	16.04
†Working Capital	1.43	1.59	2.13	2.19	2.07	2.64
Capital Expenditures	0.95	1.53	1.27	1.78	1.67	1.71

COMPUTER AND BUSINESS EQUIPMENT: The companies used for this series are: Apple Computer (added 4-11-84); Burroughs; Control Data; Data General (added 6-24-81); Datapoint (added 6-24-81); Digital Equip.; IBM; NCR; Pitney Bowes; Sperry Corp.; Storage Tech. (added 9-28-81); Tandem Computers (added 2-29-84); Wang Labs. (added 8-27-80): and Xerox. NOTE: The Office and Business Equipment index was split 10-for-1 effective 9-14-83. In addition, the index was renamed Computer and Business Equipment effective 9-30-83.

	1976	1977	1978	1979	1980	1981	1982	1983
Sales	63.94	72.96	85.44	96.21	107.16	112.79	125.66	134.88
Operating Income	19.16	21.60	24.81	25.72	27.19	27.69	31.72	33.81
Profit Margins %	29.97	29.61	29.04	27.01	25.37	24.55	25.24	25.07
Depreciation	6.55	6.63	6.94	7.52	8.44	9.31	10.81	10.96
Taxes	6.11	7.19	8.46	8.47	7.58	7.48	7.99	9.48
Earnings	6.94	8.16	9.61	9.99	10.87	9.91	10.11	13.06
Dividends	2.86	4.52	4.41	4.03	5.09	4.79	4.79	5.13
Earnings as a % of Sales	10.85	11.18	11.25	10.49	10.14	8.79	8.05	9.68
Dividends as a % of Earnings	41.22	55.39	45.90	40.34	46.83	48.34	47.38	39.31
Price (1941-43 - 10)—High	119.66	113.15	124.78	129.29	125.90	122.39	146.30	195.04
—Low	96.56	98.71	96.03	105.61	91.43	88.79	90.40	144.46
Price-Earnings Ratios—High	17.24	13.87	12.98	12.94	11.58	12.35	14.47	14.95
—Low	13.91	12.10	9.99	10.57	8.41	8.96	8.94	11.07
Dividend Yield % —High	2.96	4.58	4.59	3.83	5.57	5.40	5.30	3.55
—Low	2.39	4.00	3.53	3.12	4.04	3.91	3.27	2.63
Book Value	42.09	44.50	49.46	54.95	60.03	63.91	67.60	75.31
Return on Book Value %	16.49	18.34	19.43	18.18	18.11	15.51	14.96	17.33
†Working Capital	20.33	19.53	20.38	21.40	21.24	21.41	24.70	29.67
Capital Expenditures	8.34	10.84	13.32	18.46	20.39	20.31	19.64	15.55

*NOTE: Per share data are expressed in terms of the S & P Stock Price Index, i.e., stock prices, 1941-43 - 10. Each of the items shown is first computed on a true per share basis for each company. Totals for each company are then reconstructed using the same number of shares outstanding as was used to compute our stock price index as of December 31. This is done because the shares used on December 31st, although the latest known at the time, may differ from those reported in the annual reports which are not available for six or eight weeks after the end of the year. The sum of these reconstructed totals is then related to the base period value used to compute the stock price index. As a double check, we relate the various items to the dividends, as these are the most stable series. So, for example, if total sales amount to fifteen times the total dividend payments, then, with per share dividends at 3.50 the indicated per share sales will be (15 x 3.50) 52.50 in terms of the S & P Stock Price Index. For comparability between the various groups, all data are on a calendar year basis, corporate data being posted in the year in which most months fall. Fiscal years ending June 30th are posted in the calendar year in which the fiscal year ends. †Current assets less current liabilities, without allowance for long-term debt. R-Revised.

COMPARATIVE COMPANY ANALYSIS

GROWTH RECORD

Revenues (1967 = 100)

Company	*Yr. End.	‡1967 Rev.	1981	1982	1983	1984
Computer Manufacturers						
Amdahl Corp.	D	[1]14.4	3,077	3,208	5,402	5,409
Burroughs Corp.	D	550.6	603	744	797	873
CPT Corp.	Jn	[3]20	505	725	890	1,000
Computer Automation	Jn	[2]4.88	1,549	1,402	1,242	115
Computervision Corp.	D	16	1,693	2,031	2,500	...
Control Data	D	326.9	949	1,313	1,402	1,538
Convergent Technologies	D	[7]13	100	746	1,262	2,785
Cray Research	D	[5]11.4	895	1,237	1,491	2,009
Data General	S	30	2,457	2,887	2,763	3,870
Datapoint Corp.	Jl	34	1,165	1,494	1,588	1,765
Digital Equipment	Jn	[4]422	561	919	1,012	1,323
Floating Point Systems	O	9.3	623	931	1,075	1,269
Hewlett-Packard	O	479	747	888	983	1,262
Honeywell Inc.	D	1,045	512	525	465	581
Int'l Bus. Machines	D	5,345	544	643	752	859
NBI Inc.	Jn	[8]13	446	769	931	1,361
NCR Corp.	D	1,005	342	351	371	405
Prime Computer	D	[4]6.53	5,565	6,677	7,917	9,847
Sperry Corp.	Mr	1,563	356	325	314	...
Tandem Computers	S	[5]7.7	2,701	4,052	5,429	6,922
Wang Laboratories	Jn	47	1,821	2,468	3,272	4,849
Peripherals, Components & Subsystems						
Cipher Data Products	Jn	[8]14	164	393	585	892
Dataproducts Corp.	Mr	23.1	1,165	1,277	1,727	...
Hazeltine Corp.	D	60	243	210	238	290
Quantum Corp.	Mr	[9]13.7	Nil	100	305	490
Seagate Technology	Jn	[9]40	25	100	275	860
Storage Technology	D	[2]26.3	3,506	4,103	3,373	...
Tandon Corp.	S	[7]54	100	204	561	928
Telex Corp.	Mr	34.0	598	797	935	...
Software, EDP Services & Systems						
ASK Comp. Systems	Jn	2.8	464	814	1,407	2,325
Applied Data Research	D	[4]11.9	439	575	749	1,076
Ashton-Tate	Ja	[8]3.7	14	100	489	1,162
Automatic Data Processing	Jn	11.0	5,073	6,082	6,845	8,082
Computer Sciences	Mr	55.8	1,129	1,246	1,276	...
Comshare Inc.	Jn	5.3	1,564	1,481	1,440	1,377
Cullinet Software	Ap	3.4	1,450	2,311	3,529	...
HBO & Co.	D	[3]13	299	428	520	682
Lotus Development	D	[10]53		Nil	100	296
Management Science America	D	[3]26	258	369	535	546
Pansophic Systems	Ap	[5]11.0	323	392	483	...
Policy Management Systems	D	[3]12.6	253	353	494	673
Shared Medical Systems	D	[1]23	585	709	909	1,109
UCCEL Corp.	D	128	115	110	120	135
Copying & Office Equipment						
Bell & Howell	D	[1]453	155	135	150	158
Pitney Bowes	D	[1]447	316	326	359	387
SCM Corp.	Jn	705.2	275	263	236	278
Savin Corp.	Ap	13.5	3,437	3,081	2,852	...
Xerox Corp.	D	738.9	1,176	1,114	1,145	1,190
Desktop Computers						
Apple Computer	S	[6]48	698	1,215	2,048	3,158
COMPAQ Computer	D	[10]111			100	...
Commodore Intl.	Jn	13	1,438	2,346	5,238	9,748
Tandy Corp.	Jn	357	474	569	693	767
Engineering Workstations & Systems						
Apollo Computer	D	[9]18.1	19	100	448	1,193
Daisy Systems	S	[9]4.8	NM	100	380	1,502
Intergraph Corp.	D	[3]20	455	780	1,290	2,020

*Explanation of fiscal yr. Any yr. ending in January through May will be treated as a prior year. Ex.: March 1983 will appear as 1982. ‡In millions of dollars. [1]1975 = 100. [2]1972 = 100. [3]1978 = 100. [4]1974 = 100. [5]1977 = 100. [6]1979 = 100. [7]1981 = 100. [8]1979 = 100. [9]1982 = 100. [10]1983 = 100.

Net Income (1967 = 100)

Company	*Yr. End.	‡1967 Net	1981	1982	1983	1984
Computer Manufacturers						
Amdahl Corp.	D	[6]11.7	229	42	370	311
Burroughs Corp.	D	34.8	428	261	566	704
CPT Corp.	Jn	[1]2.0	625	795	885	870
Computer Automation	Jn	[4]0.32	516	535	def.	def.
Computervision Corp.	D	1.5	2,380	2,160	2,353	...
Control Data	D	41.7	408	372	388	77
Convergent Technologies	D	[3]11.9	7	100	125	6
Cray Research	D	[7]1.03	1,768	1,845	2,534	4,406
Data General	S	[2]0.54	7,556	3,667	4,278	14,777
Datapoint Corp.	Jl	[8]1.18	4,136	203	686	2,237
Digital Equipment	Jn	[5]4.4	568	948	645	747
Floating Point Systems	O	1.33	477	865	985	1,142
Hewlett-Packard	O	37	843	1,035	1,168	1,797
Honeywell Inc.	D	42.3	605	641	546	792
Int'l Bus. Machines	D	651.5	508	677	842	1,010
NBI Inc.	Jn	[3]3.2	225	344	144	431
NCR Corp.	D	36.5	570	641	789	940
Prime Computer	D	[8]1.2	2,842	3,742	2,708	4,975
Sperry Corp.	Mr	64.0	347	184	313	...
Tandem Computers	S	2.2	1,206	1,359	1,400	1,950
Wang Laboratories	Jn	5.0	1,560	2,140	3,040	4,200
Peripherals, Components & Subsystems						
Cipher Data Products	Jn	[3]2.2	5	100	236	523
Dataproducts Corp.	Mr	0.97	680	1,412	2,680	...
Hazeltine Corp.	D	1.19	157	630	220	899
Quantum Corp.	Mr	[3]0.2	def.	100	3,500	5,350
Seagate Technology	Jn	[3]6.9	25	100	190	609
Storage Technology	D	[4]2.34	3,521	2,705	def.	...
Tandon Corp.	S	[1]1.5	300	1,047	1,580	1,960
Telex Corp.	Mr	1.20	983	2,050	3,008	...
Software, EDP Services & Systems						
ASK Comp. Systems	Jn	0.24	621	975	1,629	2,568
Applied Data Research	D	[6]1.06	290	425	658	911
Ashton-Tate	Ja	[10]1.07	4	def.	100	493
Automatic Data Processing	Jn	1.11	4,270	5,207	5,811	6,765
Computer Sciences	Mr	3.38	527	530	541	...
Comshare Inc.	Jn	0.42	936	198	317	331
Cullinet Software	Ap	0.50	1,520	2,320	3,300	...
HBO & Co.	D	[1]1.6	313	469	625	869
Lotus Development	D	[10]13.7		def.	100	263
Management Science America	D	[8]2.5	220	380	432	548
Pansophic Systems	Ap	[1]1.32	351	438	631	...
Policy Management Systems	D	[5]1.46	260	454	666	938
Shared Medical Systems	D	[6]5.3	313	404	515	638
UCCEL Corp.	D	2.6	231	158	8	304
Copying & Office Equipment						
Bell & Howell	D	[4]12.8	135	147	195	258
Pitney Bowes	D	[6]31	226	268	381	445
SCM Corp.	Jn	25.1	225	105	105	166
Savin Corp.	Ap	[3]3.1	def.	def.	def.	...
Xerox Corp.	D	99.9	599	368	459	376
Desktop Computers						
Apple Computer	S	[6]5.1	773	1,202	1,504	1,256
COMPAQ Computer	D	[10]2.6		def.	100	...
Commodore Intl.	Jn	2.3	1,083	1,765	3,826	6,261
Tandy Corp.	Jn	11	1,545	2,036	2,564	2,584
Engineering Workstations & Systems						
Apollo Computer	D	[10]11.2	def.	3	100	213
Daisy Systems	S	[10]2.3	def.	4	100	478
Intergraph Corp.	D	[7]1.4	593	929	2,093	4,493

Def.-deficit. [1]1978 = 100. [2]1970 = 100. [3]1982 = 100. [4]1972 = 100. [5]1980 = 100. [6]1976 = 100. [7]1977 = 100. [8]1973 = 100. [9]1979 = 100. [10]1983 = 100. ‡See revenues table for explanation. *See revenues table for explanation of fiscal yr.

MANAGEMENT EFFICIENCY

Earnings Record (% chg. yr. to yr.)

Company	1981	1982	1983	1984	5-Yr. Grth. (%)
Computer Manufacturers					
Amdahl Corp.	76.3	-81.7	NM	-15.97	16.3
Burroughs Corp.	81.7	-38.9	116.5	24.4	NM
CPT Corp.	104.9	27.2	11.3	-1.7	[1]37.0
Computer Automation	-64.1	3.6	-127.5	NM	NM
Computervision Corp.	53.2	-9.2	9.0	...	...
Control Data	14.9	-8.8	4.5	-80.3	NM
Convergent Technologies	123.5	NM	25.2	-95.3	NA
Cray Research	67.0	4.4	37.4	73.9	[1]43.0
Data General	-25.4	-51.5	16.7	245.5	9.9
Datapoint Corp.	45.7	-95.1	237.5	225.9	0.9
Digital Equipment	37.2	21.6	-31.9	15.8	13.0
Floating Point Systems	49.8	79.7	13.9	16.0	[1]50.0
Hewlett-Packard	16.0	22.4	12.8	53.9	[1]27.0
Honeywell Inc.	-8.9	5.9	-14.8	45.0	6.9
Int'l Bus. Machines	-7.1	33.3	24.4	20.0	16.9
NBI Inc.	125.0	52.7	-58.2	200.0	[1]71.0
NCR Corp.	-18.4	12.5	23.1	19.1	7.8
Prime Computer	20.8	19.1	-27.6	83.7	[1]29.0
Sperry Corp.	-29.1	-46.8	69.5	...	...
Tandem Computers	152.4	12.8	3.0	39.3	[1]55.0
Wang Laboratories	50.0	37.2	42.1	38.2	[1]48.0
Peripherals, Components & Subsystems					
Cipher Data Products	-88.9	NM	136.4	121.1	[1]75.0
Dataproducts Corp.	-61.6	107.6	89.8	...	...
Hazeltine Corp.	-61.4	301.1	-65.1	311.5	14.7
Quantum Corp.	...	111.1	NM	52.9	NA
Seagate Technology	NM	305.9	89.9	220.6	NA
Storage Technology	81.5	-23.2	-164.6	...	...
Tandon Corp.	200.0	248.9	51.0	24.1	NM
Telex Corp.	45.7	108.5	46.7	...	...
Software, EDP Services & Systems					
ASK Comp. Systems	50.5	57.0	67.1	57.0	[1]86.0
Applied Data Research	227.3	46.6	55.1	38.4	[1]79.0
Ashton-Tate	...	NM	NM	406.7	NA
Automatic Data Processing	18.2	21.9	11.6	16.4	17.8
Computer Sciences	-27.9	0.6	2.2	...	...
Comshare Inc.	-5.8	-78.9	60.2	4.5	NM
Cullinet Software	18.3	52.6	43.5	...	...
HBO & Co.	66.7	50.0	33.3	39.0	[1]42.0
Lotus Development	...	...	NM	162.8	NA
Management Science America	71.9	63.6	20.0	26.9	[1]40.0
Pansophic Systems	86.7	24.8	44.1	...	...
Policy Management Systems	159.6	74.9	46.8	41.2	NA
Shared Medical Systems	24.8	28.9	27.6	23.8	[1]26.0
UCCEL Corp.	-1.6	-31.7	-95.1	NM	11.0
Copying & Office Equipment					
Bell & Howell	-9.9	6.9	33.0	34.1	14.5
Pitney Bowes	-6.7	18.6	42.2	16.9	16.8
SCM Corp.	4.8	-49.2	-8.4	58.6	NM
Savin Corp.	NM	NM	NM	...	...
Xerox Corp.	-3.4	-38.5	24.7	-19.3	NM
Desktop Computers					
Apple Computer	236.7	55.6	25.1	-18.4	[1]65.0
COMPAQ Computer	...	...	NM	...	...
Commodore Intl.	53.7	63.1	116.7	63.6	[1]90.0
Tandy Corp.	51.8	31.8	24.5	1.1	[1]27.0
Engineering Workstations & Systems					
Apollo Computer	NM	110.0	NM	113.4	NA
Daisy Systems	...	112.5	NM	378.3	NA
Intergraph Corp.	80.4	56.6	125.4	114.7	NA

NM-Not meaningful. NA-Not available. [1]Approximately.

Return on Equity (%)

Company	1980	1981	1982	1983	1984
Computer Manufacturers					
Amdahl Corp.	6.8	10.5	1.6	12.9	8.3
Burroughs Corp.	3.8	6.9	4.3	8.9	10.8
CPT Corp.	23.3	28.7	21.4	17.5	14.4
Computer Automation	19.2	5.9	5.7	NM	NM
Computervision Corp.	30.4	28.0	19.9	17.4	...
Control Data	10.8	11.3	9.4	9.0	1.7
Convergent Technologies	...	...	29.4	9.3	0.3
Cray Research	20.3	21.2	15.5	16.4	23.0
Data General	19.0	11.5	4.8	5.1	14.5
Datapoint Corp.	22.2	19.0	0.7	2.5	7.7
Digital Equipment	17.2	14.8	14.2	8.4	6.6
Floating Point Systems	21.0	16.0	18.9	16.7	18.5
Hewlett-Packard	19.2	17.9	17.8	16.4	20.6
Honeywell Inc.	15.7	12.7	12.9	10.2	14.3
Int'l Bus. Machines	22.7	19.0	22.9	25.2	26.4
NBI Inc.	31.0	21.9	17.1	5.5	17.1
NCR Corp.	15.9	11.7	12.3	14.5	17.1
Prime Computer	42.0	31.1	23.7	13.0	20.1
Sperry Corp.	14.1	9.2	4.8	7.1	...
Tandem Computers	19.8	18.3	12.9	10.7	12.4
Wang Laboratories	33.0	22.6	20.5	19.3	18.8
Peripherals, Components & Subsystems					
Cipher Data Products	22.1	1.3	17.2	8.3	11.5
Dataproducts Corp.	13.0	4.3	8.5	12.6	...
Hazeltine Corp.	11.1	4.1	16.7	5.8	21.6
Quantum Corp.	...	NM	NM	29.9	19.6
Seagate Technology	NM	NM	35.7	16.1	29.3
Storage Technology	21.2	21.4	12.4	NM	...
Tandon Corp.	...	27.3	23.7	14.6	13.0
Telex Corp.	17.7	21.3	27.2	28.0	...
Software, EDP Services & Systems					
ASK Comp. Systems	NM	71.6	26.5	17.3	18.8
Applied Data Research	10.6	19.5	20.3	17.5	17.5
Ashton-Tate	...	...	NM	NM	44.7
Automatic Data Processing	20.5	17.4	16.9	16.3	16.7
Computer Sciences	27.9	16.0	13.8	12.3	...
Comshare Inc.	16.2	10.5	2.1	3.6	4.4
Cullinet Software	22.9	23.2	Nil	18.7	...
HBO & Co.	61.3	26.1	24.3	21.8	31.5
Lotus Development	...	...	NM	43.9	46.5
Management Science America	34.6	22.7	20.4	11.5	...
Pansophic Systems	64.8	37.5	25.8	13.5	...
Policy Management Systems	...	...	21.3	16.9	16.1
Shared Medical Systems	28.7	28.7	29.0	30.2	29.8
UCCEL Corp.	26.7	10.5	6.8	0.3	9.2
Copying & Office Equipment					
Bell & Howell	11.5	9.5	10.4	11.5	13.6
Pitney Bowes	21.0	15.6	17.2	21.8	22.1
SCM Corp.	12.4	12.0	5.8	5.2	8.0
Savin Corp.	NM	NM	55.9	NM	...
Xerox Corp.	18.1	16.3	9.9	10.0	7.8
Desktop Computers					
Apple Computer	65.7	38.1	27.8	23.8	15.1
COMPAQ Computer	...	...	NM	NM	...
Commodore Intl.	58.0	50.9	48.5	59.1	55.8
Tandy Corp.	46.9	37.6	32.2	28.7	28.4
Engineering Workstations & Systems					
Apollo Computer	NM	NM	4.7	25.2	19.4
Daisy Systems	...	NM	4.8	9.9	24.4
Intergraph Corp.	43.4	24.4	22.5	25.1	31.8

NM-Not meaningful. **Definition:** Net income (less preferred dividend requirements) divided by average common shareholder's equity.

MANAGEMENT EFFICIENCY, con't

Return on Assets (%)

Company	1980	1981	1982	1983	1984
Computer Manufacturers					
Amdahl Corp.	3.8	6.2	0.9	6.4	4.1
Burroughs Corp.	2.3	3.6	2.1	4.6	5.7
CPT Corp.	14.3	16.1	11.4	9.9	8.6
Computer Automation	8.7	3.3	3.8	NM	NM
Computervision Corp.	17.7	17.8	12.8	11.2	...
Control Data	5.9	6.3	3.2	2.0	0.3
Convergent Technologies	...	7.4	20.2	7.9	0.3
Cray Research	14.0	15.0	10.3	10.4	14.9
Data General	9.7	5.9	2.6	2.8	8.1
Datapoint Corp.	16.8	13.1	0.4	1.4	4.4
Digital Equipment	10.5	10.3	11.1	6.6	6.4
Floating Point Systems	12.3	10.2	12.7	11.5	12.5
Hewlett-Packard	12.6	12.1	12.2	11.2	14.2
Honeywell Inc.	7.7	6.2	6.2	5.0	7.1
Int'l Bus. Machines	13.9	11.7	14.1	15.6	16.4
NBI Inc.	17.0	15.5	12.6	3.5	8.8
NCR Corp.	8.0	6.2	6.9	8.3	9.9
Prime Computer	15.9	13.8	12.8	7.9	12.6
Sperry Corp.	8.5	4.1	2.1	3.4	...
Tandem Computers	14.2	14.3	9.9	8.0	9.2
Wang Laboratories	11.6	9.9	10.3	10.2	10.5
Peripherals, Components & Subsystems					
Cipher Data Products	7.6	0.5	6.8	5.5	9.9
Dataproducts Corp.	7.6	2.6	5.4	8.4	...
Hazeltine Corp.	5.6	2.0	8.0	2.6	9.5
Quantum Corp.	...	NM	2.3	20.4	16.2
Seagate Technology	NM	26.8	25.4	12.6	22.5
Storage Technology	7.5	6.4	5.5	NM	...
Tandon Corp.	...	11.4	14.5	9.7	8.8
Telex Corp.	5.6	7.8	13.6	17.4	...
Software, EDP Services & Systems					
ASK Comp. Systems	40.3	28.3	16.8	12.7	13.5
Applied Data Research	3.6	8.0	9.3	8.7	9.3
Ashton-Tate	...	...	NM	30.6	26.9
Automatic Data Processing	12.7	10.8	11.0	10.6	10.5
Computer Sciences	9.0	5.9	5.3	4.8	...
Comshare Inc.	7.5	5.4	1.2	2.2	2.8
Cullinet Software	16.5	16.9	14.1	13.1	...
HBO & Co.	13.8	13.9	15.9	14.0	19.2
Lotus Development	...	...	NM	33.4	35.9
Management Science America	14.8	12.8	13.6	8.5	...
Pansophic Systems	13.8	20.1	19.5	11.5	...
Policy Management Systems	10.3	16.7	17.8	13.9	13.3
Shared Medical Systems	18.3	17.7	17.2	18.5	19.2
UCCEL Corp.	7.6	4.7	3.5	0.1	4.4
Copying & Office Equipment					
Bell & Howell	5.3	4.3	4.6	5.4	6.2
Pitney Bowes	7.3	5.8	6.5	8.2	8.8
SCM Corp.	5.4	5.5	2.6	2.3	3.8
Savin Corp.	NM	NM	NM	NM	...
Xerox Corp.	8.9	8.0	4.6	5.2	4.0
Desktop Computers					
Apple Computer	27.0	23.9	19.7	18.5	9.4
COMPAQ Computer	...	...	NM	NM	...
Commodore Intl.	22.3	21.1	21.4	20.6	22.2
Tandy Corp.	17.5	19.3	20.8	19.8	18.4
Engineering Workstations & Systems					
Apollo Computer	NM	NM	2.2	19.3	15.2
Daisy Systems	...	NM	2.3	7.5	20.8
Intergraph Corp.	14.9	11.9	12.5	15.3	20.8

NM-Not meaningful. **Definition:** Net income divided by average total assets.

Operating Income (as a % of revenues)

Company	1980	1981	1982	1983	1984
Computer Manufacturers					
Amdahl Corp.	17.4	14.4	8.2	17.1	14.5
Burroughs Corp.	14.6	18.6	13.1	17.0	16.7
CPT Corp.	22.9	22.6	22.9	22.0	19.2
Computer Automation	12.4	8.1	6.6	2.5	NM
Computervision Corp.	21.6	25.1	19.5	19.8	...
Control Data	14.7	15.0	19.7	17.9	17.8
Convergent Technologies	NM	10.9	20.6	9.7	1.2
Cray Research	45.3	45.3	38.0	37.0	40.8
Data General	20.3	15.4	9.7	11.1	15.0
Datapoint Corp.	27.1	25.3	12.1	13.1	17.2
Digital Equipment	19.1	20.0	19.0	13.3	11.6
Floating Point Systems	22.0	20.2	22.2	24.2	22.4
Hewlett-Packard	19.9	19.6	19.6	19.5	18.2
Honeywell Inc.	13.8	13.3	11.6	11.5	12.5
Int'l Bus. Machines	30.9	30.7	32.6	33.0	32.0
NBI Inc.	22.2	23.4	21.6	11.5	21.2
NCR Corp.	20.6	17.1	18.0	19.4	19.0
Prime Computer	22.1	19.8	20.5	15.4	17.6
Sperry Corp.	16.4	14.4	11.1	13.0	...
Tandem Computers	20.1	21.4	16.3	16.3	13.9
Wang Laboratories	22.8	20.4	19.4	21.0	19.6
Peripherals, Components & Subsystems					
Cipher Data Products	8.4	4.4	11.4	15.5	16.1
Dataproducts Corp.	13.3	6.6	9.3	10.4	...
Hazeltine Corp.	7.9	6.1	12.3	12.1	11.9
Quantum Corp.	...	NM	2.9	29.7	25.5
Seagate Technology	NM	8.9	26.5	17.0	18.5
Storage Technology	22.4	23.6	18.3	10.9	...
Tandon Corp.	14.7	16.3	18.9	13.5	13.9
Telex Corp.	15.7	19.7	26.1	27.2	...
Software, EDP Services & Systems					
ASK Comp. Systems	22.4	20.5	15.6	17.2	19.6
Applied Data Research	7.0	12.1	14.0	15.2	15.0
Ashton-Tate	...	11.9	NM	11.3	27.2
Automatic Data Processing	24.3	24.7	24.0	23.7	24.2
Computer Sciences	10.6	8.3	7.8	7.6	...
Comshare Inc.	19.4	18.2	11.4	13.1	12.7
Cullinet Software	24.0	23.9	25.1	25.7	...
HBO & Co.	42.0	39.6	38.1	36.9	36.8
Lotus Development	...	...	NM	50.8	40.4
Management Science America	12.6	9.8	12.2	12.5	...
Pansophic Systems	24.3	27.2	26.0	31.6	...
Policy Management Systems	19.7	26.0	25.3	23.6	25.5
Shared Medical Systems	33.7	32.3	32.7	31.1	31.0
UCCEL Corp.	13.8	10.4	7.3	4.2	11.6
Copying & Office Equipment					
Bell & Howell	7.9	6.3	7.7	7.4	7.6
Pitney Bowes	15.5	13.8	13.6	16.1	16.3
SCM Corp.	8.0	7.7	5.5	7.0	6.9
Savin Corp.	10.1	10.5	4.4	NM	...
Xerox Corp.	26.3	23.8	19.6	17.1	17.7
Desktop Computers					
Apple Computer	21.3	22.3	20.4	15.5	8.5
COMPAQ Computer	...	...	NM	4.2	...
Commodore Intl.	19.9	21.1	21.3	19.9	20.9
Tandy Corp.	17.8	20.3	20.9	21.7	19.8
Engineering Workstations & Systems					
Apollo Computer	NM	NM	4.9	20.0	21.5
Daisy Systems	...	NM	5.6	15.5	27.4
Intergraph Corp.	17.8	17.6	18.6	23.4	28.8

NM-Not meaningful. **Definition:** Net sales and operating revenues divided into operating income (net sales and oper. revs. less cost of goods sold and oper. expenses).

Net Income (as a % of revenues)

Company	1980	1981	1982	1983	1984
Computer Manufacturers					
Amdahl Corp.	3.9	6.0	1.1	5.6	4.7
Burroughs Corp.	2.9	4.5	2.2	4.5	5.1
CPT Corp.	10.4	12.4	10.9	9.9	8.7
Computer Automation	5.7	2.2	2.5	NM	NM
Computervision Corp.	10.4	13.2	10.0	8.8	...
Control Data	5.3	5.5	3.6	3.5	0.6
Convergent Technologies	NM	5.9	12.4	9.1	0.2
Cray Research	17.9	17.9	13.5	15.4	19.8
Data General	8.4	5.5	2.5	2.8	6.9
Datapoint Corp.	10.5	12.3	0.5	1.5	4.4
Digital Equipment	10.6	10.7	10.7	6.6	5.9
Floating Point Systems	10.0	11.0	13.3	13.0	12.8
Hewlett-Packard	8.7	8.7	9.0	9.2	11.0
Honeywell Inc.	5.7	4.8	4.9	4.7	5.5
Int'l Bus. Machines	13.6	11.4	12.8	13.7	14.3
NBI Inc.	9.9	12.4	11.0	3.8	7.8
NCR Corp.	7.7	6.1	6.6	7.7	8.4
Prime Computer	11.7	10.3	10.3	6.3	9.3
Sperry Corp.	5.8	4.0	2.3	4.1	...
Tandem Computers	9.8	12.7	9.6	7.4	8.1
Wang Laboratories	9.6	9.1	9.2	9.9	9.6
Peripherals, Components & Subsystems					
Cipher Data Products	4.1	0.4	4.1	6.8	9.9
Dataproducts Corp.	6.4	2.4	4.6	6.5	...
Hazeltine Corp.	3.6	1.3	6.0	1.8	6.2
Quantum Corp.	...	NM	1.3	16.6	15.9
Seagate Technology	NM	17.2	17.2	11.9	12.2
Storage Technology	7.5	8.9	5.9	NM	...
Tandon Corp.	6.6	8.3	10.5	7.8	7.3
Telex Corp.	4.4	5.8	9.1	11.3	...
Software, EDP Services & Systems					
ASK Comp. Systems	11.9	11.5	10.3	9.9	9.4
Applied Data Research	2.4	5.9	6.6	7.8	7.5
Ashton-Tate	...	8.6	NM	5.9	12.3
Automatic Data Processing	8.8	8.5	8.6	8.6	8.5
Computer Sciences	4.1	2.8	2.6	2.6	...
Comshare Inc.	5.3	4.7	1.1	1.7	1.9
Cullinet Software	15.5	15.4	14.7	13.7	...
HBO & Co.	10.3	12.8	13.5	14.8	15.7
Lotus Development	...	...	NM	25.9	23.0
Management Science America	6.2	8.2	9.3	7.7	9.7
Pansophic Systems	8.2	13.0	13.4	15.7	...
Policy Management Systems	6.6	11.9	14.9	15.6	16.2
Shared Medical Systems	12.6	12.8	13.1	13.1	13.2
UCCEL Corp.	5.2	4.1	2.9	0.1	4.6
Copying & Office Equipment					
Bell & Howell	3.0	2.5	3.0	3.6	4.6
Pitney Bowes	6.0	4.9	5.7	7.3	8.0
SCM Corp.	2.8	2.9	1.5	1.6	2.1
Savin Corp.	NM	NM	NM	NM	...
Xerox Corp.	7.6	6.9	4.3	5.4	4.3
Desktop Computers					
Apple Computer	10.0	11.8	10.5	7.8	4.2
COMPAQ Computer	...	...	NM	2.3	...
Commodore Intl.	12.9	13.4	13.3	12.9	11.3
Tandy Corp.	8.1	10.0	11.0	11.3	10.3
Engineering Workstations & Systems					
Apollo Computer	NM	NM	1.7	13.9	11.1
Daisy Systems	...	NM	2.7	13.3	16.0
Intergraph Corp.	8.1	9.1	8.4	11.6	15.6

NM-Not meaningful.

INVESTMENT RATIOS

Dividend Payout Ratio (%)

Company	1980	1981	1982	1983	1984
Computer Manufacturers					
Amdahl Corp.	44	26	167	21	26
Burroughs Corp.	132	73	120	57	48
CPT Corp.	Nil	Nil	Nil	Nil	Nil
Computer Automation	NM	Nil	Nil	Nil	Nil
Computervision Corp.	Nil	Nil	Nil	Nil	Nil
Control Data	8	10	13	14	81
Convergent Technologies	...	Nil	Nil	Nil	Nil
Cray Research	Nil	Nil	Nil	Nil	Nil
Data General	Nil	Nil	Nil	Nil	Nil
Datapoint Corp.	Nil	Nil	Nil	Nil	Nil
Digital Equipment	Nil	Nil	Nil	Nil	Nil
Floating Point Systems	Nil	Nil	Nil	Nil	Nil
Hewlett-Packard	9	9	8	9	7
Honeywell Inc.	23	29	29	35	27
Int'l Bus. Machines	58	62	47	41	38
NBI Inc.	Nil	Nil	Nil	Nil	Nil
NCR Corp.	21	28	27	25	23
Prime Computer	Nil	Nil	Nil	Nil	Nil
Sperry Corp.	23	36	74	50	...
Tandem Computers	Nil	Nil	Nil	Nil	Nil
Wang Laboratories	8	8	7	8	8
Peripherals, Components & Subsystems					
Cipher Data Products	Nil	Nil	Nil	Nil	Nil
Dataproducts Corp.	13	40	19	13	...
Hazeltine Corp.	32	88	22	76	20
Quantum Corp.	...	Nil	Nil	Nil	Nil
Seagate Techology	Nil	Nil	Nil	Nil	Nil
Storage Techology	Nil	Nil	Nil	Nil	...
Tandon Corp.	Nil	Nil	Nil	Nil	Nil
Telex Corp.	Nil	Nil	Nil	Nil	...
Software, EDP Services & Systems					
ASK Comp. Systems	Nil	Nil	Nil	Nil	Nil
Applied Data Research	6	Nil	Nil	Nil	Nil
Ashton-Tate	...	Nil	Nil	Nil	Nil
Automatic Data Processing	26	28	27	28	27
Computer Sciences	Nil	Nil	Nil	Nil	...
Comshare Inc.	Nil	Nil	Nil	Nil	Nil
Cullinet Software	Nil	Nil	48	49	...
HBO & Co.	Nil	3	11	11	17
Lotus Development	...	...	Nil	Nil	Nil
Management Science America	Nil	Nil	Nil	Nil	Nil
Pansophic Systems	Nil	Nil	Nil	Nil	Nil
Policy Management Systems	Nil	Nil	Nil	Nil	Nil
Shared Medical Systems	27	28	25	30	31
UCCEL Corp.	Nil	Nil	Nil	Nil	Nil
Copying & Office Equipment					
Bell & Howell	28	31	29	23	17
Pitney Bowes	31	41	34	27	30
SCM Corp.	25	31	66	73	47
Savin Corp.	NM	NM	Nil	Nil	Nil
Xerox Corp.	38	42	69	69	88
Desktop Computers					
Apple Computer	Nil	Nil	Nil	Nil	Nil
COMPAQ Computer	...	...	Nil	Nil	Nil
Commodore Intl.	Nil	Nil	Nil	Nil	Nil
Tandy Corp.	Nil	Nil	Nil	Nil	Nil
Engineering Workstations & Systems					
Apollo Computer	Nil	Nil	Nil	Nil	Nil
Daisy System	...	Nil	Nil	Nil	Nil
Intergraph Corp.	Nil	Nil	Nil	Nil	Nil

Definition: Dividends as a percent of earnings. NM-Not meaningful.

INVESTMENT RATIOS, con't.

Price-Earnings Ratio (%)

Company	1980 High-Low	1981 High-Low	1982 High-Low	1983 High-Low	1984 High-Low
Computer Manufacturers					
Amdahl Corp.	46-18	35-18	NM	31-15	25-12
Burroughs Corp.	44-23	15-8	23-14	13-9	11-8
CPT Corp.	28-11	26-13	21-10	26-10	16-6
Computer Automation	12-5	24-11	20-6	NM	NM
Computervision Corp.	48-11	38-20	32-16	43-24	28-17
Control Data	9-5	9-7	10-5	15-8	[1]...-30
Convergent Technologies	...	...	[1]...-17	NM	NM
Cray Research	[1]...-15	37-21	33-14	32-21	19-13
Data General	17-10	18-11	30-11	43-20	19-12
Datapoint Corp.	31-12	28-16	NM	[1]...-44	24-10
Digital Equipment	18-10	17-12	15-8	26-13	19-12
Floating Point Systems	31-10	37-15	23-12	31-17	21-7
Hewlett-Packard	22-11	21-15	27-12	29-20	18-12
Honeywell Inc.	9-5	10-6	9-5	14-8	9-6
Int'l Bus. Machines	12-8	13-9	13-8	15-10	12-9
NBI Inc.	[1]...-19	49-24	34-16	NM	20-10
NCR Corp.	9-5	10-5	11-4	13-8	10-6
Prime Computer	39-8	39-14	26-11	44-19	17-9
Sperry Corp.	8-5	13-6	13-8	12-8	...
Tandem Computers	[1]...-17	48-28	43-19	[1]...-31	39-13
Wang Laboratories	45-14	22-14	36-14	37-24	25-15
Peripherals, Components & Subsystems					
Cipher Data Products	...	...	45-17	[1]...-22	32-17
Dataproducts Corp.	17-5	[1]...-25	23-10	25-13	...
Hazeltine Corp.	15-8	31-20	12-7	[1]...-31	20-9
Quantum Corp.	...	...	...	25-23	31-14
Seagate Technology	...	NM	[1]...-23	[1]...-25	18-4
Storage Technology	15-7	15-7	20-9	NM	...
Tandon Corp.	...	[1]...-30	[1]...-15	[1]...-31	35-8
Telex Corp.	10-4	10-5	16-3	13-8	...
Software, EDP Services & Systems					
ASK Comp. Systems	...	44-29	[1]...-24	[1]...-32	38-25
Applied Data Research	39-10	13-6	19-7	26-13	16-10
Ashton-Tate	...	...	...	...	21-18
Automatic Data Processing	20-12	21-15	22-12	24-18	19-14
Computer Sciences	16-8	19-9	16-8	17-12	...
Comshare Inc.	19-10	18-8	48-31	42-22	40-18
Cullinet Software	27-9	34-15	34-14	48-21	...
HBO & Co.	...	33-19	39-18	49-25	29-18
Lotus Development	...	...	...	32-18	18-7
Management Science America	...	31-19	34-14	[1]...-29	39-11
Pansophic Systems	...	23-16	25-10	30-17	...
Policy Management Systems	...	32-28	48-18	[1]...-29	36-26
Shared Medical Systems	25-13	27-18	31-15	39-23	25-10
UCCEL Corp.	41-11	37-15	44-24	NM	26-16
Copying & Office Equipment					
Bell & Howell	10-5	10-5	10-5	13-6	10-6
Pitney Bowes	9-7	9-6	11-5	12-7	10-8
SCM Corp.	6-3	5-4	10-7	14-10	10-8
Savin Corp.	NM	NM	NM	NM	NM
Xerox Corp.	10-7	9-5	10-6	12-8	15-10
Desktop Computers					
Apple Computer	NM	49-20	33-10	49-13	33-21
COMPAQ Computer	...	...	...	[1]...	31-7
Commodore Intl.	35-5	21-10	28-9	21-10	11-4
Tandy Corp.	23-6	24-12	28-10	24-14	16-8
Engineering Workstations & Systems					
Apollo Computer	...	...	...	[1]...-40	39-21
Daisy Systems	...	...	...	NM	39-24
Intergraph Corp.	...	44-24	45-14	44-19	24-13

NM-Not meaningful. NA-Not available. [1]Ratios over 50 are not calculated.
Definition: High and Low calendar-year market prices divided by earnings per share.

Yields (%)

Company	1980 High-Low	1981 High-Low	1982 High-Low	1983 High-Low	1984 High-Low
Computer Manufacturers					
Amdahl Corp.	2.6-1.0	1.7-0.9	2.3-1.2	1.4-0.7	2.1-1.0
Burroughs Corp.	5.6-3.0	9.8-4.7	8.8-5.3	8.5-4.5	5.9-4.3
CPT Corp.	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Computer Automation	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Computervision Corp.	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Control Data	1.4-0.8	1.6-1.1	2.6-1.3	1.7-0.9	2.7-1.4
Convergent Technologies	...	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Cray Research	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Data General	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Datapoint Corp.	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Digital Equipment	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Floating Point Systems	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Hewlett-Packard	0.8-0.4	0.6-0.4	0.7-0.3	0.5-0.3	0.6-0.4
Honeywell Inc.	4.3-2.4	4.6-2.8	5.9-3.3	4.3-2.6	4.1-2.8
Int'l Bus. Machines	6.8-4.7	7.1-4.8	6.2-3.5	4.0-2.8	4.1-3.2
NBI Inc.	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
NCR Corp.	3.9-2.5	5.6-2.9	6.2-2.5	3.2-1.9	3.9-2.4
Prime Computer	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Sperry Corp.	4.1-2.6	6.4-2.9	9.4-5.4	6.1-4.1	...
Tandem Computers	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Wang Laboratories	0.6-0.2	0.4-0.2	0.5-0.2	0.3-0.2	0.5-0.3
Peripherals, Components & Subsystems					
Cipher Data Products	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Dataproducts Corp.	2.8-0.8	1.6-0.6	1.9-0.8	1.0-0.5	...
Hazeltine Corp.	4.0-2.2	4.4-2.8	3.4-1.9	2.4-1.0	2.2-1.0
Quantum Corp.	...	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Seagate Technology	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Storage Technology	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	...
Tandon Corp.	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Telex Corp.	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	...
Software, EDP Services & Systems					
ASK Comp. Systems	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Applied Data Research	0.7-0.2	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Ashton-Tate	...	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Automatic Data Processing	2.1-1.3	1.7-1.2	2.2-1.2	1.6-1.2	1.9-1.4
Computer Sciences	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	...
Comshare Inc.	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Cullinet Software	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	...
HBO & Co.	Nil-Nil	0.2-0.1	0.6-0.3	0.4-0.2	1.0-0.6
Lotus Development	...	...	Nil-Nil	Nil-Nil	Nil-Nil
Management Science America	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Pansophic Systems	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Policy Management Systems	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Shared Medical Systems	2.0-1.1	1.6-1.0	1.7-0.8	1.4-0.8	2.0-1.2
UCCEL Corp.	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Copying & Office Equipment					
Bell & Howell	5.3-2.8	5.7-3.1	5.4-2.8	3.8-1.7	2.7-1.7
Pitney Bowes	5.1-3.0	7.3-4.5	7.4-3.3	4.2-2.4	3.9-2.9
SCM Corp.	8.6-4.4	8.5-5.9	10.2-6.3	7.0-5.1	5.9-4.8
Savin Corp.	5.4-3.2	2.4-1.1	Nil-Nil	Nil-Nil	Nil-Nil
Xerox Corp.	5.8-3.9	8.0-4.7	11.1-7.2	8.6-5.8	9.0-5.9
Desktop Computers					
Apple Computer	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
COMPAQ Computer	...	...	Nil-Nil	Nil-Nil	Nil-Nil
Commodore Intl.	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Tandy Corp.	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Engineering Workstations & Systems					
Apollo Computer	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Daisy Systems	...	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil
Intergraph Corp.	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil	Nil-Nil

Definition: Dividends paid, divided by calendar-year price ranges of common stock.

LIQUIDITY & LEVERAGE ANALYSIS

Debt/Capital Ratio (%)

Company	1980	1981	1982	1983	1984
Computer Manufacturers					
Amdahl Corp.	9.0	8.6	19.3	11.0	22.0
Burroughs Corp.	14.4	26.1	27.8	19.8	24.2
CPT Corp.	11.6	30.8	32.6	27.8	24.2
Computer Automation	5.5	21.7	7.1	8.7	25.3
Computervision Corp.	15.2	16.9	14.6	12.7	...
Control Data	17.6	18.7	65.8	71.5	74.0
Convergent Technologies	...	2.9	...	0.3	8.6
Cray Research	8.9	10.7	17.1	16.3	6.1
Data General	29.7	25.8	23.3	21.8	18.2
Datapoint Corp.	2.3	24.3	28.8	26.8	23.7
Digital Equipment	22.4	3.1	2.8	2.5	9.8
Floating Point Systems	14.1	5.6	6.2	3.2	3.4
Hewlett-Packard	1.8	1.3	1.5	2.2	2.2
Honeywell Inc.	18.2	20.2	21.9	21.6	20.9
Int'l Bus. Machines	11.2	12.7	12.3	10.1	10.3
NBI Inc.	3.4	1.7	0.7	33.3	33.6
NCR Corp.	15.4	13.5	14.6	13.3	9.5
Prime Computer	33.3	24.3	5.7	4.7	4.0
Sperry Corp.	20.8	19.2	22.2	18.0	...
Tandem Computers	2.2	1.0	7.3	6.7	4.2
Wang Laboratories	50.4	33.5	34.8	26.5	21.0
Peripherals, Components & Subsystems					
Cipher Data Products	7.2	40.3	50.2	Nil	Nil
Dataproducts Corp.	17.4	16.9	13.4	6.2	...
Hazeltine Corp.	6.2	5.4	0.4	Nil	Nil
Quantum Corp.	...	Nil	Nil	Nil	Nil
Seagate Technology	Nil	16.3	1.2	5.6	5.3
Storage Technology	49.4	32.3	33.9	41.4	...
Tandon Corp.	4.7	0.7	0.1	Nil	Nil
Telex Corp.	56.1	48.7	22.6	14.1	...
Software, EDP Services & Systems					
ASK Comp. Systems	Nil	Nil	Nil	3.4	2.6
Applied Data Research	42.8	23.2	33.4	19.4	21.9
Ashton-Tate	...	...	Nil	Nil	4.1
Automatic Data Processing	18.7	16.7	12.7	11.6	11.7
Computer Sciences	34.3	29.4	25.4	21.2	...
Comshare Inc.	29.5	15.3	18.9	4.5	4.1
Cullinet Software	Nil	Nil	Nil	Nil	...
HBO & Co.	51.9	1.2	8.2	6.6	4.9
Lotus Development	...	...	Nil	Nil	Nil
Management Science America	27.4	4.3	2.2	0.5	...
Pansophic Systems	49.9	Nil	2.7	2.2	...
Policy Management Systems	...	Nil	Nil	1.0	1.5
Shared Medical Systems	12.2	11.8	8.3	6.2	6.0
UCCEL Corp.	26.7	10.4	20.1	14.5	13.1
Copying & Office Equipment					
Bell & Howell	24.8	23.8	28.4	15.7	28.4
Pitney Bowes	21.5	20.2	18.1	15.6	14.0
SCM Corp.	32.0	31.1	30.5	33.1	30.4
Savin Corp.	56.5	54.8	NM	61.9	66.4
Xerox Corp.	17.2	16.0	15.9	21.5	23.9
Desktop Computers					
Apple Computer	2.4	1.0	0.8	0.3	Nil
COMPAQ Computer	...	...	Nil	Nil	...
Commodore Intl.	40.6	33.7	29.2	32.1	18.9
Tandy Corp.	43.9	17.8	14.7	10.8	25.6
Engineering Workstations & Systems					
Apollo Computer	6.4	12.5	15.1	2.2	0.5
Daisy Systems	...	11.6	6.4	1.2	Nil
Intergraph Corp.	29.8	10.4	3.1	6.1	Nil

Definition: Debt as a % of invested capital.

LTD as % of Net Working Capital

Company	1980	1981	1982	1983	1984
Computer Manufacturers					
Amdahl Corp.	17.2	17.7	43.9	26.4	49.0
Burroughs Corp.	48.5	84.6	66.4	48.9	56.6
CPT Corp.	17.3	43.6	52.3	44.6	35.8
Computer Automation	8.7	26.5	8.8	8.8	32.2
Computervision Corp.	27.1	36.8	32.7	39.7	...
Control Data	65.4	69.2	NA	NA	NA
Convergent Technologies	108.5	3.3	1.2	0.3	9.9
Cray Research	14.7	20.0	33.1	29.1	13.3
Data General	40.1	34.7	31.5	32.9	28.8
Datapoint Corp.	4.1	35.3	72.5	56.9	50.5
Digital Equipment	29.5	4.3	4.2	3.9	14.7
Floating Point Systems	25.4	9.6	10.8	4.9	5.5
Hewlett-Packard	3.8	2.6	2.9	4.1	4.3
Honeywell Inc.	48.1	61.7	59.0	59.6	57.7
Int'l Bus. Machines	61.7	89.5	59.3	34.4	30.5
NBI Inc.	5.9	2.3	1.1	56.6	61.6
NCR Corp.	31.1	28.0	29.6	28.4	19.9
Prime Computer	51.4	39.8	10.4	8.0	7.2
Sperry Corp.	62.4	80.2	101.9	65.6	...
Tandem Computers	2.7	1.1	10.8	9.4	6.5
Wang Laboratories	88.8	56.4	62.9	58.6	61.3
Peripherals, Components & Subsystems					
Cipher Data Products	9.3	51.7	88.4	Nil	Nil
Dataproducts Corp.	24.9	25.4	19.7	8.8	...
Hazeltine Corp.	10.9	10.1	0.7	Nil	Nil
Quantum Corp.	...	Nil	Nil	Nil	Nil
Seagate Technology	Nil	58.0	1.5	8.8	10.1
Storage Technology	127.8	113.4	106.7	117.1	...
Tandon Corp.	6.2	1.0	0.1	Nil	Nil
Telex Corp.	102.3	90.1	NA	NA	...
Software, EDP Services & Systems					
ASK Comp. Systems	Nil	Nil	Nil	3.4	3.4
Applied Data Research	123.3	65.0	74.2	58.9	66.3
Ashton-Tate	...	...	Nil	Nil	6.3
Automatic Data Processing	93.4	65.6	67.7	57.8	77.5
Computer Sciences	99.4	113.2	76.0	54.5	...
Comshare Inc.	236.1	69.7	80.6	22.3	20.5
Cullinet Software	Nil	Nil	Nil	Nil	...
HBO & Co.	NM	5.9	41.1	30.8	14.4
Lotus Development	...	...	Nil	Nil	Nil
Management Science America	76.3	4.6	3.2	0.6	...
Pansophic Systems	216.1	Nil	4.6	2.9	...
Policy Management Systems	0.6	Nil	Nil	2.0	4.0
Shared Medical Systems	44.2	63.5	32.8	33.6	25.6
UCCEL Corp.	74.9	29.4	34.7	21.2	24.1
Copying & Office Equipment					
Bell & Howell	38.0	39.2	64.4	26.5	52.6
Pitney Bowes	83.0	83.8	76.4	82.4	81.2
SCM Corp.	62.1	65.9	68.4	64.4	64.1
Savin Corp.	125.6	110.7	125.6	233.3	NM
Xerox Corp.	58.7	56.7	51.9	108.3	125.3
Desktop Computers					
Apple Computer	1.6	1.2	0.9	0.4	Nil
COMPAQ Computer	...	...	Nil	Nil	...
Commodore Intl.	63.9	51.8	44.9	44.9	25.4
Tandy Corp.	63.3	25.0	20.0	14.1	36.4
Engineering Workstations & Systems					
Apollo Computer	...	16.0	25.5	2.6	0.8
Daisy Systems	...	13.6	7.1	1.3	Nil
Intergraph Corp.	61.3	15.4	5.3	9.6	5.7

LTD-Long-term debt. NA-Not available. NM-Not meaningful.

STATISTICAL DATA

Computer manufacturers

AMDAHL CORP. — YEARS TO DEC. 31

Long-Term Debt: $120,142,000; Com., 39,634,000 Shs., $0.05 Par.

Year	Net Sales (Million $)	*Oper. Inc. (Million $)	Net Bef. Taxes (Million $)	Net Income (Million $)	Earns. (Common $ Per Share)	Divs. (Common $ Per Share)	Price Range (Calendar Yrs.)	Book Value	†Net Wkg. Cap.	Curr. Ratio Assets to Liabs.
1984	779	113	36.7	36.4	0.80	0.20	20⅛- 9⅝	9.15	298	2.3-1
1983	778	133	72.6	43.3	0.96	0.20	29⅝-14⅞	9.60	213	2.0-1
1982	462	38	8.2	4.9	0.12	0.20	16⅞- 8⅝	7.71	178	2.1-1
1981	443	64	42.4	26.8	0.66	0.20	23 -11⅞	7.68	166	2.4-1
1980	394	69	26.6	15.2	0.42	0.20	19⅝- 7⅝	7.10	159	2.9-1
1979	300	57	28.7	17.1	0.51	0.20	26½- 8⅛	6.09	123	2.8-1
1978	321	110	98.1	48.2	1.43	0.15	35⅞-10⅝	5.44	120	2.4-1
1977	188	58	54.2	26.6	0.85	0.03⅛	13⅞- 5⅝	3.62	72	2.4-1
1976	92	28	24.0	11.6	0.61	Nil	9⅞- 5⅝	2.11	35	2.1-1
1975	14	d3	d8.7	*d3.1	1.58	Nil	...	...	d5	0.7-1

Per sh. data adj. for 2-for-1 splits in 1983 & 1978.

BURROUGHS CORP. — YEARS TO DEC. 31

Long-Term Debt: $742,200,000; Com., 45,358,000 Shs., $5 Par.

Year	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range	Book Value	†Net Wkg. Cap.	Curr. Ratio
1984	4,808	801	363	245	5.40	2.60	59⅞-44⅝	50.65	1,311	1.9-1
1983	4,297	730	303	197	4.60	2.60	57⅝-29⅝	49.12	1,155	1.9-1
1982	4,095	536	75	91	2.17	2.60	49⅛-29⅝	48.38	1,251	2.1-1
1981	3,318	618	254	149	3.58	2.60	55⅝-27⅛	51.88	950	1.7-1
1980	2,857	418	134	82	1.99	2.60	87½-46⅛	51.19	767	1.6-1
1979	2,785	764	528	306	7.45	2.10	83 -64⅝	51.84	789	1.8-1
1978	2,422	695	475	253	6.21	1.50	88 -58⅝	46.41	725	2.0-1
1977	2,090	599	394	215	5.31	0.82	91⅝-54½	41.61	654	1.9-1
1976	1,870	515	315	185	4.62	0.66	108½-83⅛	37.08	534	1.7-1
1975	1,675	465	291	164	4.14	0.57½	110⅝-61⅛	32.75	385	1.4-1

CPT CORP. — YEARS TO JUNE 30

Long-term Debt: $42,663,000; Com., 18,000,000 shs., $0.05 Par.

Year	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range	Book Value	†Net Wkg. Cap.	Curr. Ratio
1984	200	38.4	23.4	17.4	1.05	Nil	16⅝- 5⅞	7.76	119.8	4.1-1
1983	178	39.6	23.8	17.7	1.07	Nil	28 -12⅝	6.75	99.1	4.4-1
1982	145	33.3	25.2	15.9	0.97	Nil	20½- 9⅞	5.49	85.5	3.9-1
1981	101	22.9	18.4	12.5	0.83	Nil	21⅞-10½	3.63	55.1	3.4-1
1980	59	13.5	11.1	6.1	0.45	Nil	12⅝- 4⅞	2.35	25.8	2.9-1
1979	34	7.9	6.8	3.5	0.30	Nil	8⅝- 3⅝	1.40	14.4	3.2-1
1978	20	4.4	3.8	2.0	0.20	Nil	4½- 1⅝	0.88	8.5	3.2-1
1977	13	3.1	2.6	1.3	0.15	Nil	1⅞- 1	0.54	4.9	2.9-1
1976	11	2.4	1.9	1.0	0.12	Nil	1½- ½	0.40	2.4	2.0-1
1975	8	1.6	1.2	0.7	0.09	Nil	⅝- ⅜	0.27	1.6	2.2-1

Per sh. data adj. for stk. splits of 3-for-1 in 1981, 3-for-2 in 1979 & 1978, 5-for-4 in Nov. 1975 & Apr. 1975.

COMPUTERVISION CORP. — YEARS TO DEC. 31

Long-Term Debt: $31,881,000; Com., 28,571,825 shs., $0.05 Par.

Year	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range	Book Value	†Net Wkg. Cap.	Curr. Ratio
1984	...	...	...	...	1.66	Nil	46⅛-29		...	...
1983	400	79.0	53.5	35.3	1.24	Nil	52⅞-30	7.77	80.3	1.8-1
1982	325	63.4	49.5	32.4	1.18	Nil	37⅝-19⅛	6.56	93.8	2.5-1
1981	271	67.9	58.7	35.7	1.30	Nil	49⅝-26⅛	5.31	80.4	2.4-1
1980	224	48.4	39.2	23.3	0.90	Nil	42⅞- 9⅞	4.06	72.0	2.8-1
1979	132	28.5	23.6	13.0	0.53	Nil	14⅝- 3⅛	1.69	28.0	1.9-1
1978	72	12.5	9.1	5.2	0.26	Nil	3⅝- 1⅛	1.09	19.0	2.2-1
1977	46	6.0	4.1	2.7	0.15	Nil	1½- ⅝	0.54	12.8	2.4-1
1976	34	3.7	1.9	1.1	0.06	Nil	⅞- ½	0.38	10.9	2.3-1
1975	22	d0.9	d6.1	d4.1	d0.23	Nil	1⅝- ½	0.28	8.2	1.7-1

Per sh. data adj. for 2-for-1 stk. splits in 1981, 1980 & 1979.

*Before depreciation. d—Deficit. †In millions of dollars. P—Preliminary.

Computer manufacturers

CONTROL DATA CORP. — YEARS TO DEC. 31

Long-Term Debt: $5,847,000,000; Com., 38,590,000 Shs., $0.50 Par.

Year	Net Sales (Million $)	*Oper. Inc. (Million $)	Net Bef. Taxes (Million $)	Net Income (Million $)	Earns. (Common $ Per Share)	Divs. (Common $ Per Share)	Price Range (Calendar Yrs.)	Book Value	†Net Wkg. Cap.	Curr. Ratio Assets to Liabs.
1984	5,027	893	2	32	0.81	0.66	48½-24⅝	48.06	...	...
1983	4,583	820	214	162	4.20	0.60	64⅝-35½	47.59	...	...
1982	4,292	847	223	155	4.11	0.55	42⅝-21⅛	46.10	...	...
1981	3,101	464	258	170	4.46	0.47½	42⅛-29⅝	42.20	549	1.7-1
1980	2,766	407	230	148	4.15	0.30	38⅞-21½	38.43	500	1.8-1
1979	2,249	300	183	119	3.43	0.20	28½-14⅛	34.55	402	1.6-1
1978	1,846	247	137	85	2.44	0.12½	22⅝-11½	30.42	358	1.8-1
1977	1,493	194	90	62	1.81	0.07½	14⅝- 9⅝	27.91	292	1.6-1
1976	1,331	183	62	47	1.37	Nil	13⅝- 8⅛	25.61	243	1.5-1
1975	1,218	184	59	40	1.20	Nil	11⅞- 5⅝	23.39	225	1.5-1

Per sh. data adj. for 2-for-1 stk. split in 1981.

DATA GENERAL CORP. — YEARS TO SEPT. 30

Long-Term Debt: $134,916,000; Com., 24,566,218 Shs., $0.01 Par.

Year	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range	Book Value	†Net Wkg. Cap.	Curr. Ratio
1984	1,161	174	110	79.8	3.08	Nil	59⅝-38	24.32	469	2.4-1
1983	829	92	41	23.1	0.97	Nil	41⅝-19⅛	20.71	422	3.0-1
1982	806	78	37	19.8	0.92	Nil	27⅝-10⅛	19.56	442	3.4-1
1981	737	113	76	40.8	1.93	Nil	34½-20⅝	18.21	418	3.6-1
1980	654	133	101	54.7	2.60	Nil	43⅞-26½	15.50	362	3.3-1
1979	507	107	93	49.8	2.41	Nil	37⅝-23	12.53	222	2.4-1
1978	380	85	77	40.3	2.00	Nil	35⅝-21	9.85	194	3.0-1
1977	254	58	54	28.5	1.44	Nil	26⅞-17	7.67	168	3.5-1
1976	161	38	36	18.9	0.99	Nil	30½-18⅝	6.05	83	2.8-1
1975	108	27	24	12.8	0.76	Nil	19⅞- 4⅝	4.96	74	4.4-1

Per sh. data adj. for 2-for-1 stk. split in 1983.

DATAPOINT CORP. — YEARS TO JULY 31

Long-Term Debt: $109,297,000; Com., 19,903,667 Shs., $0.25 Par.

Year	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range	Book Value	†Net Wkg. Cap.	Curr. Ratio
1984	600	103	48.9	26.4	1.29	Nil	30½-13⅛	13.12	220	2.5-1
1983	540	71	5.7	8.1	0.40	Nil	30 -17⅝	11.31	218	3.1-1
1982	508	62	4.1	2.4	0.12	Nil	51⅛-10⅞	10.70	182	2.7-1
1981	396	100	80.6	48.8	2.45	Nil	67½-38⅝	16.17	291	5.5-1
1980	319	86	56.4	25.2	1.91	Nil	59⅞-22⅛	9.95	94	3.0-1
1979	232	66	42.8	25.2	1.47	Nil	26½-16⅝	7.83	67	2.9-1
1978	162	46	23.9	15.3	1.05	Nil	19⅞- 8⅝	6.19	51	3.0-1
1977	103	28	11.5	8.3	0.64	Nil	10½- 4½	4.26	25	2.5-1
1976	72	19	7.8	5.9	0.51	Nil	11½- 5⅞	3.64	23	3.0-1
1975	46	11	4.6	3.0	0.42	Nil	6½- 1½	2.13	16	3.4-1

Per sh. data adj. for 2-for-1 splits in 1980 & 1981.

DIGITAL EQUIPMENT CORP. — YEARS TO JUNE 30

Long-Term Debt: $841,313,000; Com., 58,048,905 Shs., $1 Par.

Year	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range	Book Value	†Net Wkg. Cap.	Curr. Ratio
1984	5,584	647	401	329	5.73	Nil	105⅝-70⅝	68.83	3,001	3.8-1
1983	4,272	566	411	284	5.00	Nil	132⅛-64	62.84	2,377	3.9-1
1982	3,881	737	673	417	7.53	Nil	115 -61⅝	57.30	2,182	4.1-1
1981	3,198	638	567	343	6.70	Nil	113⅛-80⅛	49.31	2,030	4.2-1
1980	2,368	453	410	250	5.45	Nil	98⅝-56⅝	36.25	1,659	4.5-1
1979	1,804	341	295	178	4.10	Nil	69½-48⅝	27.59	1,077	3.8-1
1978	1,437	288	228	142	3.40	Nil	54⅞-38½	22.69	887	4.9-1
1977	1,058	206	176	108	2.78	Nil	54 -36⅝	18.73	574	3.5-1
1976	736	139	119	73	1.98	Nil	60⅞-45⅛	15.61	498	4.3-1
1975	533	91	73	46	1.28	Nil	47 -15⅛	10.94	333	5.2-1

Per sh. data adj. for 3-for-1 split in 1976.

Computer manufacturers

FLOATING POINT SYSTEMS INC.

Long-term Debt: $3,092,000; Com., 8,108,714 shs., No Par.

¹YEARS TO OCT. 31

	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range (Calendar Yrs.)	Book Value	†Net Wkg. Cap.	Curr. Ratio Assets to Liabs.
	Million $				Common $ Per Share					
1984	118	26.5	23.2	15.2	1.77	Nil	38¾-12½	10.68	56.1	2.4-1
1983	100	24.3	21.1	13.1	1.47	Nil	44¾-25⅛	9.67	59.0	2.9-1
1982	86	19.3	18.0	11.5	1.32	Nil	30½-16	7.74	43.0	2.6-1
1981	57	11.7	10.6	6.3	0.81	Nil	29⅝-12½	6.14	34.0	2.6-1
1980	42	9.4	7.6	4.2	0.58	Nil	18 - 6	3.04	15.3	2.4-1
1979	29	4.6	3.5	2.0	0.27	Nil	8½- 4⅜	2.40	12.4	2.9-1
1978	25	5.5	4.4	2.4	0.42	Nil	13⅝- 5⅛	2.18	12.2	3.2-1
1977	9	2.7	2.4	1.3	0.26	Nil	......	0.33	1.8	1.4-1
1976	3	1.0	0.9	0.4	0.11	Nil	......	...	...	...
1975	1	Nil	Nil	0.0	d0.01	Nil	......	...	...	...

¹Yrs. end. Dec. 31 prior to 1977. Per sh. data adj. for stk. splits of 2-for-1 in 1981, 30-for-1 in 1978 & 100-for-1 in 1977.

HONEYWELL, INC.

Long-Term Debt: $665,600,000; Com., 45,965,290 Shs., $1.50 Par.

YEARS TO DEC. 31

	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range (Calendar Yrs.)	Book Value	†Net Wkg. Cap.	Curr. Ratio Assets to Liabs.
1984	6,074	761	431	335	7.14	1.90	67¾-46⅝	47.50	1,175	1.8-1
1983	5,753	660	315	231	5.03	1.80	69¾-41½	46.62	1,184	1.9-1
1982	5,490	634	384	271	6.05	1.75	52⅞-29⅞	44.55	1,167	1.9-1
1981	5,351	714	363	256	5.63	1.60	57⅝-34½	43.07	1,003	1.9-1
1980	4,925	678	443	281	6.29	1.40	57⅝-32⅝	39.76	1,009	1.9-1
1979	4,210	654	416	240	5.48	1.20	42¾-31⅝	34.97	843	1.9-1
1978	3,548	575	322	182	4.24	1.02½	36½-21½	30.61	611	1.7-1
1977	2,911	495	227	134	3.20	0.87½	27⅝-21⅝	28.69	590	1.9-1
1976	2,495	386	168	105	2.56	0.75	28⅛-16½	25.78	534	2.0-1
1975	2,291	322	100	76	1.95	0.70	20⅝-10½	23.84	474	2.1-1

Per sh. data adj. for 2-for-1 stk. split in 1984.

INTERNATIONAL BUSINESS MACHINES CORP.

Long-Term Debt: $3,269,000,000; Cap. Stk., 613,818,810 Shs., $1.25 Par.

YEARS TO DEC. 31

	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range (Calendar Yrs.)	Book Value	†Net Wkg. Cap.	Curr. Ratio Assets to Liabs.
1984	45,937	14,704	11,623	6,582	10.77	4.10	128½-99	41.79	10,735	2.1-1
1983	40,180	13,262	9,940	5,485	9.04	3.71	134¼-92¼	38.02	7,763	1.8-1
1982	34,364	11,199	7,930	4,409	7.39	3.44	98 -55⅝	33.13	4,805	1.6-1
1981	29,070	8,926	5,988	3,308	5.63	3.44	71½-48⅜	30.66	2,983	1.4-1
1980	26,213	8,102	5,897	3,562	6.10	3.44	72¾-50⅜	28.18	3,399	1.5-1
1979	22,863	7,215	5,553	3,011	5.16	3.44	80⅜-61⅛	25.64	4,406	1.7-1
1978	21,076	7,265	5,798	3,111	5.32	2.88	77½-58¾	23.14	4,511	1.8-1
1977	18,133	6,463	5,092	2,719	4.58	2.50	71½-61⅛	21.39	4,864	1.9-1
1976	16,304	5,786	4,519	2,398	3.99	2.00	72⅛-55⅞	21.15	5,838	2.4-1
1975	14,436	5,103	3,720	1,989	3.34	1.62½	56⅞-39⅝	19.05	4,751	2.4-1

Per sh. figs. adj. for stock splits of 4-for-1 in 1979.

NCR CORP.

Long-Term Debt: $247,699,000; Min. Int., $74,639,000; Com., 101,977,507 Shs., $5 Par.

YEARS TO DEC. 31

	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range (Calendar Yrs.)	Book Value	†Net Wkg. Cap.	Curr. Ratio Assets to Liabs.
1984	4,074	772	572	343	3.30	0.80	33 -20½	19.63	1,133	2.0-1
1983	3,731	723	523	288	2.64	0.65	34⅛-20½	18.16	1,146	2.1-1
1982	3,526	634	435	234	2.19	0.60	24⅝- 9¾	16.92	1,145	2.2-1
1981	3,433	586	363	208	1.93	0.55	18⅞- 9⅞	16.17	1,073	2.0-1
1980	3,322	683	469	255	2.38	0.50	20⅝-12⅞	14.72	1,037	1.9-1
1979	3,003	626	449	235	2.20	0.40	20½-14¼	12.98	982	2.0-1
1978	2,611	561	365	194	1.81	0.25	16⅞- 9¼	12.35	966	2.2-1
1977	2,521	498	269	143	1.34	0.20	11⅞- 8	9.69	865	2.2-1
1976	2,312	361	173	90	0.88	0.18	9½- 5⅞	8.54	775	2.1-1
1975	2,165	316	123	65	0.68	0.18	9⅞- 3⅝	8.29	707	2.1-1

Per sh. data adj. for 4-for-1 stk. split in 1984.

*Before depreciation. d—Deficit. †In millions of dollars. P—Preliminary.

Computer manufacturers

SPERRY CORP.

Long Term Debt: $687,800,000; Com., 55,177,354 Shs., $0.50 Par.

¹YEARS TO MAR. 31

	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range (Calendar Yrs.)	Book Value	†Net Wkg. Cap.	Curr. Ratio Assets to Liabs.
	Million $				Common $ Per Share					
1983	4,914	638	304	200	3.86	1.92	47⅞-31⅞	51.57	1,083	1.7-1
1982	5,076	563	164	118	2.65	1.92	35¼-20½	52.68	795	1.5-1
1981	5,571	801	355	222	5.25	1.88	65⅝-29½	55.21	843	1.5-1
1980	5,427	891	541	313	7.68	1.71	63⅝-41⅜	56.81	1,192	1.7-1
1979	4,785	780	507	277	7.60	1.50	52⅝-42¼	51.01	958	1.7-1
1978	4,179	666	441	224	6.35	0.99	49⅝-32⅜	46.13	803	1.6-1
1977	3,649	571	344	176	5.08	1.07	43⅛-29⅝	41.30	759	1.7-1
1976	3,270	512	301	156	4.51	0.88	51¾-38⅞	37.34	818	2.0-1
1975	3,202	501	277	145	4.19	0.76	48⅝-25⅝	33.75	687	1.9-1
1974	3,040	460	243	125	3.63	0.73½	44⅝-23⅛	30.70	617	1.7-1

¹Of foll. cal. yr.

Peripherals, components & subsystems

SEAGATE TECHNOLOGY

Long-Term Debt: $11,091,000; Com., 43,840,187, No Par.

YEARS TO JUNE 30

	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range (Calendar Yrs.)	Book Value	†Net Wkg. Cap.	Curr. Ratio Assets to Liabs.
1984	344	63.6	65.3	42.0	0.95	Nil	17 - 4	3.74	96.3	4.1-1
1983	110	18.8	18.5	13.1	0.33	Nil	22⅞- 8¼	2.76	82.7	4.0-1
1982	40	10.7	12.7	6.9	0.19	Nil	12½- 4⅜	0.96	29.3	5.4-1
1981	10	0.9	2.9	1.7	0.06	Nil	8⅞- 5	0.09	1.0	1.2-1
1980	Nil	d0.7	d0.3	d0.3	d0.02	Nil		NM	0.7	2.6-1

Per sh. data adj. for 2-for-1 stk. split in 1983.

Peripheral equipment

STORAGE TECHNOLOGY CORP.

Long-Term Debt: $348,638,000; Com., 34,568,183 Shs., $0.10 Par.

YEARS TO DEC. 31

	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range (Calendar Yrs.)	Book Value	†Net Wkg. Cap.	Curr. Ratio Assets to Liabs.
1983	887	97	d32	d9.4	d0.28	Nil	25 -13½	14.06	352	2.3-1
1982	1,079	198	99	63.3	1.84	Nil	36⅞-16¼	15.44	313	2.4-1
1981	922	218	129	82.4	2.61	Nil	40⅝-17¾	13.44	224	1.8-1
1980	603	135	77	45.4	1.76	Nil	26 -11⅞	9.07	227	2.5-1
1979	479	112	69	39.7	1.58	Nil	23⅝-13¼	6.33	111	2.0-1
1978	300	77	50	26.8	1.15	Nil	19½- 4⅝	4.69	54	1.6-1
1977	162	40	21	11.4	0.60	Nil	5⅝- 2½	2.99	32	1.8-1
1976	121	32	13	7.6	0.42	Nil	3⅛- 2	2.39	36	3.0-1
1975	98	25	10	5.7	0.32	Nil	4 - 1¼	2.01	31	2.4-1
1974	78	22	10	5.2	0.33	Nil	3⅛- 1¼	1.70	30	2.4-1

Per sh. data adj. for stk. divs. of 6% in 1976 and 1977, 5% in 1975 & 2-for-1 splits in 1978 & 1979.

Software, EDP services & systems

ASK COMPUTER SYSTEMS INC.

Long-term Debt: $976,000; Com., 11,660,000 shs., No Par.

YEARS TO JUNE 30

	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range (Calendar Yrs.)	Book Value	†Net Wkg. Cap.	Curr. Ratio Assets to Liabs.
1984	65.1	12.8	10.9	6.14	0.53	Nil	20⅛-13	3.13	28.8	3.0-1
1983	39.4	6.7	6.6	3.91	0.35	Nil	21¼-11⅞	2.49	21.7	3.4-1
1982	22.8	3.5	4.2	2.34	0.24	Nil	13½- 5⅛	1.40	11.4	3.1-1
1981	13.0	2.6	2.7	1.49	0.19	Nil	8½- 5½	0.35	2.0	1.5-1
1980	8.3	1.8	1.9	0.99	0.14	Nil	......	0.18	1.0	1.5-1
1979	2.8	0.4	0.4	0.24	0.03	Nil	......	0.04	...	...
1978	0.5	...	Nil	Nil	Nil	Nil	......	0.01	...	...
1977	0.3	...	Nil	0.03	0.01	Nil	......	...	...	...

Per sh. data adj. for 3-for-2 stk. split in 1981 & 2-for-1 in 1983.

Software, EDP services & systems

AUTOMATIC DATA PROCESSING, INC.

YEARS TO JUNE 30

Long-Term Debt $74,476,000; Com., 35,297,065 Shs., $0.10 Par.

	Net Sales	*Oper. Inc.	Net Bef. Taxes	Net Income	Earns.	Divs.	Price Range (Calendar Yrs.)	Book Value	†Net Wkg. Cap.	Curr. Ratio Assets to Liabs.
	Million $				Common $ Per Share					
1984	889	215	133	75.1	2.14	0.57½	40⅝-29½	10.81	88	1.5-1
1983	753	179	115	64.5	1.86	0.51½	44½-32⅞	9.93	104	1.9-1
1982	669	160	107	57.8	1.71	0.45½	38 -20⅝	8.30	84	1.8-1
1981	558	138	89	47.4	1.51	0.39½	31⅛-23⅜	7.23	102	2.3-1
1980	455	111	76	40.1	1.31	0.33½	26½-16⅝	5.12	57	1.8-1
1979	371	90	64	33.2	1.11	0.27½	20½-14⅜	4.52	38	1.7-1
1978	299	72	54	27.4	0.92	0.21½	18⅝-11½	3.73	30	1.6-1
1977	245	58	45	23.3	0.79	0.14	15⅝-10⅞	3.35	36	2.2-1
1976	187	43	34	17.6	0.63	0.10½	17⅞-12½	2.65	34	2.2-1
1975	154	33	27	13.8	0.50	0.05	16⅝- 6⅞	2.29	34	2.9-1

Per sh. data adj. for splits of 2-for-1 in 1976 & 1981.

COMPUTER SCIENCES CORP.

[1]YEARS TO MAR. 31

Long-Term Debt: $41,823,000; Com., 13,689,238 Shs., $1 Par

1983	712	54.2	30.5	18.3	1.32	Nil	23 -15½	10.31	78	1.4-1
1982	695	64.0	32.5	17.9	1.32	Nil	21 -11⅞	8.92	62	1.4-1
1981	630	52.0	33.6	17.8	1.31	Nil	24⅝-11⅛	7.57	44	1.3-1
1980	601	63.6	47.1	24.7	1.82	Nil	29⅜-14⅞	6.22	53	1.4-1
1979	453	56.4	43.2	22.7	1.70	Nil	19⅝-10½	4.39	53	1.4-1
1978	343	43.2	28.4	14.2	1.07	Nil	17 - 8	3.41	49	1.6-1
1977	276	39.4	26.0	13.8	1.00	Nil	9⅝- 6⅝	2.39	40	1.7-1
1976	234	34.4	21.2	11.6	0.81	Nil	8 - 4	2.15	44	2.2-1
1975	219	26.9	14.4	7.2	0.51	Nil	6⅝- 1⅜	1.40	30	1.8-1
1974	177	20.3	7.2	3.6	0.26	Nil	4⅛- 1½	0.91	24	1.9-1

[1]Of the following calendar yr.

CULLINET SOFTWARE INC.

[1]YEARS TO APRIL 30

Long-term Debt: None; Com., 14,865,565 shs., $0.10 Par

1983	120	30.8	29.7	16.5	1.09	Nil	50½-23⅝	5.05	52.8	2.3-1
1982	78.6	19.7	20.8	11.6	0.81	Nil	27½-11	4.27	47.5	2.9-1
1981	49.3	11.8	14.2	7.6	0.56	Nil	18⅝- 8⅝	2.50	25.6	3.1-1
1980	29.4	7.0	8.3	4.5	0.37	Nil	10 - 3⅝	2.09	23.6	3.7-1
1979	20.0	4.0	4.2	2.4	0.22	Nil	3⅝- 2⅛	0.75	5.7	2.4-1
1978	13.9	2.8	3.0	1.6	0.16	Nil	3⅞- 1⅛	0.59	5.6	4.3-1
1977	8.9	1.9	1.9	1.0	0.12	Nil	...	...	...	...
1976	5.3	0.8	0.8	0.5	0.07	Nil	...	...	...	...
1975	3.4	0.4	0.4	0.2	0.04	Nil	...	...	...	...

[1]Of fol. cal. yr. Per sh. data adj. for 2-for-1 stk. splits in 1983, 1981 & 1980, and 3-for-1 in 1977.

HBO & CO.

[1]YEARS TO DEC. 31

Long-term debt: $3,489,000; Com., 23,500,000 shs., $0.05 Par

1984	88.7	32.7	23.2	13.9	0.86	0.14⅛	25 -15⅝	2.98	24.3	3.4-1
1983	67.6	25.0	16.1	10.0	0.61	0.06⅝	29⅞-15	2.47	12.0	2.6-1
1982	55.6	21.2	13.4	7.5	0.46	0.05	17⅞- 8⅜	2.11	9.5	2.7-1
1981	38.9	15.5	8.9	5.0	0.33	0.01⅛	10⅝- 6⅝	1.67	6.8	1.9-1
1980	29.4	12.4	5.6	3.0	0.23	Nil	...	0.50	1.4	1.4-1
1979	21.0	8.8	4.4	2.4	0.17	Nil	...	0.25	0.7	1.3-1
1978	13.0	5.3	2.7	1.6	0.11	Nil	...	...	...	...

Per sh. data adj. for 3-for-2 stk. splits in 1984, 1983 & 1982. [1]Prior to 1983 yr. end March 31.

*Before depreciation. d—Deficit. †In millions of dollars. P—Preliminary.

Software & EDP services

REYNOLDS & REYNOLDS CO. (THE)

YEARS TO SEPT. 30

Long-Term Debt: $6,879,573; Com., 4,460,116 Shs., Cl. A, $1.25 Par; 4,374,640 Shs., Cl. B, $0.06¼ Par.

1984	290	44.0	29.7	17.1	3.61	1.08	40¼-26	21.10	35.4	1.8-1
1983	252	33.3	19.8	11.9	2.51	1.08	52½-30⅝	18.91	39.9	2.4-1
1982	221	23.3	11.7	7.8	1.66	1.08	30⅝-17⅜	17.46	38.2	2.7-1
1981	212	28.6	13.4	7.1	1.51	1.08	24⅝-16⅛	16.97	43.4	2.8-1
1980	210	33.4	20.7	11.0	2.33	1.08	30½-19⅜	16.54	49.8	3.0-1
1979	181	38.4	28.0	14.8	3.15	0.88	33½-25½	15.29	42.8	2.8-1
1978	140	31.7	22.4	11.9	2.56	0.72	35½-17⅜	13.01	31.3	3.0-1
1977	114	25.9	18.6	9.8	2.11	0.60	21⅛-16½	11.15	28.4	3.3-1

UCCEL CORP.

YEARS TO DEC. 31

Long-term Debt: $13,465,000; Com., 16,223,080 shs., $0.10 Par.

1984	173	20.2	13.9	7.9	0.49	Nil	12½- 7⅝	4.01	58	2.2-1
1983	153	6.4	0.5	0.2	0.01	Nil	17⅝- 9	3.60	66	2.8-1
1982	141	10.3	6.5	4.1	0.30	Nil	13⅞- 7⅛	3.43	43	2.7-1
1981	147	15.2	10.5	6.0	0.44	Nil	16⅝- 6½	3.84	51	3.0-1
1980	118	16.3	11.0	6.1	0.50	Nil	20⅛- 5⅝	2.44	42	2.4-1
1979	87	13.8	7.4	4.7	0.40	Nil	7⅝- 4	0.31	13	1.8-1
1978	77	10.9	4.8	2.6	0.26	Nil	7½- 2	d0.25	4	1.2-1
1977	69	7.9	d2.6	d4.9	d2.36	Nil	9½- 2⅜	d48.36	d0	1.0-1
1976	62	5.4	d3.7	d5.7	d2.76	Nil	27½- 4½	d46.24	d106	0.2-1
1975	63	d7.9	d20.3	d20.5	d9.88	Nil	18½- 6½	d12.13	d41	0.6-1

Per sh. data adj. for 1-for-4 reverse split in 1978.

Copying & office equipment

BELL & HOWELL CO.

YEARS TO DEC. 31

Long-Term Debt: $89,431,000; Com., 7,923,321 Shs., No Par.

1984	714	54.3	46.7	33.0	3.04	0.51½	30½-19⅛	26.52	170	2.0-1
1983	679	50.2	41.6	24.6	2.15	0.49	28⅜-12⅞	32.26	163	1.9-1
1982	612	47.0	31.3	18.5	1.65	0.48	16⅞-8⅞	14.71	108	1.8-1
1981	701	44.0	26.9	17.3	1.53	0.48	15⅝-8⅝	15.87	151	2.0-1
1980	640	50.4	31.9	19.2	1.71	0.48	17⅛-9	15.29	160	2.2-1
1979	538	44.8	27.5	16.8	1.51	0.48	12⅛-7½	13.56	146	2.4-1
1978	568	34.0	19.3	12.3	1.10	0.43½	11⅝-6⅞	16.67	168	2.4-1
1977	491	37.1	23.0	11.8	1.03	0.42	11½-7½	15.72	160	2.3-1
1976	437	39.3	27.3	4.0	1.11	0.42	12⅞-7½	15.09	162	3.1-1
1975	374	34.6	27.8	d5.8	1.10	0.42	11½-5⅛	15.36	126	2.1-1

Per sh. data adj. for 2-for-1 stk. split in 1983.

PITNEY BOWES, INC.

YEARS TO DEC. 31

Long-Term Debt: $134,729,000; Com., 35,696,684 Shs., $2 Par.

1984	1,732	282	227	138	3.51	1.04	36⅛-26½	16.28	181	1.3-1
1983	1,606	258	206	118	3.01	0.89	36½-21	13.75	176	1.3-1
1982	1,455	198	135	83	2.16	0.80	24⅞-10⅞	12.16	208	1.5-1
1981	1,414	195	126	69	1.89	0.80	17⅝-11	10.75	191	1.5-1
1980	1,257	195	132	75	2.16	0.72½	20⅛-14⅛	9.38	176	1.4-1
1979	1,025	174	118	63	2.01	0.62½	16⅝-11½	7.95	181	1.6-1
1978	711	137	89	45	1.66	0.52½	14½- 9⅛	8.49	102	1.5-1
1977	605	114	73	37	1.35	0.42½	10⅝- 7⅝	7.31	124	1.7-1
1976	539	88	55	20	1.15	0.34	9 - 6⅞	6.37	117	1.8-1
1975	460	76	47	25	0.98	0.30	10⅛- 5⅝	5.96	119	1.9-1

Per sh. data adj. for 2-for-1 stk. split in 1983.

Copying & office equipment

SAVIN CORP.

¹YEARS TO APR. 30

Long-Term Debt: $147,748,000; Com., 19,747,769 Shs., $0.10 Par

1983	385	d7.0	d61.0	d58.9	d4.09	Nil	9¾- 5	3.71	60	1.5-1
1982	416	18.3	d38.2	d21.1	d1.52	Nil	10⅛- 4⅜	7.04	117	2.2-1
1981	464	48.6	d58.7	d32.2	d4.77	0.17	15¼- 7	6.16	131	2.1-1
1980	435	43.9	d5.9	d2.2	d0.52	0.61	19 -11⅜	14.03	117	1.9-1
1979	357	65.8	47.2	28.3	4.35	0.70	19¾-12⅝	15.21	108	2.3-1
1978	291	58.1	57.7	32.3	4.55	0.47½	24¼-11⅜	11.94	104	3.1-1
1977	221	49.5	50.0	26.0	3.71	0.35	25 - 9⅛	7.96	45	1.9-1
1976	127	18.0	19.8	10.6	1.57	0.08¾	9¾- 3½	4.33	25	2.0-1
1975	64	1.4	4.1	2.7	0.44	Nil	3¼- ⅞	2.75	19	2.2-1
1974	52	d2.7	3.2	1.6	0.27	Nil	3 - 3¾	2.27	12	1.6-1

¹Of foll. cal. yr. Per sh. data adj. for 2-for-1 stock split in 1977.

XEROX CORP.

YEARS TO DEC. 31

Long-Term Debt: $1,614,300,000; Min. Int., $440,900,000; Com., 95,849,139 Shs., $1 Par

1984	8,792	1,557	614	376	3.42	3.00	51⅛-33¼	42.77	1,288	1.5-1
1983	8,464	1,444	667	466	4.35	3.00	52⅛-35	44.40	1,349	1.6-1
1982	8,456	1,654	614	368	4.34	3.00	41¾-27⅛	43.96	1,639	1.8-1
1981	8,691	2,071	1,180	598	7.08	3.00	64 -37⅜	44.11	1,535	1.7-1
1980	8,196	2,155	1,351	619	7.33	2.80	71¾-48⅝	42.90	1,531	1.8-1
1979	7,027	2,054	1,283	563	6.69	2.40	69⅛-52½	38.29	1,425	1.8-1
1978	5,902	1,807	1,067	465	5.77	2.00	64 -40½	34.59	1,228	1.9-1
1977	5,076	1,599	917	406	5.06	1.50	58¾-43⅛	31.50	1,099	1.9-1
1976	4,403	1,485	804	358	4.51	1.10	68⅝-48¾	28.04	973	1.9-1
1975	4,053	1,396	788	244	3.07	1.00	87⅝-46⅛	24.52	571	1.5-1
1974	3,576	1,335	761	331	4.18	1.00	127⅛-49	22.40	592	1.6-1

Desktop computers

APPLE COMPUTER INC.

YEARS TO SEPT. 30

Long-Term Debt: None, Com., 60,724,449 Shs., No Par

1984	1,516	129	109	64.1	1.05	Nil	34⅛-21¾	7.67	433	2.7-1
1983	983	152	146	76.7	1.28	Nil	63¼-17¼	6.38	340	3.6-1
1982	583	119	117	61.3	1.06	Nil	34⅛-10⅜	4.50	231	3.7-1
1981	335	75	77	39.4	0.70	Nil	34½-14¼	3.14	156	3.2-1
1980	117	25	24	11.7	0.24	Nil	36 -22	0.42	42	1.4-1
1979	48	10	10	5.1	0.12	Nil	...	0.22	d17	1.8-1
1978	8	2	2	0.8	0.03	Nil	...	...	...	...

COMPAQ COMPUTER CORP.

YEARS TO DEC. 31

Long-Term Debt: None; Com., 26,180,378 shs., $0.01 Par

1984	...	...	...	...	0.47	Nil	14⅝- 3½	...		
1983	111	4.7	4.9	2.6	0.13	Nil	12⅜-10⅞	NM	74.6	4.0-1
1982	NM	...	d4.6	d4.6	d1.48	Nil	...	NM	3.5	3.6-1

Desktop computers

COMMODORE INTERNATIONAL LTD.

YEARS TO JUNE 30

Long-Term Debt: $127,600,000; Com., 31,252,534 Shs., $1 Par

1984	1,267	264	225	144	4.66	Nil	49⅜-16¼	10.56	304	2.1-1
1983	681	135	113	88.0	2.86	Nil	60⅝-29¼	6.23	205	1.6-1
1982	305	64	50	40.6	1.32	Nil	42⅝-11⅝	3.50	98	2.2-1
1981	187	39	30	24.9	0.81	Nil	17⅞- 8	2.04	61	2.2-1
1980	126	25	18	16.2	0.52	Nil	18 - 2½	1.20	37	2.3-1
1979	71	12	8	6.0	0.21	Nil	3⅜- ⅞	0.65	11	1.4-1
1978	50	7	5	3.4	0.12	Nil	1⅛- ¾	0.44	7	1.4-1
1977	46	4	2	1.5	0.06	Nil	1 - ⅝	0.30	5	1.3-1
1976	56	4	3	1.7	0.07	Nil	½- ¼	0.24	4	1.3-1
1975	56	d3	d5	d4.4	d0.17	Nil	⅝- ⅛	0.14	1	1.1-1

Per sh. data adj. for stock splits of 2-for-1 in 1983, 3-for-1 in 1980, 3-for-2 in 1982, 1980 & 1979.

Engineering workstations & subsystems

APOLLO COMPUTERS INC.

YEARS TO DEC. 31

Long-Term Debt: None; Com., 30,411,871 shs., $0.02 Par

1984	216	46.4	40.5	23.9	0.75	Nil	29¼-15¾	5.04	122.2	3.9-1
1983	80	16.1	17.2	11.2	0.37	Nil	33⅜-14⅝	2.55	58.6	4.4-1
1982	18	0.9	0.3	0.3	0.01	Nil	...	0.45	8.2	2.5-1
1981	3	d3.3	d3.0	d3.0	d0.46	Nil	...	0.18	5.7	5.6-1
1980	NM	d1.2	d1.1	d1.1	d0.25	Nil	...	0.05	...	...

Per sh. data adj. for 3-for-2 stk. split in 1984.

DAISY SYSTEMS CORP.

YEARS TO SEPT. 30

Long-Term Debt: $667,000; Com., 16,943,669 Shs., $0.01 Par

1984	69.1	19.0	19.4	11.0	0.73	Nil	28½-17½	3.54	39.4	4.2-1
1983	17.5	2.7	3.3	2.3	0.17	Nil	27 -14	2.75	37.1	10.8-1
1982	4.6	0.3	0.2	0.1	0.01	Nil	...	0.54	7.7	10.3-1
1981	NM	NM	d0.8	d0.8	d0.29	Nil	...	NM	1.1	9.0-1

INTERGRAPH CORP.

YEARS TO DEC. 31

Long-Term Debt: $10,525,000; Com., 25,701,056 Shs. $0.10 Par

1984	404	116	110	62.9	2.44	Nil	57¾-32¾	9.04	178	2.6-1
1983	252	59	57	29.3	1.16	Nil	51⅛-22⅝	6.35	109.9	2.4-1
1982	156	28	25	13.0	0.56	Nil	25⅝- 7⅝	2.82	39.8	1.8-1
1981	91	16	16	8.3	0.38	Nil	16½- 9	2.19	38.2	2.3-1
1980	57	10	8	4.6	0.25	Nil		0.74	10.1	1.5-1
1979	30	5	4	2.5	0.15	Nil		0.38	4.2	1.4-1
1978	20	3	2	1.4	0.09	Nil		0.21	...	...

Per sh. data adj. for 2-for-1 stk. split in 1983.

Glossary of terms

Application software—Computer programs designed to accomplish user tasks. As opposed to operating software, which directs the operations of the computer.

Artificial intelligence (AI)—Technologies, including both hardware and software, designed to emulate some aspect of human thinking.

Batch processing—Running more than one algorithm or job during a single computer run.

Bit—A "binary digit" that takes on the value 0 or 1. The most basic building block of computer communication, it can be represented by the two electrical states on and off (or charge and no charge, or positive and negative).

Byte—A group of bits (usually eight) which the computer operates on as a unit.

C—A high-level programming language which reputedly is as efficient as assembly language. Was developed by AT&T's Bell Labs as the systems programming language of the *UNIX* operating system on the DEC *PDP-11*.

Central processing unit (CPU)—The heart of a computer. Consists of storage elements called registers, the arithmetic and logical unit (ALU), and the control unit (CU).

Chip—A rectangular piece of silicon on which one or more circuits are implanted.

Compatibility—The ability of a computer to operate and share data and programs with different models from the same manufacturer or with computers from other vendors. Also a computers ability to work with peripheral devices.

Compiler—A computer program that converts a high-level programming language into binary or machine code.

Computer-aided design/Computer-aided manufacturing (CAD/CAM)—Uses computer hardware and software to help design parts and machinery, generate schematics, diagram complex wiring arrangements and printed circuit boards, and automate other aspects of manufacturing.

Control unit (CU)—The part of the CPU which controls the flow of operations and data between the ALU and main memory.

Database management software—Software that allows the storage and manipulation of large sets of related data.

Disk—A circular plate coated with magnetic material on both sides, used for random-access mass storage of data or programs.

Disk drive—The peripheral device on which a disk resides and from which information is retrieved or entered into disk storage. Used in all sizes of computers.

Expert system—A computer program designed to act as an "expert" in a particular topic, by capturing the logic and rules of thumb that human experts apply to that topic.

Hard disk—A rigid storage disk permanently housed in a disk drive (or in a cassette which is inserted into the drive). Typically has a larger capacity than floppy disks, but is less portable.

Hardware—Physical components of a computer system, such as CPUs and I/O and storage devices, as opposed to the software that makes a system run.

Input/output (I/O) **device**—A peripheral capable of performing input and output functions.

Integrated circuit—A system of interconnected conductors and related electronic components of a transistor on a semiconductor chip.

Integrated software package—Applications software designed to perform a combination of functions, such as word processing, spreadsheet analysis, graphics, and data communication, and to allow the easy transfer of data and program output among the various functions.

Integrated systems—The integration of hardware, peripherals, and operating and applications software into a single, coherent system designed (often customized) for a particular user's needs. Integrated systems are beginning to include the integration of data and voice communications and networking capabilities.

K—One kilobyte (1,024 bytes) of information; unit in which the size of a computer's memory is measured.

LISP—A high-level programming language designed to handle symbols rather than numerical relationships.

Main memory—The fastest-access storage in a computer, used to store programs and data used in the CPU (e.g., magnetic core and LSI circuits).

Mass memory—The slowest and least costly form of memory. Used to store data and programs "off-line" when they are not being used, usually on magnetic tape or floppy disks.

Microprocessor—A central processor unit on a single integrated circuit chip.

MS/DOS—Microsoft's disk operating system, the standard operating system used by 16-bit microcomputers.

Multitasking—A combination of software and hardware which allows a CPU to run more than one job "simultaneously."

Multiuser—Describes CPUs that can be used simultaneously by several users.

Network—A means of interconnecting several CPUs and peripherals so they can interchange data and share resources such as databases or printers. Also, a system of networked hardware and the software which allows the interconnection.

Operating systems—Software containing routines to carry out simple housekeeping chores such as input/output procedures, sort-merge and data-conversion routines, or tests. Often referred to as the CPU's "traffic cop."

Original equipment manufacturer (OEM)—Illogically refers to a vendor who assembles computer systems from components originally manufactured by other suppliers. The original manufacturers are sometimes described as "selling their products OEM" to the vendor who assembles the system.

Parallel processing—Simultaneous processing of several pieces of data by two or more CPUs in a single computer.

Peripherals—Computer components—such as input, output, and auxiliary storage devices—that support the activities of the CPU.

Pipelining—Carrying out operations in a computer in an "assembly line" fashion.

Plug-compatible manufacturer (PCM)—A manufacturer of peripherals (including main memory) that are "plug-compatible" with IBM computers (that is, can be plugged into them) or CPUs that can run programs written for an IBM system with little or no modification.

Portability—The ability of a program written for one computer to be run on another.

Program—the sequence of instructions that directs a computer to accomplish a task such as updating a database or calculating and printing out the current month's statements for the customers of a bank.

Random Access Memory (RAM)—Main memory in a computer which can read from or be written on by the user, and which is lost when the electric current is turned off.

Read-only memory (ROM)—Memory which cannot be written on by the user. The programs in this memory do not disappear when the power is shut off.

Real-time systems—Systems in which the computer must perform its tasks within the time constraints of some process, or simultaneously with another systems, or fast enough to keep up with the person interacting with it.

Semiconductor—A solid state (no moving parts or electron tubes) device that controls the flow of electricity. The term comes from the electrical properties of the silicon from which many of these products are made. Silicon acts as a conductor of electricity at certain times and as an insulator at others.

Software—Computer programs which either direct the operation of the computer or accomplish user tasks.

Spreadsheet package—An application package that allows the user to perform financial or other analysis of data which historically have been done with pencil on a paper "spreadsheet."

Terminal—An I/O device which allows on-line communication (interaction) between the computer and the user.

Time sharing—The use of a single computer by two or more users during the same time interval. The computer appears to serve both users simultaneously, but actually switches between them at high speeds.

UNIX—An operating system, developed by AT&T's Bell Labs which has multiuser, multitasking, and networking capabilities.

Value-Added Reseller (VAR)—a vendor who assembles hardware components into a computer system, "adds value" to it by installing software (often customized), and resells it to the final purchaser.

Virtual memory—A technique that permits the user to treat disk storage as an extension of main memory.

Winchester—Trade name, now used generically, for a hard disk used as a storage device in microcomputers.

Xenix—Version of *UNIX* developed by Microsoft for use in IBM microcomputers.

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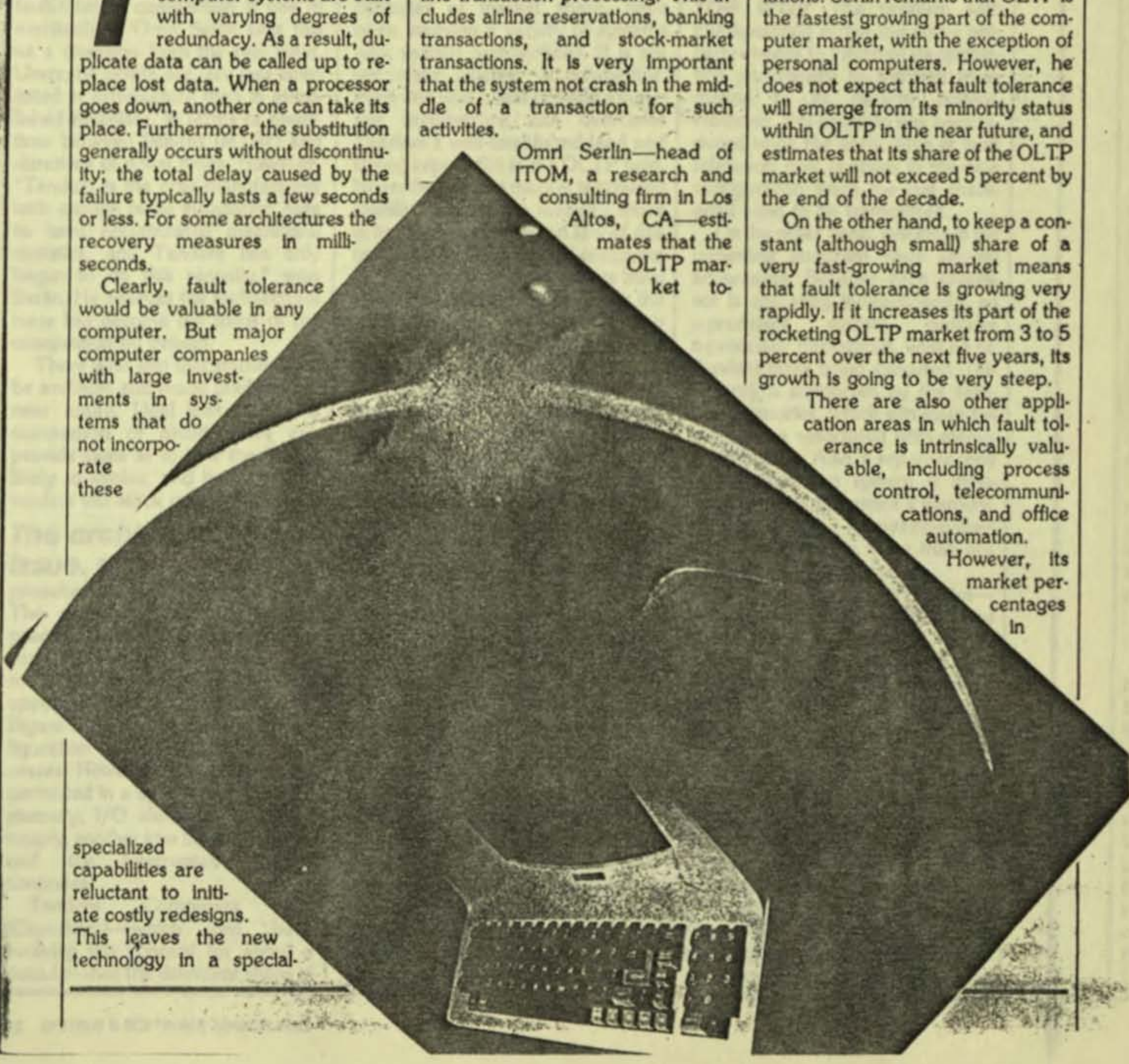
Fault-tolerant computers mature

MICHAEL CHESTER

To achieve fault tolerance, computer systems are built with varying degrees of redundancy. As a result, duplicate data can be called up to replace lost data. When a processor goes down, another one can take its place. Furthermore, the substitution generally occurs without discontinuity; the total delay caused by the failure typically lasts a few seconds or less. For some architectures the recovery measures in milliseconds.

Clearly, fault tolerance would be valuable in any computer. But major computer companies with large investments in systems that do not incorporate these



specialized capabilities are reluctant to initiate costly redesigns. This leaves the new technology in a specialized role with a relatively small market share, even in areas where it is most beneficial. So far, the biggest area for fault tolerance has been online transaction processing. This includes airline reservations, banking transactions, and stock-market transactions. It is very important that the system not crash in the middle of a transaction for such activities.

Omri Serlin—head of ITOM, a research and consulting firm in Los Altos, CA—estimates that the OLTP market totalled $22.5 billion in 1984. Fault-tolerant systems, he adds, came to a $700-million total, making up about 3 percent of the OLTP installations. Serlin remarks that OLTP is the fastest growing part of the computer market, with the exception of personal computers. However, he does not expect that fault tolerance will emerge from its minority status within OLTP in the near future, and estimates that its share of the OLTP market will not exceed 5 percent by the end of the decade.

On the other hand, to keep a constant (although small) share of a very fast-growing market means that fault tolerance is growing very rapidly. If it increases its part of the rocketing OLTP market from 3 to 5 percent over the next five years, its growth is going to be very steep.

There are also other application areas in which fault tolerance is intrinsically valuable, including process control, telecommunications, and office automation.

However, its market percentages in

these activities are still minimal.

From its small base, fault tolerance is working its way into the market. Specialized companies are building systems from the ground up with this capability. Also, some of the attributes of this technology are appearing in systems from large existing vendors and start-ups, in generalized architectures. This infiltration should do much to eventually move fault tolerance out of its specialized niche and into the mainstream of the market.

The present emphasis in the fault-tolerant competition is one of architecture. Omri Serlin sees this as a diversion from the real issue. Users, he points out, are less interested in architecture than in established reliability, in terms of meantime between failures (MTBF) and durations of down times. However, "Tandem is the only manufacturer with enough of an installation base to have accumulated meaningful statistics, and Tandem has only begun to do this recently," says Serlin. He believes the architectural issue has become the focus of the competition by default.

There is no sign that statistics will be available and made public in the near future. Until that occurs, a comparison of architectures can provide clues as to how the field is likely to evolve, and how the contenders will stack up.

The architectural issue. Several architectural approaches to fault tolerance exist. The most prevalent makes use process of loosely coupled processors, each with its own dedicated memory, corresponding to the upper-left quadrant in the matrix of Figure 1. All cpus in this kind of configuration run independent processes. However, if a failure is experienced in a cpu or its associated memory, I/O elements, or power supply, another cpu inherits its task, and the interrupted process continues.

Tandem Computers Inc. (Cupertino,)—which has been evolving this concept for about a decade—has the dominant share of the fault-tolerant market concentrating on OLTP, with an installated base of 5,000 to 10,000 systems. The nearest competitor's installations total in the hundreds, and many of the contenders are still in beta testing, or just starting to deliver their first systems.

The contending fault-tolerant systems in the OLTP arena are generally large—in the supermini or mainframe class—and support hundreds or sometimes thousands of terminals. Tandem's competitors, intending to claim significant percentages of market share, have been evolving a variety of systems with various architectures. It is not yet clear whether a competitor, even one who might provide a superior architecture, can overcome Tandem's well-established lead and strong reputation in the OLTP field. Nevertheless, the market is growing rapidly, and even a minority share in its revenues can mean lots of dollars. Also, as the personal computer and operating-system markets have shown, no matter how dominant the leader in a field may be, there is no guarantee that the company will stay in first place.

The challenges to Tandem embody a wealth of designs—both within the same generic approach Tandem has taken (i.e.: the upper-left-hand quadrant of Figure 1), and through entirely different approaches (the remaining quadrants).

It should be noted that some structural features of fault-tolerant systems are architecture-independent and are found in virtually all of these systems. Examples include redundant power supplies and, to protect the integrity of databases, the use of mirrored disk drives—paired drives with every write operation duplicated on the two drives.

A key issue in the upper-left-hand quadrant is how to keep processor B updated as to what processor A is doing, so that if A fails, B can take over with as little delay as possible to provide an environment of perpetual processing. The classical approach to this problem involves a procedure known as checkpointing. A processor periodically sends a copy of its data and stack to one or more designated backup processors. The data is stored in the backup processor's memory, but is not executed until there is an indication that the primary processor has failed. Therefore, the backup processor is not burdened with executing a redundant program, and is free to carry out other applications, which are backed up elsewhere in the complex.

Independent all the way The problem with checkpointing is that the active processor needs to interrupt its application periodically to transmit information to its backup system. However, this problem has been reduced since the early days of fault tolerance; only changes in the data configuration since the last checkpoint need to be transmitted.

On the other hand, systems in the upper-left quadrant have several advantages. Because each processor is operating independently, an n-processor system provides n-processor throughput, with no redundant tasks being executed. This linearity is supported by the separate memories, which eliminate the bottlenecks associated with memory contention. Also, a separate copy of the operating system is maintained in each processor's memory, so that a single operating-system bug cannot disable more than one processor and its memory.

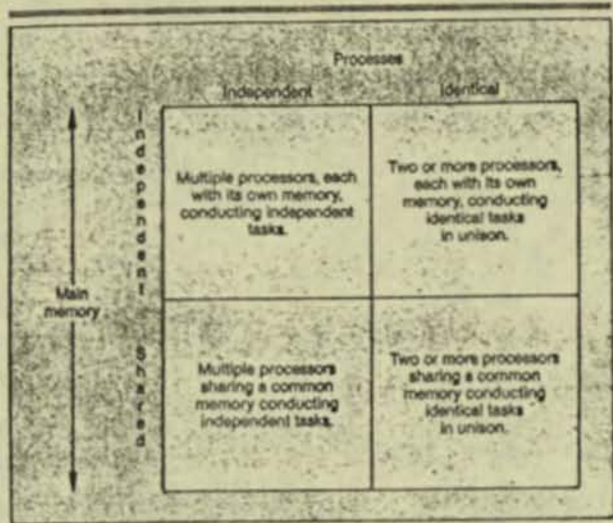
Tandem's NonStop series—including the 16-bit NonStop I and II, and the 32-bit NonStop TXP—exemplify this kind of design. The latest model, the TXP (Fig. 2), includes from 2 to 16 processors, which can be added in modular fashion. All the processors are connected by a set of dual high-speed buses, so that two independent, bidirectional paths link any pair of processors in the system. Each processor supports up to 32 I/O device controllers. The dual ports of these controllers continue the redundancy theme as each controller connects to two processors. Upon the failure of a processor or controller, the operating system will switch the dual-port access to reestablish a functioning processor-controller pair.

Some manufacturers have evolved methods within the independent-processor independent memory class of systems that require less overhead than classical checkpointing. Instead of receiving the complete image of the active process, a backup processor is given only the inputs to the process. These can be keyboard inputs or inputs from other parts of the system, such as disk drives. The incoming messages are preserved on a stack in the memories of the active and backup processors.

If a failure occurs, the backup processor has to pick up the process from the beginning to reexecute the program. This is because the primary processor's image has not been transferred. However, the backup processor doesn't have to await inputs because stacked inputs are available. In fact, because the inputs are accepted at chip-level speeds rather than at the slow rates characteristic of disk and keyboard inputs, the process runs faster than it did before the failure.

Nevertheless, the overall recovery period is greater than that of classical checkpointing because the backup process is unable to tap the relatively up-to-date image of the primary process. A tradeoff is involved. The stacking of inputs provides faster processing in the normal running condition than does classical checkpointing, but its recovery process is slower.

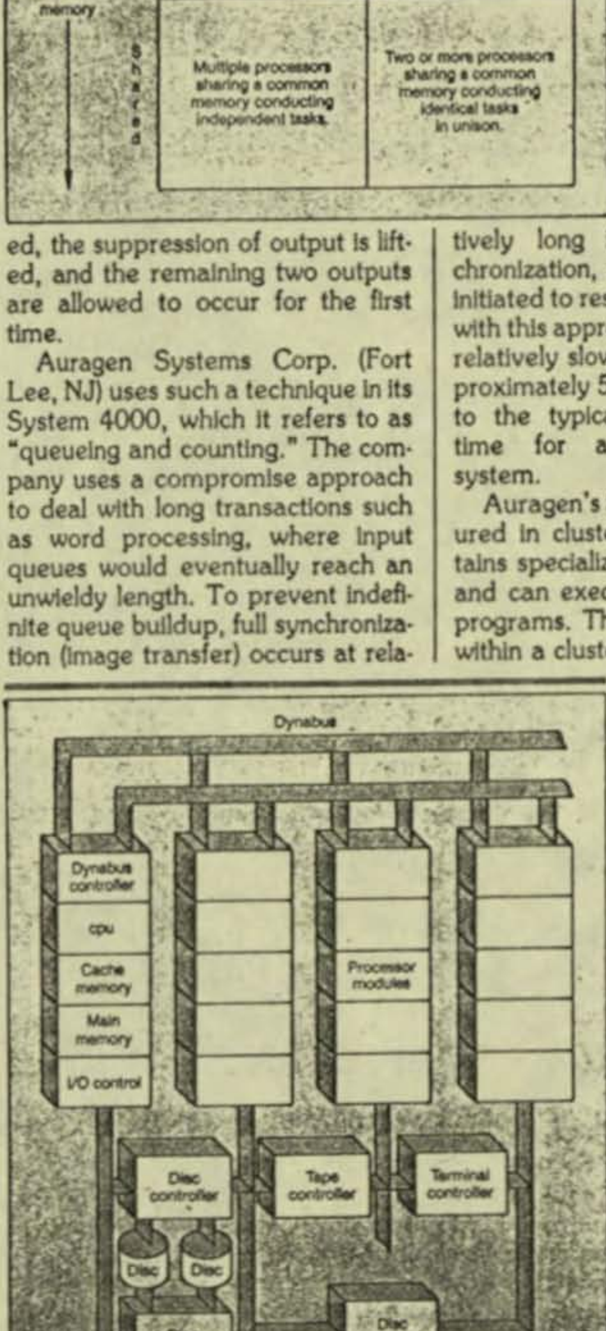
The input-stacking method also involves the counting of outputs. Suppose the initial process involves five outputs—for example, messages displayed on a screen, or funds added to or subtracted from an account. Assume that three outputs were executed prior to the fault. When the backup processor reruns the sequence, it must not repeat the first three outputs. Therefore, the system has to be able to count the outputs, suppressing the new ones that would be repeats. After the first three outputs have been counted, the suppression of output is lifted, and the remaining two outputs are allowed to occur for the first time.



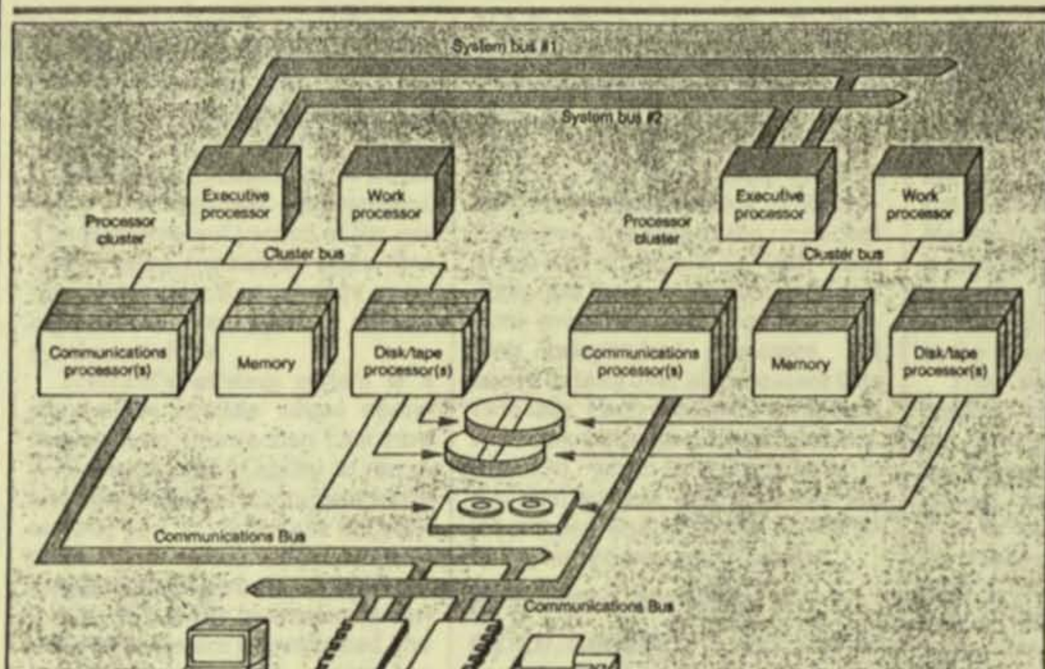
1. A 2-by-2 matrix describes the architectures used in fault-tolerant computers. No existing systems fall entirely in the lower-right-hand square of this matrix, nor are any likely to do so in the future. However, some mixed systems overlap this square, combining shared memory with lock-step processes as a facet of a more general architecture.

Auragen Systems Corp. (Fort Lee, NJ) uses such a technique in its System 4000, which it refers to as "queueing and counting." The company uses a compromise approach to deal with long transactions such as word processing, where input queues would eventually reach an unwieldy length. To prevent indefinite queue buildup, full synchronization (image transfer) occurs at relatively long intervals. After synchronization, new input stacks are initiated to restart the process. Even with this approach, the system has a relatively slow recovery time of approximately 5 seconds—in contrast to the typical 1-second recovery time for a full checkpointing system.

Auragen's System 4000 is configured in clusters. Each cluster contains specialized processors (Fig. 3) and can execute two simultaneous programs. There is no redundance within a cluster. Redundant backup



2. Tandem's NonStop TXP system illustrates a fault-tolerant system in which separate processors run independent applications using separate memories. When a processor fails, another can pick up its task.



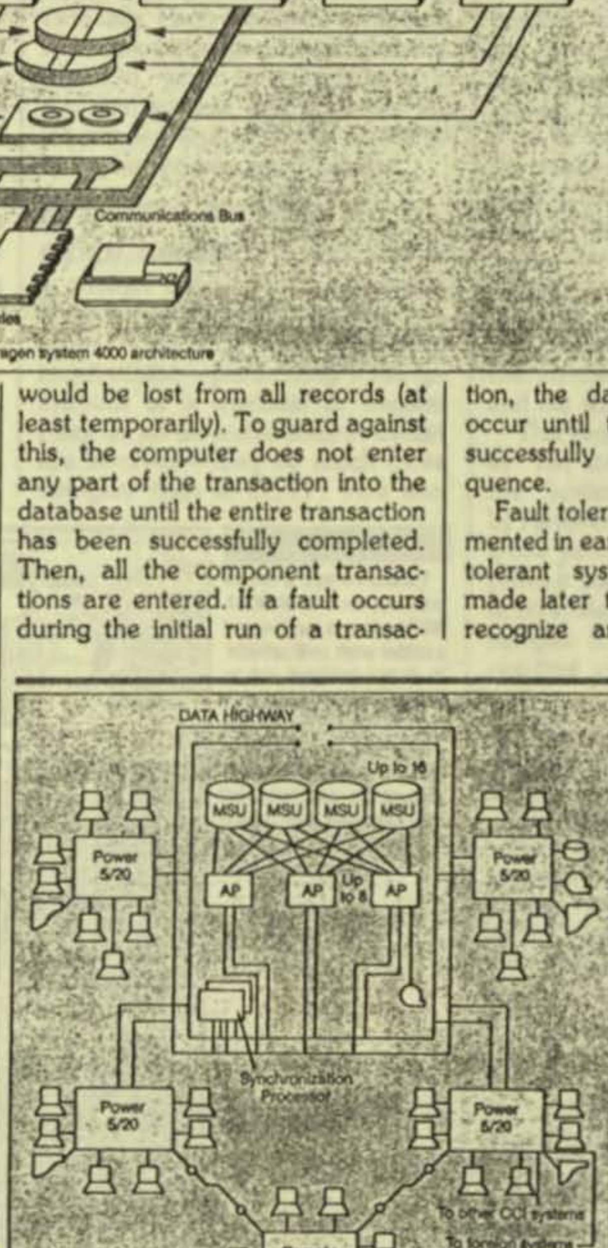
3. Each cluster in Auragen's System 4000 is a stand-alone system based on specialized processing modules. Separate clusters back each other up in the event of failure.

for any cluster is provided by another one. A system can consist of a single cluster without fault tolerance, or as many clusters as the user orders in fault-tolerant configurations altogether. (Auragen has installed 70 clusters.) The modular structure is expandable; a user can upgrade a system by adding more clusters. An entry system can be purchased for $68,000, and later expanded at $34,000 per cluster.

Other companies employ a purer form of queueing and counting, without periodic synchronization. These systems are designed strictly for shorter transactions where queue buildup is not a problem. Therefore, they can travel with a light software overhead. An example of this purer approach is the Power5/55 from Computer Consoles Inc. (Rochester, NY) (Fig. 4).

A key issue in OLTP for any system designed to recover from faults is protection of the database from an interrupted transaction. A typical example is a transfer of funds from one bank account to another. If a failure occurred after the withdrawal from the first account, but before the deposit into the second, a discrepancy would result. The funds would be lost from all records (at least temporarily). To guard against this, the computer does not enter any part of the transaction into the database until the entire transaction has been successfully completed. Then, all the component transactions are entered. If a fault occurs during the initial run of a transaction, the database entries never occur until the backup processor successfully runs the whole sequence.

Fault tolerance is typically implemented in early versions of the fault-tolerant system, with provisions made later to enable the logic to recognize and abort incomplete



4. Each application processor (AP) in the Power5/55 from Computer Consoles connects to each mass-storage unit (MSU). The input messages of each process are saved on a stack, and are reexecuted when a backup processor takes over for a failed processor.

transactions. But, Tolerant Systems Inc. (San Jose,)—manufacturer of the Eternity series computer—has reversed the usual process by creating techniques for dealing with incomplete transactions before developing fault-tolerant redundancy. The fault-tolerant version of the system is to be announced some time this year, and will use a pure queuing and counting approach without synchronizations.

Tolerant's existing system is a stand-alone module whose operating system, Transaction Executive (TX), has a built-in ability to recognize complete and incomplete transactions, and to implement the algorithm that allows only complete transactions to be entered in the database. When the fault-tolerant version of the system is announced, the present modules will operate as loosely coupled subsystems within the larger system definition.

Some companies in the fault-tolerant arena have coupled existing computer systems to achieve fault tolerance. One example is Perkin-Elmer Corp.'s (Oceanport, NJ) Resilient system. The Resilient consists of two Perkin-Elmer 3200 super-minicomputers loosely coupled to back each other up in OLTP, timesharing services, manufacturing and distribution systems, and other environments. This configuration also falls in the upper-left quadrant of Figure 1, with each computer having its own independent processor and memory, running independent processes, but ready to take over all processes if its twin fails. Each processor contains a software package (Reconfiguration Monitor), which detects failures in the twin system, and activates the inheritance and takeover of the interrupted processes as needed.

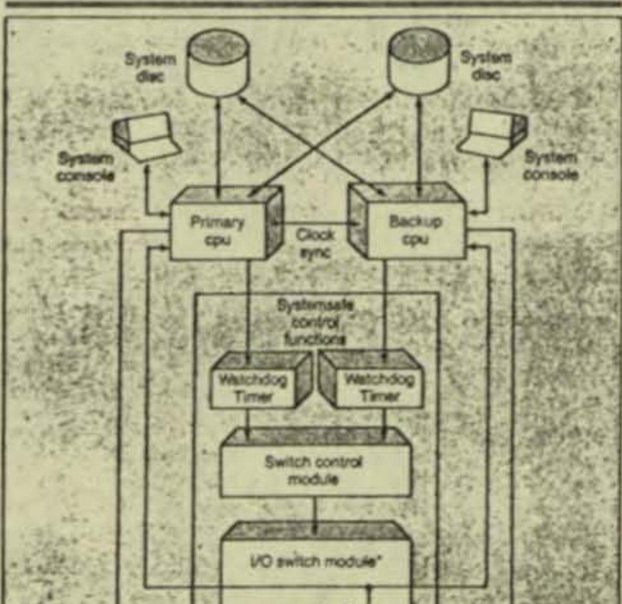
Process control application. Process control is another application in which continuous operation via redundancy is often crucial. The continuity requirement—particularly if the operations of a chemical or nuclear plant or an air-traffic-control center are involved—may be much more stringent than in OLTP. Five seconds, or even 1 second, may be too long a period of discontinuity.

The requirements in this situation have led to highly redundant systems (upper-right quadrant of Figure 1) in which separate processors run identical processes in lock-step. Maximum throughput is not the objective because two or more processors are performing a task that could be done by a single processor at the same rate.

This lock-step arrangement is typically implemented through the use of two or three processors. In the two-processor arrangement, the loosely coupled systems—each with its own memory—carry out the duplicated program. One computer is the master, which produces output. The other is the slave; while it executes all the processing steps in synchronization with the master, it doesn't produce output until a failure is detected in the master. Then, the master drops out for repairs, and the slave takes over.

This technique, often referred to as "hot standby," is illustrated by the Systemsafe/1000 introduced by Hewlett-Packard Co. (Palo Alto,) a few years ago. The system comprises a pair of HP 1000 Model 60 or 65 systems (Fig. 5). AT&T Technologies (Lisle, IL) also addresses real-time applications with its high-end, Unix-based, duplexed system—the 3B20D. Applications include telecommunications and process control.

The value of a hot-standby architecture in a crucially time-sensitive application, which can occur in process control, is that the takeover by the slave is virtually instantaneous. Also, the original processing speed is not held back by checkpointing or checkpointing substitutes. The slave needs no updates because it is doing the same task as the master. These efficiencies are counterbalanced because the dual system is dedicated to the task at hand. In many environments, this would be a wasteful allocation of resources. However, in a processing facility with very expensive equipment (the dual computer represent-



5. HP's Systemsafe/1000 is a dual system based on a pair of HP 1000s. The two halves of the system run in a process-control or scientific environment, carrying out a single task in duplex. In this hot-standby arrangement, the backup cpu takes over if the primary one fails.

ing only a small fraction of that cost), the high cost per independent application is not an issue. Where the penalties of failure may be extreme, this kind of redundancy is appropriate.

The Achilles' heel of the dual arrangement is often found in the central detection-and-switching element, which perceives a failure in the master and switches control to the slave. A failure in this single element can bring the whole system down.

Different solutions to the problem of the vulnerable switching element have been implemented by various manufacturers. One approach is to run not two, but three loosely coupled systems in lock-step with voting logic that ORs the outputs, and accepts outputs from the OR gate only when there is total agreement between processors. The acceptable output may represent unanimity of all three concurrent processors. Or, if a processor has experienced a failure, the output represents concurrence of the two survivors. There is no delay in continuing operation, and no single vulnerable failure point. The price for this high degree of reliability is the allocation of three systems to do the work of one. However, the conditions of the application may make such an allocation appropriate.

A voting architecture of this kind is illustrated by the CS330 from August Systems Inc. (Portland, OR). Designating its logic as triple modular redundancy (TMR), the company was awarded a $1.6-million contract to participate in the development of an air-traffic-control system for the Federal Aviation Administration (FAA).

A system that combines dual redundancy with hardening for harsh environments is the DAC-6000 from Autech Data Systems (Pompano Beach, FL). This ruggedized system, which uses RAM rather than disk drives to make it usable in environments that contaminate, can run a pair of controllers in lock-step. Alternately, the two controllers can be given independent tasks if fault-tolerant operation is not needed. When the mode is fault tolerant, both controllers have interfaces to common process-I/O modules (PIOs), for specific control and data-acquisition functions.

Even though the hot-standby architecture is typically found in process-control environments, these kinds of systems are designed for other applications. Syntrex Inc. (Eatontown, NJ) offers its Gemini system for use in office automation. A typical, fully redundant configuration provides 15,000 pages of storage, eight crt workstations, and six printers.

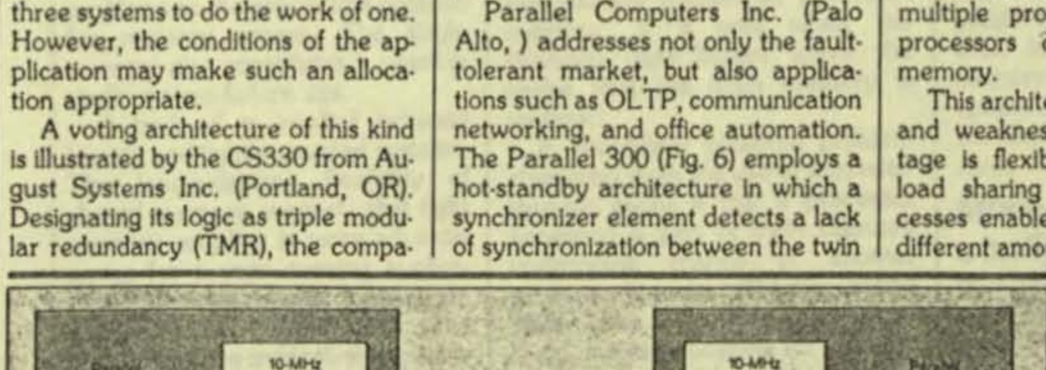
Parallel Computers Inc. (Palo Alto,) addresses not only the fault-tolerant market, but also applications such as OLTP, communication networking, and office automation. The Parallel 300 (Fig. 6) employs a hot-standby architecture in which a synchronizer element detects a lack of synchronization between the twin systems, and diagnoses the failure location. When one of the systems fails, both it and the synchronizer are taken out of operation, while the other system continues operation. The vulnerability of the synchronizer as a possible single system-failure point is taken care of; upon failure of the synchronizer, both it and the slave system are taken out of operation just as if the slave had failed.

The strictly duplex and triplex systems sell for relatively low prices for fault-tolerant systems. Few prices exceed $100,000, and some are a good deal less. For instance, the August Systems CS330 sells for a base price of $40,000. At the same time, if price per concurrent independent process is used as a criterion, some of these systems are at the higher end of the fault-tolerant spectrum, because only one process is executed at a time.

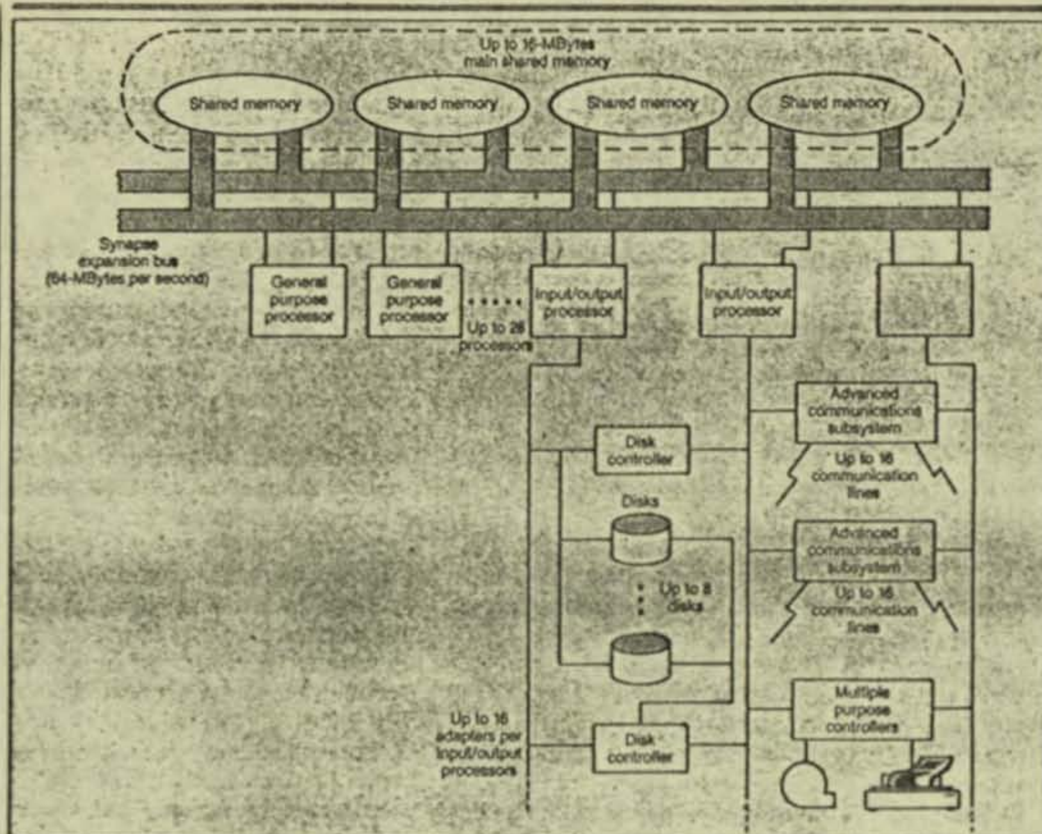
Sharing system memory.

The OLTP competition has seen the advent of shared-memory systems by a few vendors. These new entries into the fault-tolerant competition (corresponding to the lower-left quadrant of Figure 1) run independent processes on multiple processors, but all the processors draw on one main memory.

This architecture has its strengths and weaknesses. The key advantage is flexibility. Optimization of load sharing among various processes enables the system to allot different amounts of memory to the



6. The Parallel 330 from Parallel Computers illustrates the hot standby. If one of the parallel-processing units (ppu) fails, the sync module switches that processor and itself out of the system. A failure in the sync module leads to this same corrective action.



7. General-purpose processors and I/O processors share access to main memory in the Synapse N+1 system. High-speed cache enables the cpus to access main memory with a minimum of contention problems.

processes, depending on the requirements of each application. But the single memory poses bottleneck problems as the processors contend for memory access. The single memory also constitutes a possible single system-failure site.

A trade-off is implied between loosely and tightly coupled systems. The load-balancing flexibility of shared memory suggests that tight memory coupling is more advantageous for a user running applications with wide-ranging memory requirements. The more uniform the application, the more likely a user is to be drawn to a loosely coupled solution.

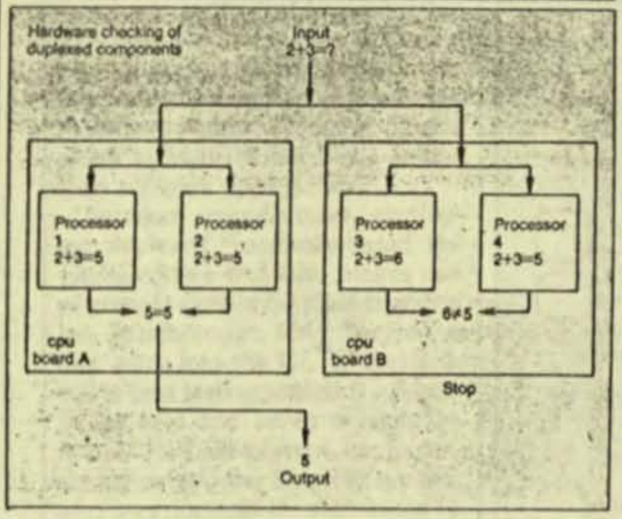
A practical solution to contention in shared-memory systems is available through the use of high-speed cache memory. When each processor is drawing on its own cache, additional problems can arise involving the high rate of bus traffic when cache updates are rewritten into main memory. The N+1 system (Fig. 7) from Synapse Computer Corp. (Milpitas,) keeps the bus traffic low through a technique known as nonwrite-through cache. When a processor writes new data into its cache memory, the changes are not immediately transferred into main memory. It is only when the changed data blocks leave the cache that the main memory is updated.

A secondary potential problem stemming from the use of nonwrite-through cache is that a processor accessing a part of main memory undergoing change in another processor's cache will be accessing stale data. Synapse Computer Corp. makes it possible for one processor to request a transfer directly from another processor's cache. The ownership of cache that is leading main memory in recent updates is always allocated to one and only one processor. A control algorithm governs the transfer of ownership, and assures that the cache is accessed (and not its lagging counterpart in main memory), until the main memory is updated.

The vulnerability of the entire system to shared-memory failure is an issue that requires qualification. Even though the memory in such a system is logically a single memory, it is physically comprised of separate banks of RAM that are independent with respect to hard failures. In the case of a transient memory failure, Synapse's N+1 system recovers by rebooting from the intact database on one of its mirrored disk drives.

Mixed configurations.

The lower-right quadrant of Figure 1 is intrinsically vacant. This results logically from the definitions of shared memory and duplex processing—the intersecting attributes of this quadrant. When identical synchronized processes are operating, they automatically use the same amounts of memory and memory regions that map onto one another at every step in their common program. In other words, synchronized processes would logically partition a shared physical memory into two mutually exclusive, identical regions. Designing a system for the lower-right quadrant would incur the problems



8. Duplexed processors on a Stratus/32 cpu board are shut down when a comparator finds that their outputs disagree, as on board B. Duplicate board A (where outputs agree) continues operation. If checking logic determines that a component has failed on board B, the failed board is removed for servicing while the system continues operation.

of shared memory, without its advantages.

However, there are mixed systems that overlap the lower-right quadrant as a natural consequence of their more general architectures. A system with a mixture of characteristics is the /32 series from Stratus Computer Inc. (Natick, MA). Stratus, second to Tandem in OLTP market share, offers an innovative architecture having several levels of built-in fault tolerance. One of the applications addressed by Stratus is a new communications system specified in a contract with the North American Aerospace Defense Command (NORAD).

Each logical cpu in a Stratus system is represented in hardware by four physical cpus (Fig. 8). Two of these operate in duplex on cpu board A, and two operate in duplex on backup cpu board B. All four carry out an identical synchronized process. A comparator on each board ORs the output from the duplexed elements. If the comparator detects a difference, the board is automatically shut down. The output is thereafter provided by the alternate board.

Figure 9 shows the two latest Stratus cpu models. Each general processor consists of the four physical processors of the previous figure. Each duplexed memory consists of two physical memories whose contents are always matched. The four logical processors of the XA 400 are each conducting an independent task, as is each of the six logical processors of the XA 600.

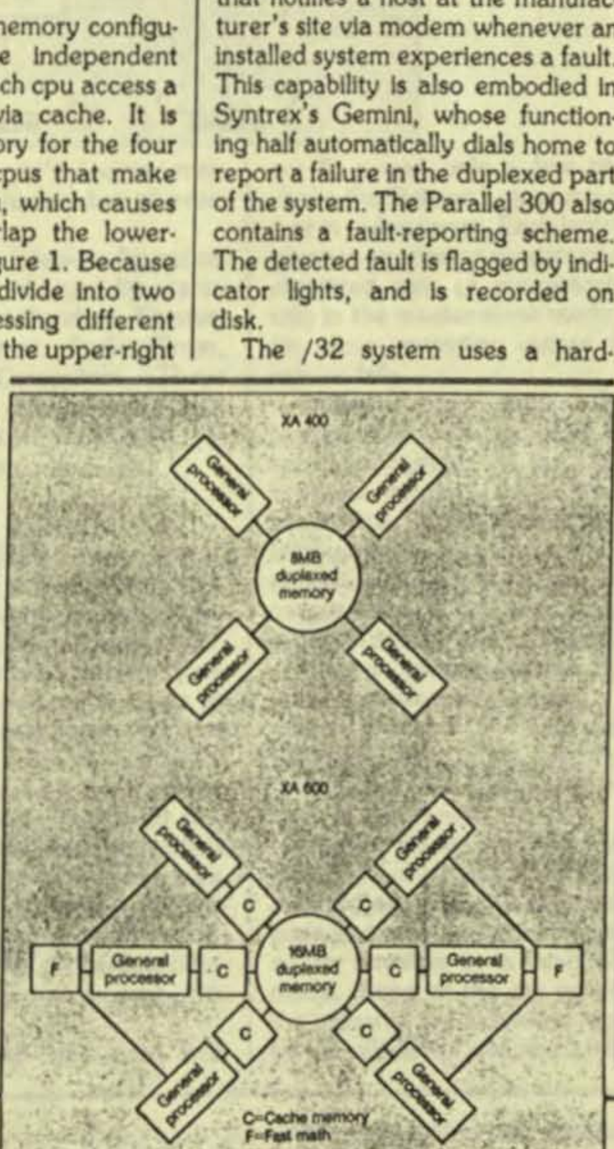
This is a shared-memory configuration because the independent processors within each cpu access a common memory via cache. It is also a shared memory for the four duplexed physical cpus that make up each logical cpu, which causes the system to overlap the lower-right quadrant of Figure 1. Because the duplexed cpus divide into two pairs (Fig. 8), accessing different duplexed memories, the upper-right quadrant is also spanned.

In the larger context of the Stratus/32 computer (Fig. 10), there can be several of these cpu boards, which may be a mixture of XA 400s, XA 600s, and Stratus's earlier FT 200s. Also, multiple /32s can be networked through the StrataLink LAN. At this level of the architecture, separate processors are accessing separate memories in a completely loosely coupled modular arrangement. This system spans all four quadrants of the Figure 1 taxonomy. As a result, the advantages of load balancing, lack of memory contention, no single point of failure, and rapid recovery are combined.

In addition, the system has a built-in, fault-announcing system that notifies a host at the manufacturer's site via modem whenever an installed system experiences a fault. This capability is also embodied in Syntrex's Gemini, whose functioning half automatically dials home to report a failure in the duplexed part of the system. The Parallel 300 also contains a fault-reporting scheme. The detected fault is flagged by indicator lights, and is recorded on disk.

The /32 system uses a hard-

9. Each logical general processor in either of these Stratus cpu designs consists of four duplexed physical processors in the duplexed arrangement of the previous figure.

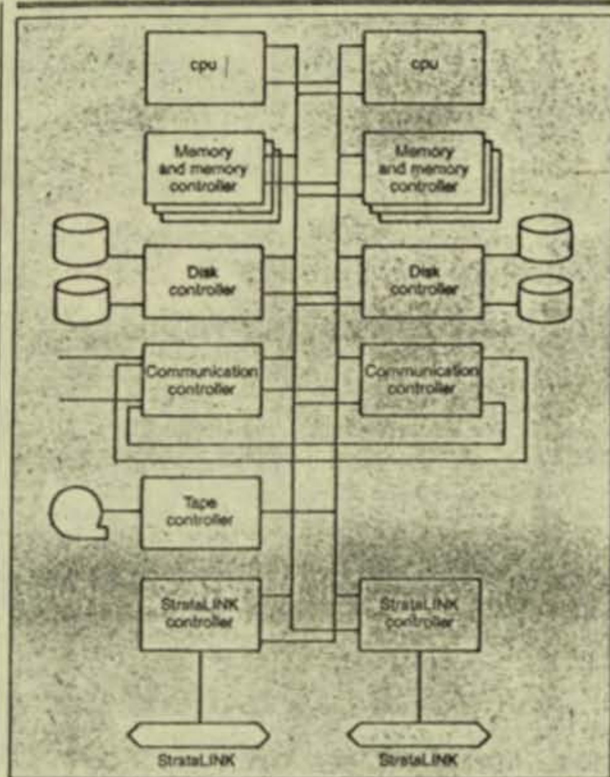


ware-only method of implementing fault tolerance, as seen in its duplex operations and comparators. As costs of hardware decrease relative to software costs, economic factors move in favor of hardware rather than software approaches.

Another manufacturer employing duplexed, hardware-based implementations that also makes use of comparators is Sequoia Systems Inc. (Marlborough, MA). Sequoia, a late entry into the OLTP arena, is still in beta testing, with two systems in the field and seven or eight inhouse. Its fault-tolerant computer, simply named the Sequoia system, also uses nonwrite-through cache to reduce memory contention.

Sequoia provides rapid recovery from failures in its shared memory. The system backs up memory data from one bank of RAM in another bank, also in main memory. This logical partitioning provides for rapid recovery in the event of a physical memory failure. Updating of the two mirrored regions during an application is carried out consecutively. The backup region is not updated until after the intactness of the primary region has been verified. This prevents the backup region from being contaminated by a logic error affecting the primary region.

Sequoia and Synapse appear to be the only two manufacturers in the fault-tolerant arena using a strictly shared-memory architecture. The prices of these systems are at the high end of the fault-tolerant market, with the Sequoia system selling at $250,000, and the Synapse N+1 at $221,000 (both in their base configurations). This reflects the fact that the base system features a full system memory and sophisticated caching arrangements. The inclusion of additional processors takes the buyer along a relatively flat price curve, because the upgrades do not require additional main memory. So, for some larger number of processors, the shared-memory systems tend to cross under the steeply ascending price curves of the loosely coupled systems. The buyer's decision may be affected by the number of processors required.



10. The Stratus/32 combines cpu boards and memories in a loosely coupled structure. Local-area networking can tie several of the /32s to expand the structure.

More typical base-configuration prices are being charged by manufacturers such as Tandem, Stratus, Auragen, Tolerant, Perkin-Elmer, and Parallel Computers. These companies are offering entry-level systems in the $75,000 to $150,000 range.

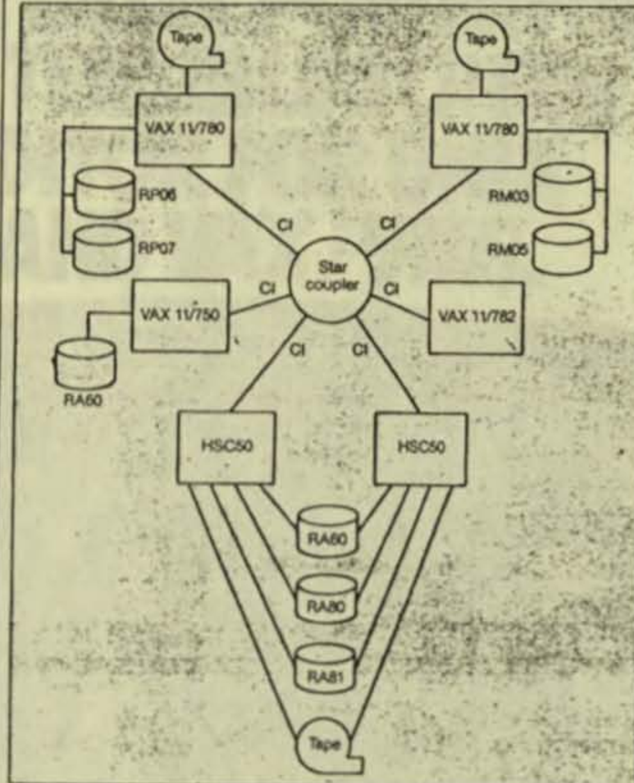
Enter the pragmatists.

Not everything happening in the fault-tolerant OLTP field is based on very large systems supporting hundreds of terminals. For example, NoHalt Computers (Farmingdale, NY) offers its Reliant I distributed system for less than $30,000. This multiuser system employs the CP/M-compatible Turbodos operating system to support 30 to 60 users through multiple independent application processors. Redundancy is provided, not in processors backing each other up, but in duplicate file processes, databases, power supplies, and mirrored disks.

NoHalt's newly announced Reliant II, priced only a few percent above the Reliant I, goes much further in redundancy. Each logical application processor consists of a synchronized pair of processors running in the master-slave mode, with the slave providing output if the master fails.

EnMasse Computer Corp.'s (Acton, MA) ECS computer based on Unix System V is $25,000. EnMasse stresses high levels of availability, rather than strict fault tolerance. This system needs to be re-booted in case of failure. The recovery time is rapid—only a few minutes rather than the virtually continuous modes offered by the more expensive, strictly fault-tolerant systems. The emphasis will be on preserving data integrity in a system that is available with a high level of assurance.

Also, as shown by the specialized fault-tolerant systems from Hewlett-Packard and Perkin-Elmer, existing minis and mainframes can be adapted to function in a fault-tolerant mode. Some of the big vendors in the industry are achieving high levels of reliability and the ability to



11. A VAX cluster is a loosely coupled combination of Digital Equipment Corp.'s VAX processors and mass-storage servers (HSC50s). All nodes connect to a common connection point, the Star Coupler. Upon failure of a node, tasks can be redistributed to other nodes.

withstand faults by clustering their systems. Prominent examples include Digital Equipment Corp. (Maynard, MA), with its VAX clusters (Fig. 11), and IBM Corp. (White Plains, NY) with its Series/1 computers.

IBM's RPS 6.2 operating system gives the Series/1 user several capabilities that he can apply in the direction of fault tolerance. First, the operating system ties multiple Series/1s so that, in effect, the user sees a single system. Secondly, RPS 6.2 provides a file-mirroring capability through which the user can designate files that are to be mirrored on a pair of disk drives. Also, the operating system supports programmable switching, enabling peripheral devices to be switched from one processor to another.

The Series/1 cpus are connected by means of a ring communications link. Two such rings can be supplied so that if one of the rings fails, the other will automatically back it up. If the processor designated as the home node fails, its network-controlling functions are automatically passed to a backup node.

Also implementing redundant features in a high-powered, general-purpose system is Elxsi (San Jose, CA). The company's multiprocessor System 6400, priced at $369,000 and up, has the ability to shift tasks

FAULT TOLERANCE

from a failed processor to a backup using a shared-memory scheme. Memory contention is reduced in this case by disallowing the caching of writeable shared data. In other words, the designers of the system perceived that when writing did not occur, most memory requirements involved operating-system elements. When writing did occur, the write usually did not involve shared processes. A simple restriction against caching those data elements that required write-through by more than one processor eliminated memory contention in almost all cases.

The incorporation of fault-tolerant attributes by less-specialized manufacturers at the high and low ends who are not committed to the highly redundant architectures may foreshadow the spread of fault tolerance as a standard feature of computer systems.

William Foster, the cofounder and president of Stratus, predicts that this will happen. He believes that these characteristics will be as pervasive as error-correction codes in memory—once specialized and esoteric—have become. But vendors of established systems with established architectures are not going to rebuild their product lines from the ground up. Therefore, the specialized fault-tolerant companies will probably find themselves coexisting with a more general, lighter type of fault tolerance as these attributes permeate the general market.

The use of Unix operating systems is another development bringing fault-tolerant computers into the mainstream. Implementations vary widely, involving Unix System III; Unix System V; Berkeley 4.2; modifications, variants, and supersets of these; and compatible operating systems. Companies involved with Unix in a definitely fault-tolerant setting include Auragen, AT&T, Computer Consoles, Parallel, Perkin-Elmer, Sequoia, Stratus, and Tolerant.

VENTURE STRATEGIES

Ed Kashi/Gamma Liaison

Charles Ryle (l.), Parallel's new president, and Mark Pine

RUNNING LATE IN FAIL-SAFE COMPUTERS

FOUR OUT OF SIX STARTUPS COULDN'T MEET DEADLINES

By Ira Sager

Sales at Tandem Computers Inc. soared nonstop to $312 million in 1982 from $7.7 million in 1977 on the strength of a computer that runs even when a part fails. Net after-tax income has gone to $29.8 million in 1982 from $325,000 in 1977. Those numbers have prodded new companies to work double-time to get their own fail-safe computers to market. And as old-line minicomputer and mainframe companies see fault tolerance as a way to sell their own computers, the fault-tolerant market has quickly grown competitive.

But problems threaten some of the six ventures—backed by more than $75 million in capital—as they prepare to come to market. After three years of development, only one fault-tolerant startup—Stratus Computer, which went public in August to raise about $32 million—is actually shipping its computers in production quantities. With 76 units in the field, Stratus has shipped more computers than all five of its fledgling competitors. A two-year-old company, Tolerant Systems Inc., is not scheduled to introduce its product until January. Others had hoped to be on the market in force by now, but they have been plagued by delays of up to a year or more—largely as a result of underestimating complex technology.

Even its $26 million grubstake couldn't help Synapse Computer Corp. stick to plan. "They've had a modest slip in the development schedule of from three to six months later than planned," says Jim Bochnowski of Technology Venture Investors, an investor. "That translates into lots of bucks." By presstime, Synapse had shipped four computers.

So far, venture capitalists have been rolling with the punches because of the size of the market these companies are entering. ITOM International, Los Altos, Calif., a research and consulting firm, estimates the fault-tolerant startups could be competing for a piece of an overall computer market worth $37 billion by 1986. Right now, fault-tolerant computers compete in the so-called "transaction processing" market, in which computers record airline reservations or banking transactions as they occur. The market for computers sold for this purpose is estimated to reach an estimated $1.3 billion by 1986, up from $400 million last year.

But eventually, say the entrepreneurs, all computers will be fault tolerant. "By 1990 everything, including personal computers, will have some level of fault tolerance," says Eli Alon, who founded Tolerant Systems, San Jose, Calif., in June, 1982, with $9.5 million from backers led by Adler & Co.

The frail startups in this new business may be less fault tolerant than the computers they make. Several tardy entrepreneurs have already had changes imposed on them, and the next step will be reductions in valuations by venture capitalists.

"The reason more money is required in some startups is that they [the fault-tolerant companies] underestimated the scope and level of effort to make the product fault tolerant," says Charles Ryle, a former Tandem marketing executive who was brought in last January as president to replace Scott Pine, cofounder at three-year-old Parallel Computers, who has left the company. Pine's brother Mark, who cofounded the company, remains as vice-president and principal engineer. Before Ryle joined Parallel, the firm realized its original design wouldn't work. Now, after switching the microprocessor at the heart of the system, the company hopes to ship production models during the first quarter of 1984.

Auragen Systems Corp., Fort Lee, N.J., lost nine months because its original design—led by veteran entrepreneur Manuel Whittels—came in 70% to 80% above target costs. In April, 1982, Auragen began redesigning its system under new management, and switched to newer microprocessors. Now, the company, still sustained by its original capital of $15 million, hopes to crank up its production line by April—about 21 months after it began redesigning the computer. Auragen has shipped three computers.

Most successful have been Synapse and Stratus, two companies with divergent strategies formed within the same six months of 1980.

The two companies took opposite technical approaches. While Synapse focused on designing fault tolerance into the software, a complex chore that some analysts say may benefit the company in the long run, Stratus implemented fault tolerance in the hardware—by literally adding many duplicate copies of hardware components in the computer. Stratus credits the strategy with keeping it on schedule. "The other guys have taken the approach that the hardware is expensive, but our feeling is that the real expense is the software," says William Foster, founder and president. After its textbook startup, Stratus raised $14.7 million privately, then went public.

There is still late-round venture capital for companies such as Sequoia, Marlboro, Mass., which is planning to close soon on its third round of financing of from $10 million to $12 million. Sequoia plans to begin production by March. Meanwhile, in Minneapolis, former Control Data Vice-President Robert Morris is getting itchy to fund his three-month-old Corinthian Systems Inc. Until he arranges his capitalization of $24 million, none of the seven other would-be founders waiting in the wings will join him.

If fault tolerance becomes a ubiquitous computer feature, then these companies—as late and overbudget as they are—may have a leg up on competition, particularly minicomputer makers. Explains Parallel's Ryle: "The problem the minicomputer companies have is selling a fault-tolerant system next to their other machines. The salesman says, 'Here are our fault-tolerant systems, and here is a computer we also sell that breaks.'"

Selma

VENTURE STRATEGIES

Charles Ryle (l.), Parallel's new president, and Mark Pine

RUNNING LATE IN FAIL-SAFE COMPUTERS

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EARLY WINTERS COMES OF AGE

TO GROW 40% A YEAR, A MAIL-ORDER MARKETER MODERNIZES ITS MIX

By C.C. Tate

Ten years ago, Bill Nicolai was living on food stamps and peddling backpacking tents at street fairs. For fiscal 1984, his Early Winters Ltd., Seattle, a direct sales marketer of outdoor equipment, projects sales of $17 million and aftertax earnings of $600,000. To achieve annual growth of 40%, Nicolai has updated operations and opened retail stores and is