DEC CONFIDENTIAL

HDTV, TELECOMMUNICATIONS, AND COMPETITIVENESS: Implications for DEC and the U.S. Computer Industry

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CONTENTS AND OUTLINE

1. INTRODUCTION

The HDTV Debate

Several groups, including the SIA, the AEA, and DARPA, have proposed to use the advent of high definition television (HDTV) and/or large-scale fiberoptic networking to re-establish a U.S. consumer electronics industry, support the semiconductor industry, provide networking for research and military needs, and/or to create a nationwide, public U.S. digital telecommunications infrastructure. This memorandum discusses the HDTV issue, including relevant technology and market trends; the major policy areas involved; the potential effects of current proposals upon the U.S. computer industry and DEC in particular; and, finally, some potentially desirable alternatives.

The HDTV issue offers major opportunities, but equal risks, for U.S. systems firms, particularly those (such as DEC) with strong CPU, networking, and software offerings but relative weakness in mass manufactured peripheral hardware. Several proposals allegedly intended to improve U.S. performance could actually harm DEC, the U.S. computer and office equipment industries, and/or the economy as a whole. For example, the HDTV debate has thusfar concentrated uniquely upon consumer equipment and its relation to displays and semiconductor components. While these are important, the debate has neglected growing Japanese penetration of digital business equipment markets (digital copiers, facsimile, laser printers, CCD imaging), which could affect DEC and other U.S. firms more rapidly and directly than Japanese dominance of HDTV per se. In short, "HDTV" in fact spans multiple markets involving very different interests, competencies, and competitors, both domestic and foreign.

And as in other cases (e.g. semiconductors), the fragmentation of U.S. industry renders American firms vulnerable to more coordinated competitors, who are often (though not always) foreign. Since the importance of HDTV derives primarily from the fact that universal digitization of information handling causes convergence and integration of previously independent technologies, companies, and industries, the formation of industrial and political coalitions will be critical to DEC's interests and to effective U.S. policy. DEC must therefore build political coalitions suitable to its policy goals, and obtain policy measures which support the industrial coalitions suitable to its business goals.

The outcome of the HDTV debate will probably have large implications for DEC's long run prosperity. For example, a modular, digital HDTV architecture with fiberoptic delivery could, under favorable policy conditions, assist in U.S. re-entry into consumer electronics, perhaps also providing much-needed support for U.S. semiconductor and display technologies. But under equally plausible alternative conditions, it could facilitate Japanese penetration of the personal computer and business networking industries via U.S. telecommunications companies and consumer distribution channels.

In general, DEC's interests appear quite consistent with an HDTV policy

that effectively strengthens U.S. high technology industries and, more generally, the U.S. economy. But in part this is because DEC's position as a global computer, software, and networking vendor mirrors the complexity of the regulatory, standards, industrial policy, national security, and trade policy issues involved. In fact, television sets and U.S. entertainment broadcasting are, in themselves, the least of DEC's -- and American industry's -- concerns in the HDTV debate.

First, "HDTV" involves many groups -- telephone companies offering public communications services, large corporations with internal networks, advertisers, information services firms, nearly the entire electronics industry, and millions of small businesses, individuals, and households. Some -- analog broadcasters, for example -- will be severely damaged by digital technology. Second, HDTV will be global, though possibly involving regionally incompatible standards, and DEC must consider differences among U.S., European, and Japanese markets and competitors. Third, DEC must balance hardware markets against software, services, and systems integration, including the services and/or products offered by regional Bell operating companies (RBOCs). Fourth, RBOCs and large end-users will use large distributed internal systems, as distinct from consumer systems, which may or may not employ similar hardware, software, and/or architectures. These large internal systems will be a large, distinct market, one of great interest to DEC.

But more importantly "HDTV," at least in conjunction with large digital networks, is just a special case, and not even the most important one, of the digitization of office and home information products (e.g. digital facsimile, scanners, copiers, displays, printers, and electronic cameras). This gradual blending of the computer, office equipment, and imaging industries is likely to move far beyond television and graphics displays, and will also have a major effect upon services such as electronic design, publishing, advertising, and banking. The impact of HDTV policy upon this gradual conversion of many industries to a common, mass-manufactured digital technology base is likely to be critical for DEC and for several large industries. For example it is very unclear that if current trends continue, Xerox can compete with Canon in digital reproduction equipment, whose future could be critical to DEC's enterprise-wide network offerings. Thus although HDTV's impact on display markets and semiconductor demand are important issues, they are not the only ones.

It seems likely, though not certain, that U.S. consumer-level HDTV service will come in two phases: first an analog, NTSC-compatible system using conventional transmission, then a more advanced, probably incompatible digital system whose deployment might overlap with the first. European consumer HDTV policy, conversely, is still in flux, while Japan is already implementing its DBS-delivered, analog MUSE system. Large office/industrial markets are less developed, although the U.S., Europe, and Japan all have some commitment to ISDN, and at least Europe and the U.S. are somewhat committed to OSI. U.S. telecommunications firms and some Europeans are also finalizing a standard, upward compatible with LAN standards and also with ISDN, for fiber-based, 40-150 megabaud Metropolitan Area Networks (MANs), which will explicitly not be usable for consumer video.

Although DEC has some interest in whether and how U.S., consumer-level, NTSC-compatible systems are deployed, the stakes for DEC and for the U.S. electronics industry are much larger with respect to more advanced non-compatible, and especially digital, equipment and delivery systems -- as architected and deployed both in the U.S. and abroad. And the stakes are even larger yet in the office, industrial, and professional markets (including the internal markets of RBOCs and large computer users). Large, integrated systems (combining computing, digital communications, scanning, imaging, and printing) will probably evolve more rapidly in business than in consumer markets, owing to public services regulation, financial incentives, coordination issues, and market structure.

Major "HDTV" Issues for DEC

Given the above, the major areas of concern for DEC in the "HDTV" policy arena are as follows:

1) potential U.S. policy towards HDTV hardware and markets to stimulate advanced display R&D, receiver production, and to provide markets for the U.S. semiconductor industry;

2) the potential use of U.S. policy, whether under the auspices of HDTV or not, to promote advanced digital networking infrastructure in the United States, for home and/or business use;

3) the potential use of U.S. policy to stimulate U.S. R&D for, and/or production of, digital office peripherals to supersede analog facsimile, copiers, and document handling systems;

4) the optimal role of the RBOCs, including various possible deregulation policies and the RBOCs potential role as a digital "Panama Canal" between the business and home environments;

5) the role of Europeans, including U.S.-European R&D cooperation, standardization, and market participation issues, particularly given that most HDTV markets will develop after 1992; and

6) the role of the Japanese, given that they dominate the world consumer electronics industry, most of the digital electronics technology base, and many high volume segments of the office electronics sector.

2. TECHNOLOGY, PRODUCT, AND COMPETITIVE TRENDS

General Trends

HDTV and related developments are the result of several product, industry, and technology trends which in turn are the result of continued progress in digital technologies -- e.g. semiconductors, chip- and board-level assembly and packaging, CCD imaging, very high bandwidth fiberoptic transmission systems, high resolution displays, laser and ink jet printing, mass storage, and CIM. Resulting HDTV-related trends include:

(1) the computer industry's shift towards mass-produced, increasingly networked personal systems relative to large, centralized systems, e.g. PCs and LANs as opposed to time-shared mainframes;

(2) the gradual convergence of the computer, office equipment, consumer electronics, and telecommunications industries; and

(3) the gradual conversion of many established industries, products, and services from analog (electronic, mechanical, and/or photochemical) technologies to digital (electronic, magnetic, and optical) technologies.

Implications for DEC & U.S. Computer Vendors

Taken together, these trends have several implications for the HDTV issue, the U.S. computer industry, and DEC.

First, the technology base of computer hardware, which was once unique to the industry, is merging with that of other industries, particularly consumer electronics, and the relative sophistication of the two arenas is shifting. Computers are becoming mass-produced goods, while the consumer electronics industry is being digitized. Both are becoming reliant on high technology mass manufacturing and standard digital technologies: DRAMs and other semiconductors, CD ROMs, surface-mount technology, printed circuit boards, automated assembly, LCDs, CCDs, CRT displays, and so forth.

Similarly, by the mid-1990s telecommunications equipment and physical networking will be dominated by server-processors (computers, digital switches), fiberoptic cabling (first narrowband, then wideband), and optoelectronics. Virtually all computers will soon be networked in some way, and public telecommunications services are already now provided, in effect, by large networks of computers connected to telephones, PCs, facsimile machines, and other customer premises equipment (CPE).

While computer hardware is gradually becoming more commoditized, consumer electronics -- formerly a labor-intensive assembly industry which used obsolete analog semiconductors -- is being digitized, and its technology level (in CD audio and video players, digital VCRs, HDTV, digital audio tape systems, etc.) is advancing. Soon, many consumer products will resemble personal computers and peripherals. VCRs already consume about 10% of world DRAM production; graphics displays resemble high quality televisions; both sectors require ASICs, printed circuit boards, surface mount technology, and even microprocessors. While the architectures and product technologies of personal computers and workstations remain somewhat more sophisticated than those of VCRs or CD systems, the difference is narrowing and the manufacturing technologies of consumer electronics are already more advanced, at least in Japan. (Apple's Fremont plant requires only 900 people -- including plant management -- to assemble all Macintoshes sold in North America; it uses a television assembly line imported from Japan.)

When consumer electronics is fully digitized, and 10-50 MIPS 32-bit personal systems with graphics displays dominate the computer hardware market, the two industries will be very similar technologically. And if a

national fiberoptics network becomes a reality, their transmission media will even be the same, and telecommuting could gradually merge their customer sets. After HDTV's commercial takeoff in the mid-1990s, HDTV sets and associated VCRs would become a major segment of the U.S. consumer electronics market. In revenue terms, they would become perhaps half the size of the U.S. personal computer market. The largest differences between PCs and HDTV boxes, probably, would be the greater price-sensitivity of consumer products and the higher processor speed of PCs.

Thusfar, the U.S. HDTV debate has focussed on the large size of the HDTV receiver industry/market, its commonality with personal computer technology, and its large demand for semiconductors, displays, and other components. But for DEC and other vendors of office equipment systems for industrial use, and even for the components industries, there are other issues related to "HDTV" and to fiberoptic networks which, in the end, will probably prove even more important. As the computer, office equipment, and consumer sectors begin to interpenetrate via hardware commonality and shared networking infrastructure, U.S. firms may have an opportunity to re-enter consumer markets. On the other hand, "HDTV" could be the means by which traditional office equipment firms, the RBOCs, and/or (most likely) Japanese electronics firms can finally penetrate the U.S. computer industry.

The Digitization of Office Equipment, Imaging, and Consumer Services

The same conversion to digital technology which is transforming consumer electronics will also affect the office equipment, imaging, and home information industries: facsimile, photocopying, printing, publishing, image capture (photography, scanning, etc.), image archiving and retrieval, banking and other services, and both home and business information delivery (advertising, billing, database services, etc.). And, for a variety of technical and market reasons, it seems quite possible that the digitization of office equipment and imaging could move faster, and have an earlier impact upon the computer industry, than "HDTV" (defined solely as consumer video). Thus office and home networking will start largely independently, but will eventually collide as office equipment overlaps with home equipment (HDTV, electronic cameras), and as metropolitan area networks overlap with consumer delivery systems.

Digital cameras, scanners, printers, facsimile machines, CD-ROM retrieval systems, and photocopiers (laser, ink-jet) are rapidly nearing commercialization or even, in some cases, mass-market takeoff. In time, they will surely use high speed (fiberoptic) transmission links and will be integrated into computer networks and/or establishment-sized distributed information systems. These technologies will also obsolete many existing mechanical, optical, thermal, and chemical processes -- sometimes quite rapidly, sometimes slowly. Furthermore, these markets are just as large as, or larger than, the HDTV market. Photography is a $15 billion market in the U.S.; the copier market is about $10 billion; other office equipment markets (fax, answering machines, OCR equipment, microfiche/microfilm systems, automated mail handling) add another several billion dollars.

The digitization of these other sectors suggest at least two possible

developments. The first is that digital office equipment will become a large market, with new digital office systems becoming integrated into corporate information systems via private, quite possibly unregulated, enterprise-wide or area-wide fiberoptic networks. For example, faxmail or electronic camera snapshots could be transmitted digitally, viewed on displays, edited, and then sent to either archival storage or a printer. (In fact, DEC recently announced several products aimed at these markets.) Because private office systems are both less price-sensitive and less regulated than the public systems that RBOCs would offer, they may reach commercial takeoff earlier.

Secondly, with the spread of fiberoptic cabling to small businesses and homes for both HDTV and telephony, it will be possible for many firms (e.g. Kodak, copying services) to offer many business and consumer services over the public network. For example, centralized photographic printing services could accept data files generated by electronic cameras and transmitted digitally for processing. Such business and consumer markets could, again, prove much larger than HDTV strictly defined, and these service providers might be a major market for DEC systems. Several experiments in this area, e.g. a GTE project for home film viewing on demand, are underway or planned. Standardization efforts for Metropolitan Area Networks (MANs), with regional contention networks offering 40 - 100 megabaud to local area network gateways, are already quite advanced, with AT&T and other major vendors beginning development efforts.

Thus a wider consideration of the HDTV issue suggests that consumer video is not the only, and possibly not the most important, market expected to follow from the combination of digitized information processing and high-speed fiberoptic networks. Nor is it the only area in which U.S. competitiveness is potentially at risk. Office systems and other consumer products and services will probably be as large or larger, and U.S. industry has an initially stronger, but seemingly eroding, position in these other areas. While U.S. reentry into consumer electronics via HDTV production might be feasible or desirable, these other markets deserve equal or even stronger consideration in DEC strategy and U.S. policymaking.

Competitive Positions: Hardware

U.S. firms still have strong positions in most office equipment sectors, although the conversion to digital technology puts them at risk. Large Japanese electronics firms such as Canon and Toshiba have penetrated markets for personal laser printers, copiers, facsimile machines, and other mass-produced office products; Canon and Sony among others have large R&D efforts in digital imaging, copying, and image retrieval. A number of U.S. firms such as Xerox, Kodak, IBM, Polaroid, Apple, Hewlett-Packard, Wang, and Pitney-Bowes still have strong technical and/or market positions, at least for now, and there are some promising startups (such as Iris Graphics in color inkjet printers). In general, U.S. firms retain the high-performance, low-volume portion of these markets, but Japanese firms hold the mass-production markets and are moving upward. Therefore DEC should be concerned with the U.S. technology base for U.S. office equipment vendors during and after the digitization of image capture, processing, display, hard copy

production, and mass reproduction. This concern should equal the degree of concern for preserving a consumer equipment production and technology base.

And in fact, if current trends continue most of the components, manufacturing processes, and base technologies for these sectors are, or soon will be, dominated by Japan, and in particular by the roughly eight companies which dominate the Japanese semiconductor, consumer electronics, and computer industries. These firms already have dominant positions in the highest-volume, most cost-sensitive portions of the office electronics market - personal laser printers, facsimile machines, personal copiers, graphics displays, and so forth. Their commodity CMOS semiconductor processes, CCDs, surface mount assembly, CRT, LCD, and printed circuit board technologies are considerably ahead of those in the United States, with the possible exception of IBM.

However, the United States still leads in many of the design-intensive, system-level technologies and high performance industrial markets specific to computers, networking, and digital telecommunications -- areas such as advanced microprocessors, software design, high speed laser printers, digital central switches, automated mail processing equipment, high performance disk drives, and computer architecture. By contrast, the Europeans are behind in both consumer and industrial electronics, but have maintained some presence in both (in part through government support), and a few European firms (Philips, Siemens, Thomson) have impressive products in some areas and substantial technological and financial resources. Moreover, most European PTTs are government-controlled, and favor domestic producers.

Competitive Positions: Software and Services

At least for the time being, the United States retains a definitive lead in software, consumer content (video programming, newspapers, publishing), and computer systems integration. This ownership of content and leadership in software/integration technology represents a substantial asset which could be used to competitive advantage by DEC and by U.S. policy. This lead, as in hardware, is more secure in office/industrial software and services than in consumer entertainment content. The reason is that although the U.S. will still originate entertainment programming, entertainment distribution has high entry costs (discouraging startups), while control of rights can be purchased without long R&D efforts. (Sony recently purchased CBS Records for over $2 billion.) It is not yet clear whether Japanese or European firms will attempt to control distribution and/or receiver markets by purchasing control of consumer entertainment content, but the possibility definitely exists.

3. POLICY ISSUES AND COMMENTS ON RECENT PROPOSALS

Given the above trends, the policy issues and proposals related to HDTV appear in a different light than when U.S. consumer and receiver markets are the only markets considered. Therefore the remainder of this document is composed of two sections: first, some brief comments on the two objectives of current HDTV discussion (receivers/displays and semiconductor demand), and then a broader discussion of DEC's policy interests.

1) Receiver Production and Display Markets

From DEC's point of view, HDTV receiver policies are an indirect subsidy to displays, which are what DEC really cares about. The benefit of concentrating upon HDTV receivers is the volume of the consumer market. It would be equally useful, therefore, for U.S. policy to support R&D for advanced display technologies; and/or to support manufacturing R&D as much as product R&D. In fact, even if HDTV receivers become the only focus of U.S. policy, any United States policy should include measures to improve U.S. manufacturing, particularly component processing and automated high volume assembly. Otherwise U.S. costs will remain high, and unprotected computer display markets will show it.

2) Semiconductor Demand: Product Demand Versus R&D

How much would a U.S. HDTV policy provide increased demand for U.S. semiconductor products? It depends upon the policy, but a highly effective policy would have a substantial effect. Receiver demand alone would not, however, be sufficient to change the long-term decline of the U.S. merchant industry unless the policy included R&D as well as product demand; other digital consumer electronics markets and industrial markets; and Europe. The U.S. consumer receiver market alone is simply insufficient. Consider the following calculation.

Suppose the semiconductor content of HDTV sets and VCRs would be 10%, U.S. firms held 70% of the U.S. HDTV/VCR market, and U.S. semiconductor producers held 70% of the semiconductor market for those U.S. HDTV vendors. This quite optimistic scenario results in a 5% U.S. semiconductor demand pull effect. A $20 billion U.S. HDTV and VCR market would therefore cause an incremental $1 billion in U.S. semiconductor production. In 1995, which is a very aggressive date for the existence of a $20 billion U.S. HDTV hardware market, this would be roughly 5% of U.S. merchant semiconductor production, and only 3% of total U.S. semiconductor production (i.e. including captive production). There are two reasons for this small effect. The first is narrowness: as indicated before, U.S. HDTV per se is only a small portion of worldwide digital electronics. The second is time. Given the rate at which the U.S. merchant industry is decaying while the world semiconductor market is growing, the advent of HDTV demand cannot reasonably be expected to make a significant difference in the health of the U.S. semiconductor industry relative to Japan's.

However, R&D funding could be a different story. If U.S. HDTV policy included significant injections of funding for semiconductor research, process development, and product design related to graphics, signal processing, optoelectronics, CCDs, packaging, and similar technologies, the result could be a substantial increase in the health of the U.S. technology base. This R&D funding could begin early enough to have an effect, tiding the industry over until large-scale HDTV commercial demand arrives in the mid- to late 1990s.

Finally, consider the set of issues confronting DEC, including the

optimal way to retain a U.S. display industry and to stimulate U.S. semiconductor demand, as well as other objectives for DEC and the U.S. high technology sector.

4. ALTERNATIVE PROPOSALS AND DEC RECOMMENDATIONS

1) U.S. policy towards consumer HDTV hardware and markets

Policy proposals now being discussed include DARPA R&D grants to U.S. universities and/or companies, a Technology Corporation of America to perform R&D and serve as a patent pool for member firms, and a large demonstration project to test technology and use procurement to subsidize R&D in the area. In principle, all are potentially beneficial, but several independent issues are important to the success of any of these approaches. First, manufacturing should be explicitly addressed. Second, there should be some mechanism(s) for preventing undesired technology leakage to foreign firms. Third, any patent pool should be open to U.S. startups, since the existing firms, e.g. Zenith, are not guaranteed to perform well. Fourth, R&D should focus upon digital, two-way systems rather than simply dumb receivers. Fifth, semiconductor technology and related industry support should be explicitly addressed through R&D, not simply by waiting for HDTV demand to appear. Sixth, there should be substantial funding for research in strategy analysis, policy analysis, and education. And seventh, very wide consortia with high coordination costs should be avoided in favor of smaller, more focussed consortia with a few firms each, and possibly with several competing consortia in each area selected.

2) U.S. policy to promote advanced digital networking infrastructure

DEC has a strong interest in the provision of large scale, public networking infrastructure because (a) RBOCs would require systems to manage their internal networks and (b) networking would become easier, stimulating demand for network-oriented systems. There is a strong case to be made for large scale R&D support and/or demonstration projects in this area, both for consumer two-way services and for industrial/office/research applications such as the fiberoptic supercomputer network recently proposed by Senator Gore of Tennessee. High-performance research workstations with real time graphics connected to hosts and supercomputers are a likely, early application of many of the technologies which, at lower cost and later in their life cycles, would be used for two-way digital "HDTV." DEC should support work in this area and its incorporation into the public policy agenda, particularly because of DEC's strong university presence.

3) U.S. policy for digital facsimile, copiers, and imaging systems

In some ways, it is very curious that consumer HDTV has acquired the political momentum that it has, given that the U.S. office equipment industry is larger, comparably important, and comparably affected by the advent of advanced digital systems. DEC should explore ways to form both private and political coalitions to re-orient the HDTV debate towards R&D and policy for industrial, office, and perhaps defense applications as well as consumer services. Demonstration projects for research contexts might be

particularly valuable here, for example one involving campus-wide networking with workstations, laser printers, CD ROM archival systems, digital facsimile, and large databases. This generic area is one in which DEC has a strong position, EXCEPT in the hardware technologies of the peripheral devices, and there exists a problem comparable to that associated with the consumer sector. Canon, Sony, Ricoh, Toshiba, and Matsushita could well take this area from Xerox, Kodak, and other U.S. firms as digitization progresses.

4) RBOCs and deregulation

This is perhaps the most complicated and immediate issue facing DEC. The RBOCs are likely to be the organizations of choice for U.S. implementation of large-scale public fiberoptic delivery and network systems. In addition, the Federal Communications Act of 1934 limits foreign penetration of U.S. common carrier markets. No common carriers -- such as broadcasters or RBOCs -- may be over 20% foreign-owned. While it is in principle possible to evade this barrier, e.g. through leasing arrangements, it seems likely that regulators would react and that, at least for now, U.S. common carriers will remain U.S.-controlled. Therefore any activities dominated by common carriers are to some extent sheltered from foreign control.

However, RBOCs are currently severely restricted both by statutory regulators and by Judge Greene. It appears to be in DEC's, and the nation's, interest to partially deregulate them, and certainly to encourage them to provide public fiberoptic infrastructure. However, DEC should not seek full deregulation.

In particular, RBOCs should not be permitted to sell consumer equipment until and unless a U.S. industry is firmly re-established, by policy and/or commercial success. Otherwise the RBOCs will almost certainly become distributors and integrators of Japanese equipment, not only for consumers but also, more dangerously, for businesses. This could easily include digital fax, printers, imaging equipment, and personal computers, as well as networking services related to them. Delaying RBOC deregulation in this area has the additional advantage that it gives the industrial market (DEC, for example) more time to establish its products and customer installed base in office systems before risking increased competition from low-end Asian hardware via the crossover between home and office markets the RBOCs could provide.

On the other hand, the RBOCs should be permitted to perform R&D and software development, with U.S. partners and probably even foreign partners, for the systems they buy and integrate into their internal networks. They should also be permitted to offer content-free digital services such as protocal conversion, facsimile mail, and so forth, as long as they are REQUIRED to offer digital dial tone -- i.e. generic digital carrier services to customers wishing to process their data internally. This structure would give DEC valuable opportunities to gain experience through joint efforts with RBOCs, and to sell both hardware and software to a large domestic market, including both RBOCs themselves and other corporate accounts. DEC

might then be able to sell such packaged systems and software to foreign markets as well. If U.S. policy provides R&D funding for RBOCs and/or Bellcore for establishment of digital standards and infrastructure, RBOCs should be permitted to license technology nonexclusively, but only to U.S. firms (or, if co-standardization agreements are reached with Europe, with European firms).

U.S. standardization is a major issue, however. The RBOCs have become quite independent of each other, and could easily progress towards incompatible systems. This would be far worse for business markets than for consumer markets, and should be avoided through policy at the Federal level.

5) the role of Europeans and U.S.-European cooperation

If at all possible, it would be highly desirable to create a joint U.S.-European common arena in not only consumer HDTV but advanced digital infrastructure and standards generally. Europe has significant consumer electronics assets and is a major market, while lacking a powerful computer industry with associated networking and software abilities. Hence it is in the U.S. interest, and in DEC's, to secure European cooperation in building both consumer equipment and the large scale infrastructure necessary to support advanced digital services for both home and office use. However, such cooperation should be conditional upon reciprocal access to markets, which could become a far more substantial issue following 1992. Cooperation with Siemens and Philips, particularly in semiconductors and displays, could be very attractive for DEC.

6) the role of the Japanese

It is difficult to imagine a U.S. or European technology base for mass production of digital systems and peripherals comparable to that of Japan. However, it is equally difficult to imagine circumstances in which Japanese dominance of future digital equipment markets would not be exceedingly dangerous for DEC and for the U.S. computer and office equipment industries generally. The best way to obtain Japanese involvement with HDTV or related arenas seems quite similar to that used by Japan twenty to thirty years ago: effective market closure followed by bargaining for technology transfer to upgrade the technology level of local production. In general, this has proven difficult for U.S. firms to do. An explicit U.S. HDTV patent pool or other similar controls, i.e. the ability to exclude Japan from advanced equipment markets might be sufficient. But such negotiations should only be opened after a strong U.S. policy is put in place, and DEC's first interest should be in obtaining such policies.

f: HDTV

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INTEROFFICE MEMORANDUM

TO: HDTV INTEREST LIST
JFS STAFF
SRG STAFF

DATE: 26 OCTOBER 1989
FROM: PAUL J. CURTIN
DEPT: NEW COMPUTING STRUCTURES
EXT: 223-6596
LOCATION: MLO12B/U10
NET ADD: ASABET::CURTIN

SUBJECT: AEA'S NEW POSITION

The AEA has moved from a position of wanting the U.S. to participate in an HDTV Consumer Business to a position of recognizing High Definition Systems (HDS) as a key component of the Information Age. HDS are a major part of the infrastructure which will support Computers, Commercial Systems and Defense Systems.

Attached is a paper presented by Pat Hubbard this week outlining AEA's position.

Attachment

"The Information Age--Will the U.S. Be a Leader?
High Definition Systems--a Key Part of the Answer"

Pat Hill Hubbard, Vice President
The American Electronics Association

Business and Technological Challenges in HDTV
Washington, D.C. Conference--Electronic Engineering Times
October 25, 1989

Fifty years ago this past April, television was officially "born" in this country. Few appreciated then what hindsight shows today--that television has played an instrumental role in fostering worldwide Globalization. Yet, the bi-centennial birthday of this momentous technology went largely unnoted in its own American birthplace. The reason is that from a position in the 1970's of virtual domination of worldwide consumer electronics--with television at its core--our Country's market position has declined to less than a 5 percent share. A party without the guest of honor is a sober celebration indeed!

But what's the big deal about a missed party? After all, the American consumer still buys and enjoys television. And "couch potatoes" in particular are looking forward to the advent of this new technology the press and trade journals are full of today--high definition television (HDTV). HDTV promises to replace that blur on our screens with pictures as clear as 35 mm movie-house film with compact disc sound to boot.

The issue is that the U.S. government and industry need to form a partnership to begin building a new high definition technlogy based industry. If they do not, 10 to 20 years from now our European and Japanese trading partners will likely be throwing parties and the U.S. will not be on their guest lists.

Losing consumer electronics was a serious error for the United States. Regaining it is a strategic necessity.

Consumer electronics now accounts for one-third or some $7 billion of the current U.S. electronics trade deficit with Japan. Furthermore, U.S. absence in consumer electronics is now used as an excuse by the Japanese as to why it is difficult for them to increase Japanese imports of U.S. semiconductors in spite of their agreement under the Semiconductor Trade Agreement to do so.

High definition television (HDTV) offers a gateway for U.S. re-entry into consumer electronics. Until a year or so ago most people looked at HDTV as simply a television technology. Today most knowledgeable people recognize that its real import is that it is a fundamental new imaging technology.

They understand that HDTV will herald introduction of fine new entertainment products. They appreciate even more, however, that eventually communications, computers, and entertainment will merge into inter-related high resolution digital technologies. This marriage will likely begin with televisions and VCRs because of their large market potentials. Predictably it will quickly spin off into military, commercial, and industrial markets where the market applications are countless--engineering work stations, computer assisted design, home marketing, air and command systems control, medical diagnostics, education and research, etc. Some 31 potential markets have already been identified.

If this were simply a market opportunity, however, AEA would not be in the picture. The downside is that if we don't participate we stand to lose serious market share over the next 20 years in a host of inter-related electronics semgents. As technology advances from ATV come about, they will "ripple" out and erode market share--first of semiconductors, then of others, such as computers, telecommunications, test equipment, software, automated manufacturing equipment. Eventually, virtually all key electronics industry segments will be impacted.

The semiconductor industry predictably will feel the new technology effects first. Unlike today's TV set, HDTVs will contain large numbers of computer memory chips (ICs). Only six percent of U.S. semiconductor units are now used in consumer products worldwide compared to 50 percent of Japan's. Following historical practice of foreign companies to produce and buy their own ICs, as HDTV production by foreign companies increases, U.S. semiconductor producers will sell fewer and fewer units.

The semiconductor impact is two-fold: loss of market volume and loss of technological know-how. The latter comes because U.S. non-HDTV manufacturers will not have benefit of HDTV's technological learning curves as product refinements advance core semiconductor technology. It is through the unique food-chain structure of the inter-releated segments of the electronics industry that HDTV has the capability over the next two decades to impact market share in other non-consumer areas.

Those who rebut the need for new U.S. entrants in HDTV usually point to the strength of today's American electronics industry. Ten years ago electronics was the sixth largest industry segment. Today it is number one, an industry which--

- Employs 2.6 million Americans
- Has created more than one million jobs since 1976
- Accounts for one out of every nine manufacturing jobs in the U.S.
- Is three times larger in employment than automobiles and nine times that of the basic steel industry

The long-term leadership of the U.S. electronics industry, however, is under serious threat today. The downward trend lines are unmistakable. The United States has an uncertain response to the changing international environment, the high cost of capital, and declining educational standards.

- Worldwide production of electronics products of the U.S. dropped from 50.4 percent in 1984 to 39.7 percent in 1987, while that of Japan rose from 21.3 percent to 27.1 percent in the same timeframe. In 25 industry product areas, the U.S. share went down in all but two.

- In 1983, the U. S. had 72.4 percent of the world wide market share in personal computers; by 1987 U.S. share had dropped to 69.1 percent. In 1988 Japan and Korea increased their world wide market share by 3.4 percent at the expense of U.S. IBM and Apple.

- In 1984 U.S. had 50 percent share of the worldwide semiconductor market and Japan had 33 percent; by 1988 U.S. share had dropped to 31 percent and Japan's had increased to 39 percent.

- In 1975 U.S. had 95.8 percent of world share of DRAMs and Japan had 4.5 percent; 12 years later, the U.S. has 17.9 percent of world share of DRAMs but Japan has 73.0 percent.

Seventy-three percent of world trade is NOT conducted by players operating in economic systems similar to our own. Our free trade policy, carried out in Washington and applauded by most--faces a Europe growing towards "controlled trade" and Japan and Korea with trade policies best described as "targeted."

Global economies of scale--driven by end-use consumer products--are becoming increasingly important. The challenge inherent in U.S. re-entry in consumer electronics is that traditional start-up practices "do not apply." In HDTV the U.S. faces not just giant multi-national firms, but multi-national company consortia assisted by government funding, some with difficult-to-penetrate home markets and with strategies of targeting foreign markets.

Advantages for those presently in today's U.S. television market combine to kept out new HDTV entrants. With the exception of Zenith, no American owned companies are yet able to participate in bringing HDTV into their own home market. Some, like Japan, with capital costs one-fourth ours have tremendous advantages in HDTV--R&D funding aimed at breakthrough technology, state-of-art manufacturing capabilities, and the luxury of pricing products without care for short-term profit returns.

The Japanese, working for some 24 years on HDTV, and Europe, for some 5 years, are in various stages of perfecting HDTV technologies. Europe has spent some $300 million via its Eureka Project 95 for HDTV prototype systems and standards. Europe also expects to impact with high definition technolgy non-consumer markets as well--especially automotive on-board navigation systems and traffic control systems.

One hour HDTV broadcasts are already taking place in Japan. The Japanese clearly see HDTV as a blurring of products and a way to capture U.S. marketshare in semiconductors, computers, and telecommunications in particular.

Fujitsui's "FM Towns" series of 16-bit PCs can easily have an HDTV standard display added to make them TV/computers. HDTV sets themselves pack so much processing power and machine memory that they can easily be adaptable the other way--as PCs. When this happens, U.S. PC and workstation manufacturers will feel the effects as they watch their market shares dwindle.

The Japanese Government's MITI is ensuring Japan's position as a leader of the Information Society of the 21st Century. They have not only developed HDTV technology at a cost of over $750 million to $1.5 billion over the last 24 years, but they continue to spending many millions more:

- Hi-Vision Cities (14 model cities)--$100 million to develop various HDTV applications)

- Teletopia and New Media Communities--Some 35 funded projects at about $5 million @ of government money matched by industry) to develop multi-media applications of advanced telecommunications technology.

- Three New R&D Consortia:

  1. High Vision Technology Lab (KTC, NEC, Seiko-Epson,and Meitek)--goal is to develop LCD display technologies to support flat panel screens. [$75 million over 4 years from government with considerably more from industry.]

  2. The Graphics Communications Technology Corporation--goal is to develop algorithms for processing 3-D and other image data, etc. This is basically computer technology and points to merging of TVs and computers. Applications will be TV telephones, CAD/CAD, factory automation, education, publishing, environmental sensing and measuring. [Around $5 million a year for four years.]

  3. "Giant Electronics" (17 companies)--goal is to develop technologies for producing high-density ICs over a large area (40% diagnonal surfaces or "Giant" electronics displays). Technology will be useful in all major display technologies, [LCD, Plasma displays, and thin-film transistors]--HDTV systems, photocopiers, touch panel screens, solar batteries.(Upwards of 90 million over seven years.)

One of the things this country seems to be missing--or at least the press seems to be missing--is that HDTV is a complex set of technologies. When people question whether the American consumer will spend the money to purchase an HDTV, their caution is essentiall right. But the caution does not lead to the typical conclusion that, therefore, the sales opportunities do not

warrant U.S. action. Unless a large scale effort is made to make the HDTV sets desirable from a TV programming as well as picture/sound quality view, make them cheap to buy, and make them seen as the "in" technology to have, few consumer will buy on their own--here or abroad. Japanese and European governments have recognized this and, Japan, in particular is "priming" its costomer pump--i.e., offering special bank accounts to encourage consumers to save money to purchase sets, developing programming, and distribution techniques, "wiring" demonstration cities, etc.

In spite of the fact that foreign companies have well-established marketing, manufacturing, and distribution infrastructure already in place in the U.S., we cannot afford to roll over without a strong effort to become a player. For one thing, American QUALITY jobs are at stake. The Europeans do extensive R&D, design, and manufacturing in the United States. The Japanese, on the other hand, have many U.S. based "screw-driver" factories where they assemble Japanese-produced electronics componentry into U.S. made TV receiver boxes. Many, are then sold down the street at Macy's, Circuit City, etc. with the notation "made in America."

Producing some 11-13 million TV tubes here does provide jobs for U.S. workers. Yet, in spite of labor economists who count all jobs gained or lost equally, manufacturing glass tubes requires significantly less skills and talent and commands lower wages than the engineering and technical skills required to design and manufacture complex integrated circuits.

Only six percent of U.S. semiconductor output is currently used in consumer electronics products compared to 50 percent of Japan's. Large numbers of consumer electronics technical "driver jobs" are clearly somewhere off our shores. HDTV is at heart an issue of these "driver jobs" for Americans.

AEA has studied the re-entry question for over a year. Finally in February of this year 36 member companies funded the Boston Consulting Group (BCG) to develop a strategy for U.S. participation in HDTV and its spin-off technologies and products.

BCG's strategy is comprehensive. AEA has reported it to Congress, beginning with Senate Science, Space, and Transportation Committee on May 10. The premise is that financial costs in this stage of the game are too high for a company or a consortia of companies. BCG calls for creation of a shared risk, industry and government partnership. This partnership would create a financially attractive environment where many companies--singly or in consortia--would be willing to match at minimum, dollar-for-dollar government resources. Key elements of the comprehensive strategy:

- Establish an industry-managed industry-government Advanced Television (ATV) Advisory Board to lead, coordinate, and monitor public and private actions needed to build a U.S. ATV industry (consumer, military, commercial markets).

- Make lower-cost capital available to the ATV industry for investment in research, infrastructure development, and business growth.

- Plug key holes in the U.S. technology base and pursue breakthrough technologies.

- Augment testing of prototype standards and select and administer the broadcast and program interchange standards in a way that fosters development of the U.S. industry.

- Following the lead of Japan, make investments which simultaneously boost program software availability and generate customer demand.

Efforts the last three months have been to communicate this plan to members of Congress and try to correct press mistatements describing it as a call for a government "giveaway;" in fact, the partnership requires a dollar-for-dollar match by industry, at minimum. To ensure that the U.S. takes the first-step of plugging HDTV technology holes, our latest efforts are directed at Congressional action to provide DARPA with $100 million in FY90.

The importance of HDTV to the U.S. technology base raises questions of national security. The chilling quote from Morita and Ishihara's new book "A Japan that Can Say No" makes the point:

> . . . If one doesn't use Japanese semiconductors, one cannot guarantee precision [in targeting missles]. No matter how much the Americans expand their military, they have come so far that they could do nothing if Japan were one day to say, "We will no longer sell you chips." For example, if Japan were to say that it will sell chips to the Soviet Union and not to America, that could instantly change the balance of military power.
>
> No to ieru Nippon, Akio Morita (Sony) and Shintaro Ishihara (Liberal Democratic Party), Kobunsha, January 1989, 4800.

AEA is also working to ensure that NIST receives adequate funding for its Advanced Technology Program." NIST acts in our strategy as a commercial counterpart to DARPA, ensuring the development of prototypes for HDTV COMMERCIAL manufacturing process technology.

The cost of capital issue is at heart of the difficulty in re-establishing U.S. manufacturing infrastructure. BCG has recommended--for want of a feasible alternative--that the government guarantee loans to the industry as well as provide low-cost loans directly. This is a strategy foreign governments have provided their industries for HDTV.

U. S. televisions bring notoriously low profits of 2-3 percent. Borrowing at U.S. interest rates of 10-13 percent makes an unattractive investment package for venture capitalists and Wall Street. This problem is amplified by the fact that HDTV market penetration will likely be some five to seven years out.

Nevertheless, investment must be made in HDTV in the 1990's in order to position for the real profits which will come in the year 2,000 and beyond.

Providing an R&D tax credit, reducing capital gains, and providing some anti-trust relief are all welcome actions by government to assist HDTV efforts. In addition, however, availability of capital at an affordable cost for manufacturing HDTV products is critical in order to jump-start a new ATV industry.

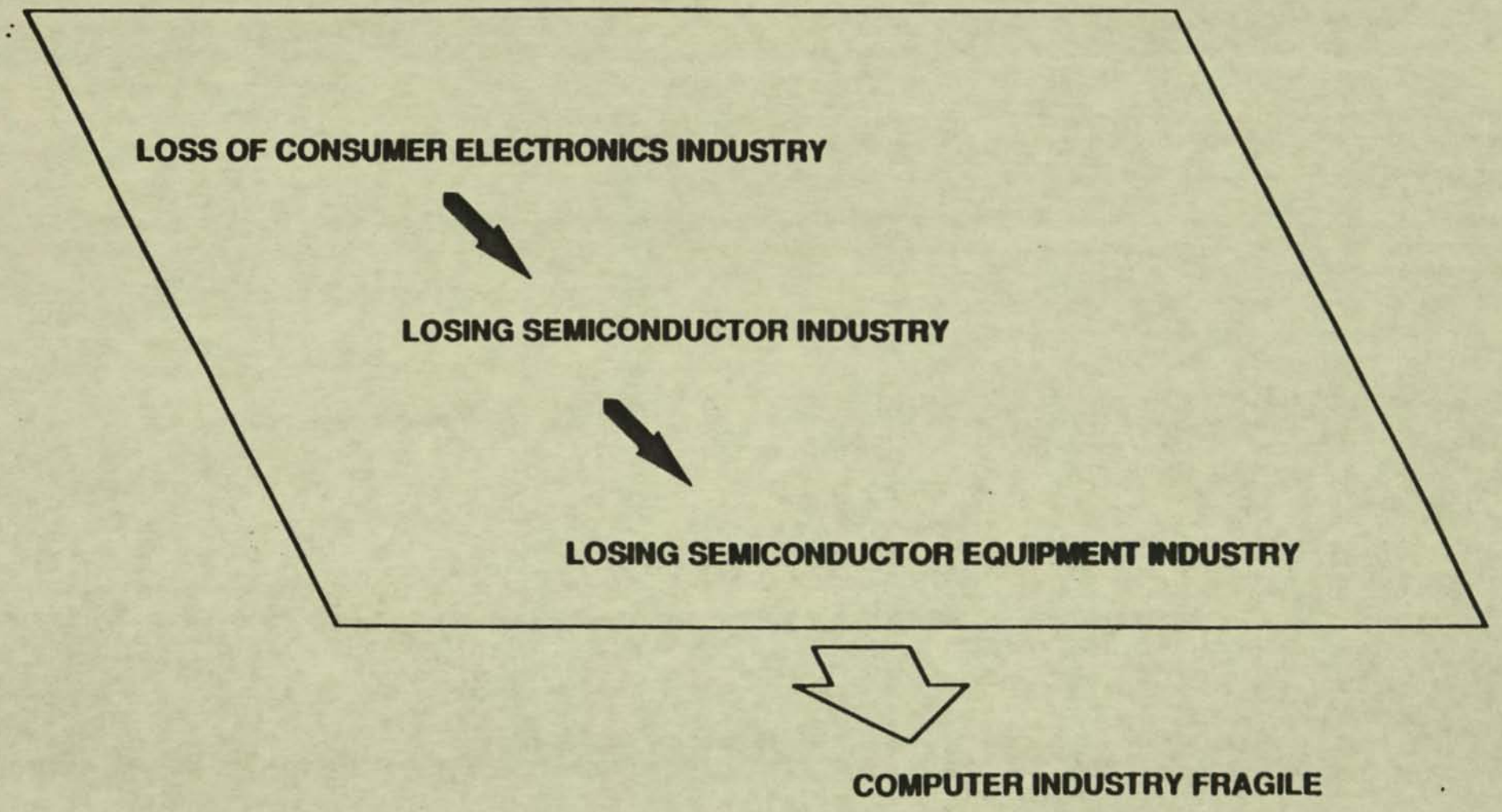
Today's Computer Age is the backbone for tomorrow's Information Age. Electronics, therefore, is not just ANY industrial segment, like autos or steel. It is strategic. It will underlie and shape the World's economy and its political organizations in the 21st Century. And high definition technologies will be at the hub of the Information Age's technological infrastructure. Every $1 billion in trade deficit accounts for 12,000 lost U.S. jobs. Lost market share translates into trade deficits. U.S. needs to gain an industry to retain an industry.

<u>American Electronics Association (AEA)</u>

AEA is a 46 year old non-profit trade group representing electronics and information technology companies. Its 3,500 member companies are located in 39 states, the District of Columbia, Puerto Rico, and Canada. AEA has 150 U.S. subsidiaries affiliated under its Tokyo trade office and until Tienemum Square had a beginning presence in China. In addition, 45 major U.S. universities are associate members of AEA, a reflection of AEA's longstanding effort to strengthen our U.S. university-industry relationships.

By David Seavey, USA TODAY

RIPPLE EFFECT



U.S. WORLD MARKET SHARE

ELECTRONIC PRODUCTS

1984	50.4%
1987	39.7%

PERSONAL COMPUTERS

1983	72.4%
1987	69.1%

SEMICONDUCTORS

1984	50%
1988	31%

DRAMS

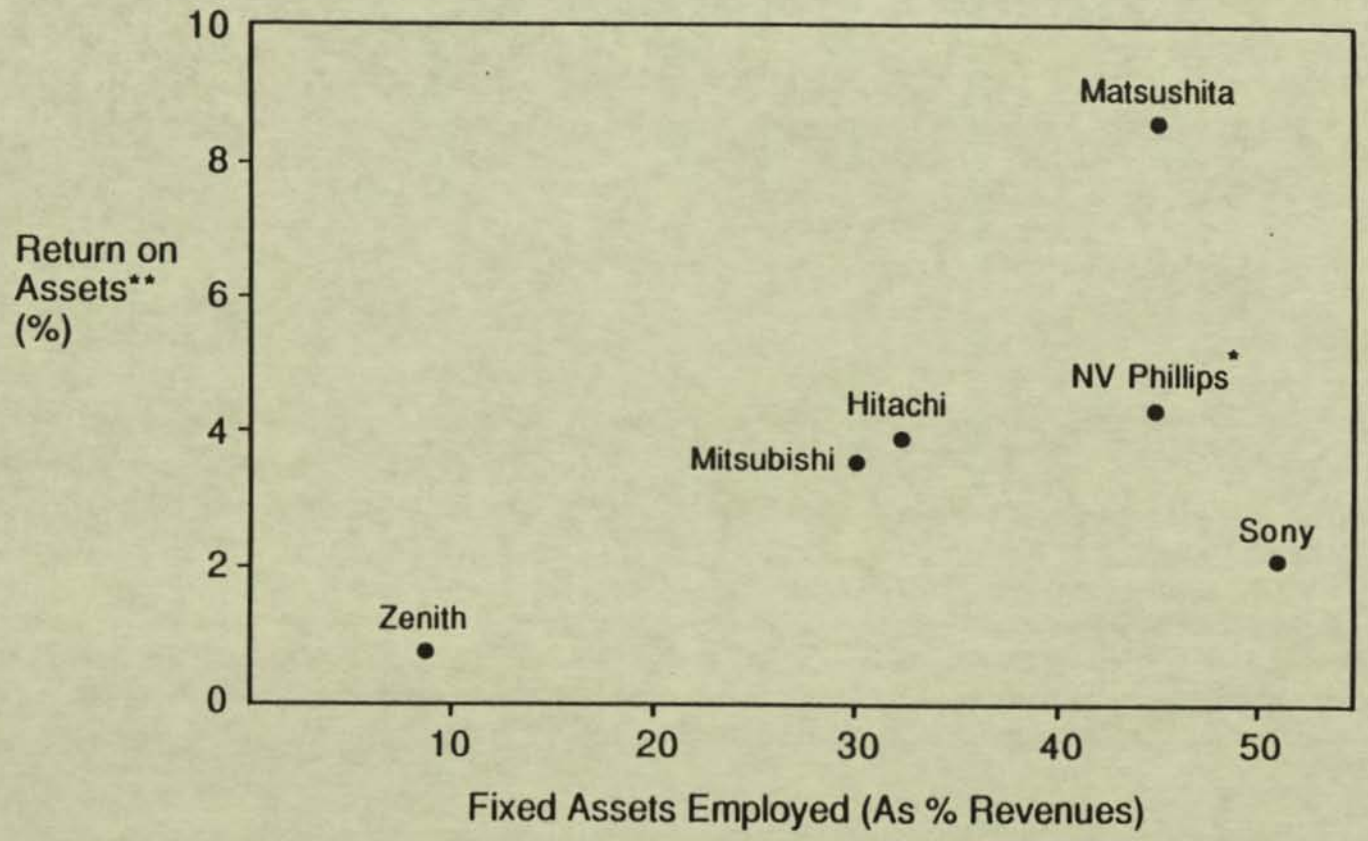
1975	95.8%
1989	12%

TELEVISIONS

1970	98%
1989	5%

FIXED ASSETS COMMITTED AND RETURNS EARNED

Major Consumer Electronics Companies, 1988



*1987

**Operating profit as percent of assets

Sources: Annual Reports; Goldman Sachs Investment Research

Japan's HDTV Technology : Not Just TV Sets

Product	*Company*	*Availability*
2000 x 2000 Pixel Workstation	Sony	Sold to U.S. 1989
Oil Field HDTV Process Control	N. Mining	February 1986
Optical Fiber HDTV Transmitter	NEC	June 1988
3D 1920 x 1035 Imaging Unit	Matsushita	July 1989
9-Processor MUSE Chip	NHK	July 1989
1950 x 1950 Pixel CAD / CAM	Hitachi	April 1989
1200-Line Video Camera	Sony	December 1988
30MHz Digital Frame Recorder	Sony	September 1989
HDTV Video Game	Namco	September 1988
Digital Videc Editor	NEC	April 1987
Mouse / Video "Videomat"	NEC	October 1988
Graphic Memory Simulation Unit	NEC	June 1988
HDTV Satellite Tuner	NEC H.E.	November 1988
Sequential Image Memory Unit	Ikegami	September 1988
Ultrasensitive Portable Camera	Ikegami	August 1988
Digital VTR	Hitachi	March 1989
Digital Video Disk Player	Sanyo	December 1988
32MHz Image Transmitter	Toshiba	February 1988
Magnetic Disk Image Bank	Toshiba	October 1987
35mm Laser Film Recorder	NAC, Inc.	January 1988
TV Camera Lenses	Fuji Optical	April 1989
230-Inch Projector	Matsushita	December 1988

AEA Japan Office

Henry Payne
Scripps Howard Newspaper Group
United Feature Syndicate

"Anyone knowing why the groom (who hasn't made a television in years) and the bride (who hasn't balanced her checkbook in memory) should not be joined in the production of high-definition TV, speak now or . . . "

AEA HIGH DEFINITION SYSTEMS TASK FORCE (HDS)

AT&T

ANADIGICS

APPLE COMPUTER

COHU, INC.

COMPRESSION LABS

CONT'L SATELLITE

DIGITAL EQUIPMENT

DOTRONIX, INC.

1ST PAC. NETWORKS

HARRIS SEMI.

HUGHES AIRCRAFT

IBM

I.T.T.

MCC

MRS TECHNOLOGY

MOTOROLA, INC.

NVISION

OMNISHORE

OVONIC IMAGING

PCO, INC.

PLANAR SYSTEMS

PROJECTAVISION

PROMETRIX CORP.

RAYCHEM CORPORATION

REBO HD STUDIO

SEATTLE SILICON

TANDEM COMPUTERS

TEKTRONIX, INC.

TEXAS INSTRUMENTS

THOMSON

VARIAN ASSOCIATES

VPL RESEARCH

XEROX CORPORATION

fr NDTV

BOOZ·ALLEN & HAMILTON INC.

555 MONTGOMERY STREET, SUITE 1700 • SAN FRANCISCO, CA 94111 • TELEPHONE: (415) 391-1900 • TELEX: 171800

To: AEA Board of Directors and
High Definition System Taskforce Members

From: Robert Lauridsen
Vice President
Booz, Allen & Hamilton

Date: February 21, 1990

Subject: Final Report, Phase I of the
High Definition Systems Taskforce

After discussion with numerous taskforce members, other AEA personnel and others outside of AEA, we have opted to prepare two distinct versions of our Phase I final report:

- Final Report
- Executive Briefing

The Final Report is a detailed report and describes the economic and competitive impact of advanced displays on the U.S. electronics industry. It is a baseline from which the HDS Taskforce will prepare its recommendations and proposed initiatives.

The second document found herein is a shorter Executive Briefing. We have prepared this document for use by you in educational efforts within your own company and for any external educational and policy discussions that you might initiate.

Sincerely,

Robert A Lauridsen

EXECUTIVE BRIEFING

PHASE ONE

COMPETITIVE AND ECONOMIC IMPACT OF HDS TECHNOLOGIES ON THE U.S. ELECTRONICS INDUSTRY

American Electronics Association AEA

AEA HIGH DEFINITION SYSTEMS TASK FORCE

FEBRUARY 21, 1990

BOOZ •ALLEN & HAMILTON INC.

PREFACE

In support of a strong and viable electronics food chain for the United States, the AEA has convened a taskforce to focus on the issues of High Definition Systems (HDS). Advanced displays were selected as a focal point since they represent a critical element of any high definition system and of the overall set of issues faced by American firms in this dynamic high technology area.

This report—prepared by Booz, Allen & Hamilton—is the final report for Phase I. The objective of the Phase I effort was to describe the likely economic and competitive impact of advanced displays on the U.S. electronics food chain. This report is intended to provide an analytical baseline for future recommendations by the AEA HDS Taskforce.

A brief Phase II report is planned. The objective of Phase II is to collect explicit feedback on the findings of Phase I from key stakeholders and corporate policy-makers in the industries most affected.

At the conclusion of Phase II, the AEA HDS Taskforce will publish under separate cover its recommendations and proposed initiatives for how the American electronics industry can ensure successful participation in this major technological area.

AEA MACROECONOMIC PERSPECTIVE

To ensure a healthy business environment for the U.S. electronics industry, AEA has long fostered macroeconomic remedies, such as:

- Improved availability of low cost, patient capital
- Permanence of the R&D tax credit
- Reduction in the capital gains tax
- Relaxation of antitrust legislation for joint manufacturing
- Strengthened funding of basic R&D

Solutions within this macroeconomic environment are essential to the future well-being of the United States. At stake is not only the future of the electronics industry itself, but the many basic U.S. industries, such as banking, steel, and autos, whose quality and productivity improvements are underpinned by electronics processes and technologies.. Ultimately, the quality of life for American citizens will be affected. Concomitant to the erosion of world markets is the loss not only of numbers but—more importantly—the quality of U.S. jobs.

Within the framework of larger economic issues, attention is also merited in microeconomic situations when the issue is a critical, fundamental emerging technology, such as high definition systems, and where non-U.S. competitors have the advantage of industry structure, government support, time, and financial resources.

AEA, February 1990

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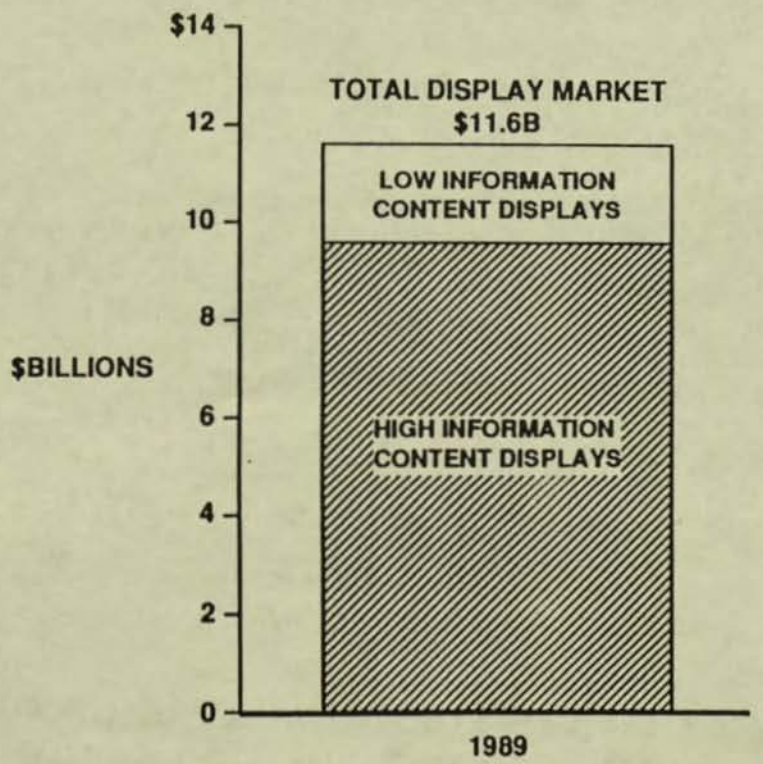
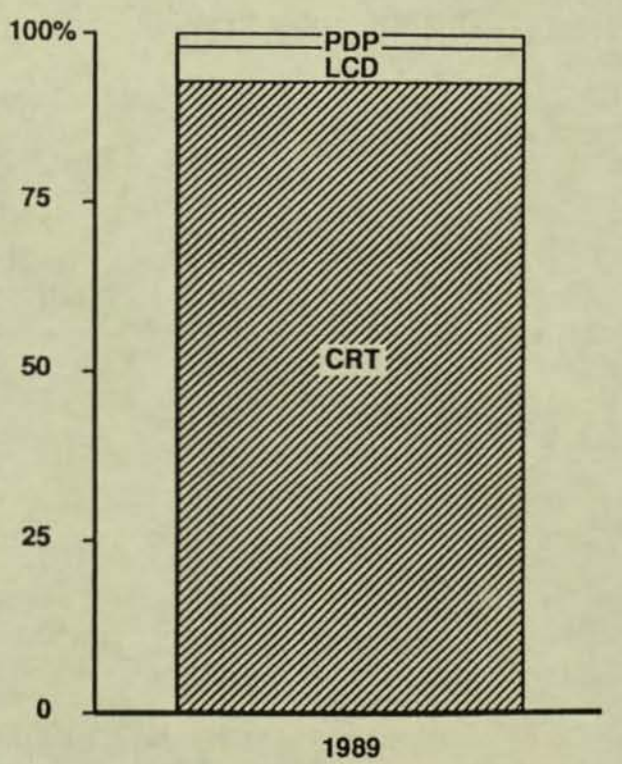
I. STRUCTURE OF THE DISPLAY INDUSTRY

CRTs CURRENTLY DOMINATE THE MARKET FOR HIGH INFORMATION CONTENT DISPLAYS, IN DOLLAR TERMS THE LARGEST SECTOR OF THE OVERALL DISPLAY MARKET

WORLDWIDE MARKET FOR HIGH INFORMATION CONTENT DISPLAYS



TECHNOLOGY SHARE IN HIGH INFORMATION CONTENT DISPLAYS
BASED ON DOLLAR SALES



NOTE: High information content is defined as > 100,000 pixels

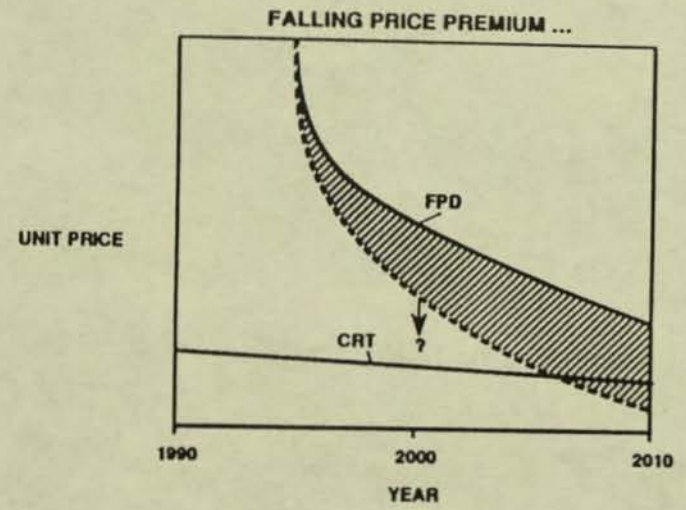
SOURCE: Stanford Resources

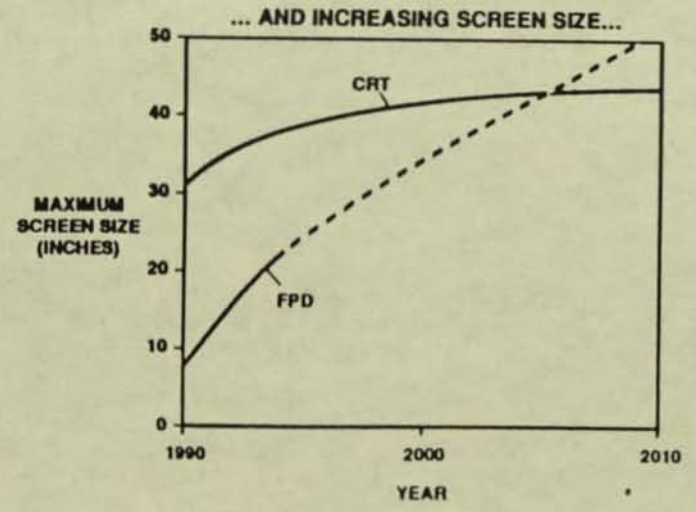
225-37663.4B

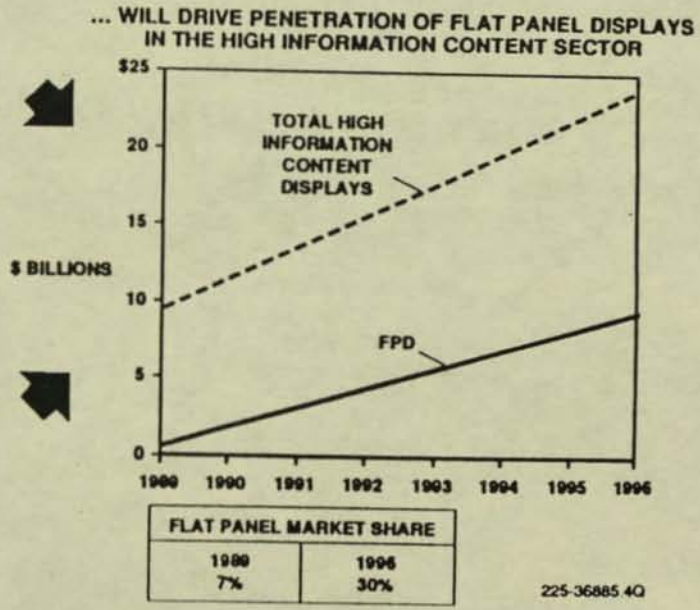
HOWEVER, BY THE END OF THE DECADE FLAT PANEL DISPLAYS ARE EXPECTED TO COMPETE WITH CRTs IN EVERY MAJOR APPLICATION SEGMENT

- CRT technology is approaching basic limitations in screen size and resolution.
  - Larger screen sizes mean substantially heavier CRTs and exponentially increasing costs.
  - Fabrication and alignment of CRTs becomes increasingly difficult as pixel densities and pixel counts continue to climb.
- While flat panel display technology is developing rapidly.
  - Current trends suggest that flat panel displays will approach CRT performance levels within the next ten years.
  - FPD technologies may ultimately allow the manufacture of larger displays than are economically viable with CRTs.
  - Scale manufacture and yield improvements will reduce their cost disadvantage over CRTs in the medium term.
  - FPDs have major intrinsic advantages over CRTs in both form factor and power consumption.

ONCE FLAT PANEL DISPLAYS HAVE ACHIEVED COMPARABLE SIZE AND PERFORMANCE TO CRTs, THEIR INTRINSIC ADVANTAGES WILL RESULT IN PENETRATION CONSTRAINED ONLY BY THEIR PRICE PREMIUM OVER CRTs







FLAT PANEL MARKET SHARE	
1989 7%	1996 30%

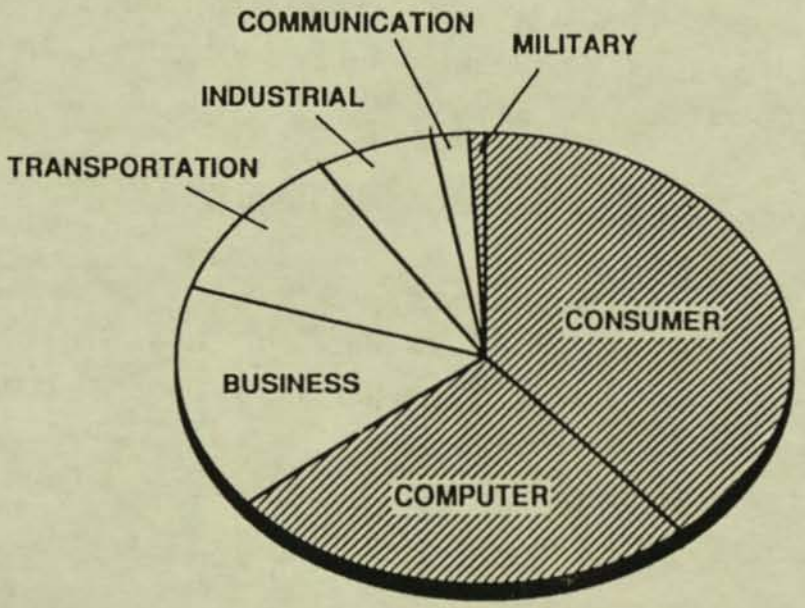
225-36885.4Q

SOURCE: Stanford Resources

II. IMPLICATIONS FOR KEY SYSTEM SEGMENTS

DISPLAY TECHNOLOGY WILL BE AN INCREASINGLY IMPORTANT FACTOR IN OVERALL COMPETITIVENESS FOR SEVERAL IMPORTANT U.S. MANUFACTURING SECTORS. WE WILL EXAMINE THREE—MILITARY, COMPUTERS, AND TELEVISION

WORLDWIDE DISPLAY MARKET FORECAST
FLAT PANEL TECHNOLOGIES - BY APPLICATION



1989
$3.2 BILLION

SOURCE: Stanford Resources, Inc.

225-36900.1Q

THE CONTINUED DEVELOPMENT OF ADVANCED WEAPONS SYSTEMS WILL REQUIRE INFORMATION SYSTEMS MADE POSSIBLE ONLY THROUGH FLAT PANEL TECHNOLOGY

- For advanced military systems, current CRT technology is seriously inadequate.
  - Limitations in brightness, definition, and screen size severely prejudice performance in key areas, including aircraft cockpit displays, shipboard and land-based command centers, and C^3I systems.
  - High power consumption, short life cycle, and fragility all limit systems reliability.
- Advanced flat panel technology has the potential to address all current display deficiencies, with considerable impact on overall weapons performance.
  - High definition and large screen areas allow integration of multiple displays into a complete situation awareness system
  - Advanced display technology can operate as a force multiplier on overall weapons performance

ACCESS TO THE MOST ADVANCED FLAT PANEL DISPLAYS WILL BE NECESSARY IF U.S. PC AND WORKSTATION MANUFACTURERS ARE TO OFFER A COMPLETE AND COMPETITIVE RANGE OF PRODUCTS

- The move to open systems makes product differentiation via processor and software increasingly difficult.

- Other bases of competition will thus assume growing importance.

  - Other forms of product differentiation
  - Manufacturing costs and quality
  - Design cycle time

- Access to display technology will play an increasingly important role.

  - In differentiation, via portable and small footprint products
  - In manufacturing, as an important part of overall costs
  - In time to market, through access to leading edge display technologies

COMPETITIVENESS IN FLAT PANEL WILL BE CRUCIAL IF THE U.S. IS TO RETAIN ITS STRONG MANUFACTURING BASE IN LARGE SCREEN RECEIVERS

- The majority of large screen receivers sold in the U.S. are manufactured domestically.
  - Color TV technology and markets were pioneered in the U.S., by U.S. companies, resulting in a very strong manufacturing infrastructure.
  - Transportation costs inhibit imports of large screen TVs.
- FPDs pose a serious long-term challenge to CRT technology.
  - The size and bulk of large screen CRTs is a substantial drawback.
  - FPDs may eventually allow the construction of much larger screen monitors.
  - FPDs allow a much smaller, lighter, and potentially cheaper, projection TV.
- A TV manufacturer must be competitive in displays.
  - The display is typically more than 50% of overall manufacturing costs.
  - Display technology will be extremely important in overall product differentiation.

ANY MERCHANT SUPPLY OF FLAT PANEL DISPLAYS WILL BE RESTRICTED AND UNCERTAIN

- There will be few manufacturers of advanced FPDs in the short term, and availability will be severely constrained.
  - Entry costs are high, and there are substantial technological barriers to entry.
  - The risk of rapid process obsolescence will retard increases in plant scale.
  - Manufacturing yields are still extremely low for larger screen size devices.
- Demand for advanced FPDs is projected to substantially exceed supply for several years.
  - Improvements in display size and performance are rapidly widening existing markets.
  - Advances in yield and scale will directly lower unit costs.
- The supply of Active Matrix LCDs is dominated by vertically integrated companies, with strong FPD demand for internal product lines
  - Portable televisions and camcorders
  - Portable PCs

CURRENT FLAT PANEL SUPPLIERS ALSO COMPETE IN GLOBAL SYSTEMS MARKETS, AND CAN USE CONTROL OF DISPLAY TECHNOLOGY TO GAIN COMPETITIVE ADVANTAGE

VERTICAL INTEGRATION BY LCD PRODUCERS INTO END PRODUCT MARKETS

LCD PRODUCER	PRESENCE IN END PRODUCT MARKET		
	PCs	WORKSTATIONS	TELEVISIONS
SHARP	▨	▨	▨
HITACHI	▨	▨	▨
OPTREX	▨	▨	▨
SEIKO EPSON	▨	▨	▨
TOSHIBA	▨	▨	▨
SANYO	▨	▨	▨
SEIKO INSTRUMENTS	▨	▨	
MATSUSHITA	▨	▨	▨

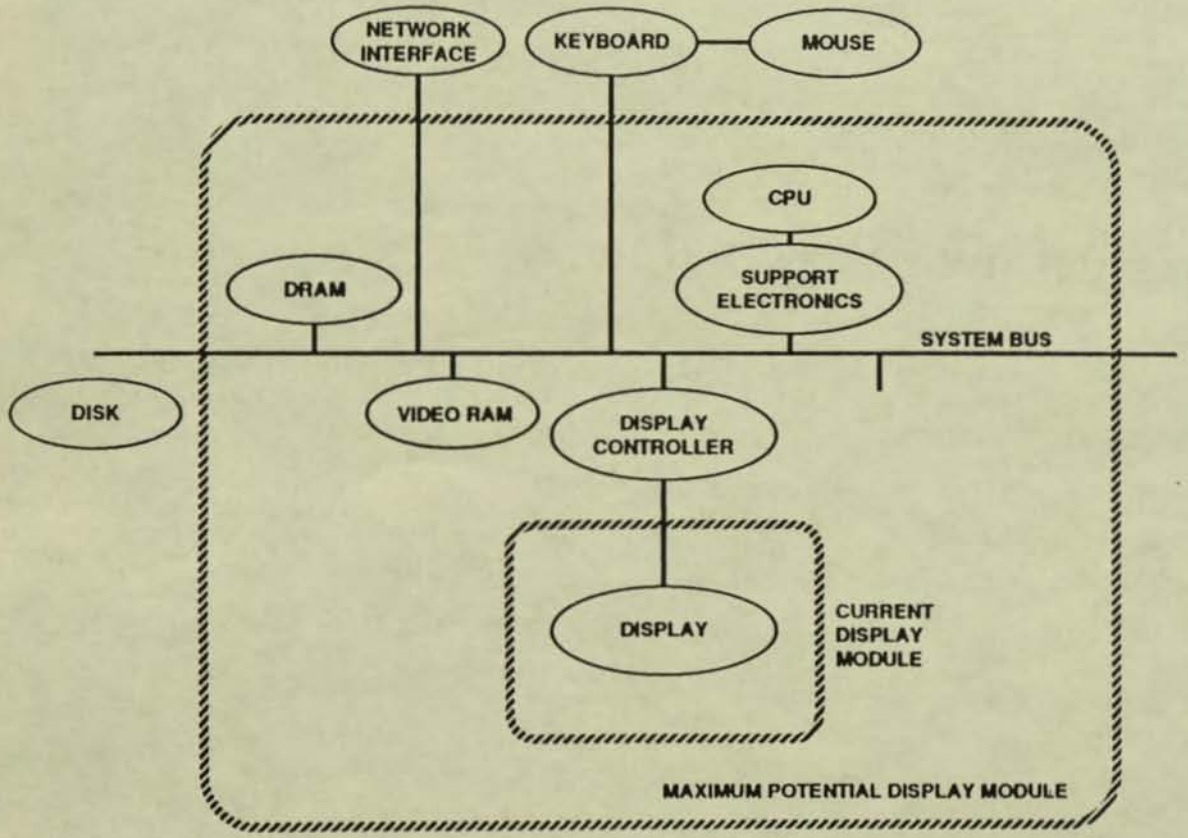
SOURCE: BAH analysis

KEY:
▨ *Indicates presence in end product market*

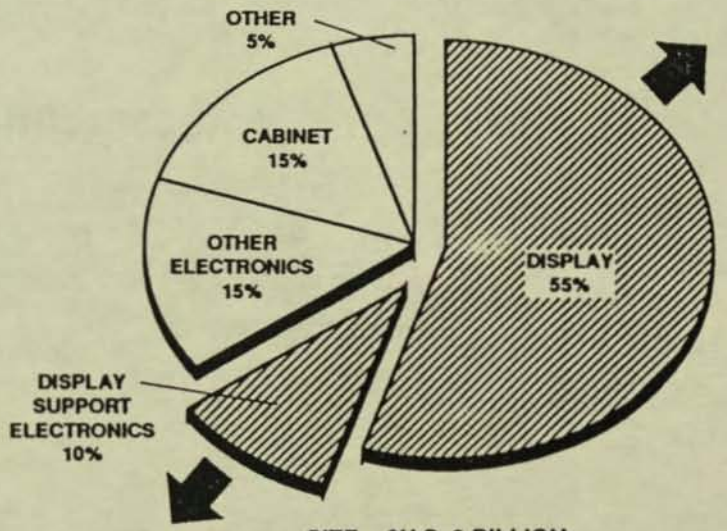
225-37725.Q

SIMULTANEOUSLY, ANY INCREASE IN SYSTEM INTEGRATION ONTO THE DISPLAY ELEMENT WILL HOLLOW OUT THE U.S. ELECTRONICS FOOD CHAIN, BY REDUCING THE VALUE ADDED AVAILABLE TO U.S. SYSTEMS PRODUCERS

POTENTIAL FOR INCREASED INTEGRATION INTO DISPLAY



BREAKDOWN OF TYPICAL LARGE SCREEN TELEVISION MANUFACTURING COST



SIZE = $U.S. 6 BILLION

NOTE: About 70% of U.S. value in a typical television is in the display component

SOURCE: BAH estimates

225-37665.2X

III. POTENTIAL FOR A U.S. BASED INDUSTRY

A SUCCESSFUL STRATEGY FOR PARTICIPATION IN FLAT PANEL DISPLAYS MUST BUILD ON FOUR BROAD CRITICAL SUCCESS FACTORS

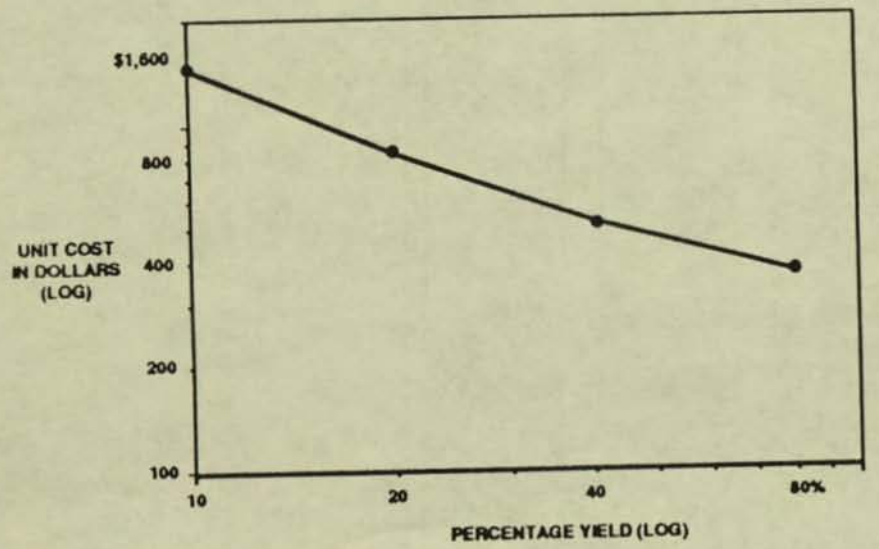
- Access to competitive technology.
- Sufficient financial resources to stay the course.
  - Start-up investment is large ($50 to over $100 million, depending on technology) but not prohibitive at current scale. However, expected rapid growth in scale will require sustained investment to remain competitive.
  - Closing any competitive gap in yields will require the ability to accept lower profitability (and possibly losses), potentially over an extended period.
  - Since both Japan and Korea have targeted FPDs as "strategic," current participants may be willing to accept low or negative returns in pursuit of long-term share.
- Sustained access to volume markets.
- Access to necessary engineering skills and to a world class industry infrastructure.

OF THESE FACTORS, SUSTAINABLE ACCESS TO VOLUME IS PERHAPS THE MOST CRITICAL FOR A U.S. ENTRANT

IN THE SHORT TERM ACCESS TO SUFFICIENT VOLUME FOR VIABLE MANUFACTURE CAN BE ACHIEVED IN THE COMPUTER MARKET

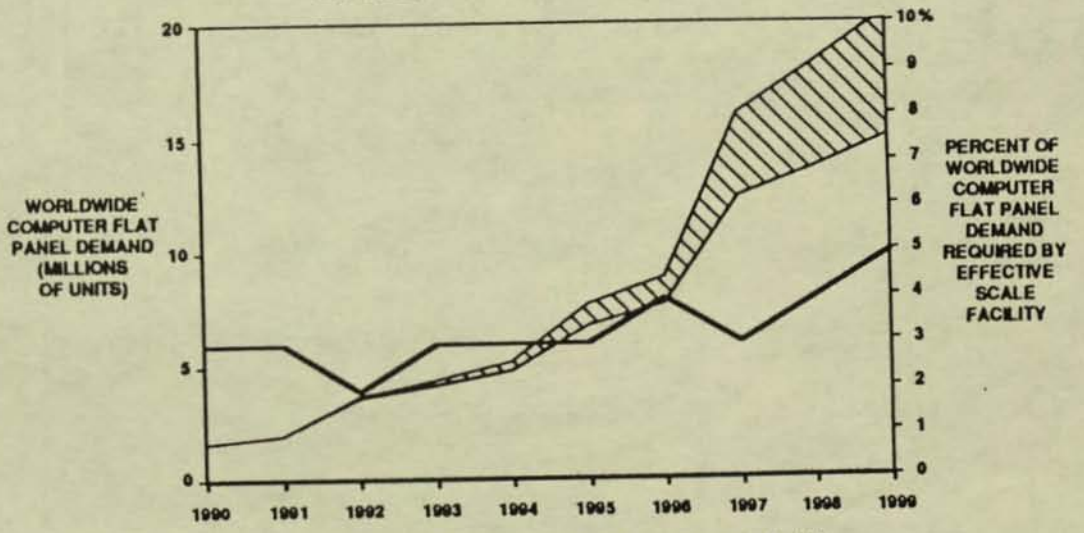
- Manufacturing scale in the short term will be relatively small.
  - Yield is the crucial cost driver and is broadly insensitive to scale.
  - There will be few facilities and their maximum scale is limited by equipment technology and the rapid rate of change in manufacturing process.
- Yielded output from an optimally sized facility will be a small fraction of overall computer demand.
- The market for advanced FPDs will develop in computers well in advance of mainstream TV.
  - The bulk of the TV market lies at substantially larger screen sizes than computers.
  - The TV market is extremely price sensitive, particularly in the small and medium screen segments where flat panel displays will first appear.

YIELD CURVE FOR AMLCD 6X8 INCH PANELS
(200,000 START FACILITY)



SOURCES: BAH analysis, Stanford Resources

SHARE OF WORLDWIDE COMPUTER FLAT PANEL DEMAND REQUIRED BY AN EFFECTIVE SCALE FACILITY



FACILITY SCALE ASSUMPTIONS: 1990 - 200K starts, 20% yield
1995 - 500K starts, 40% yield
1999 - 1,000K starts, 80% yield

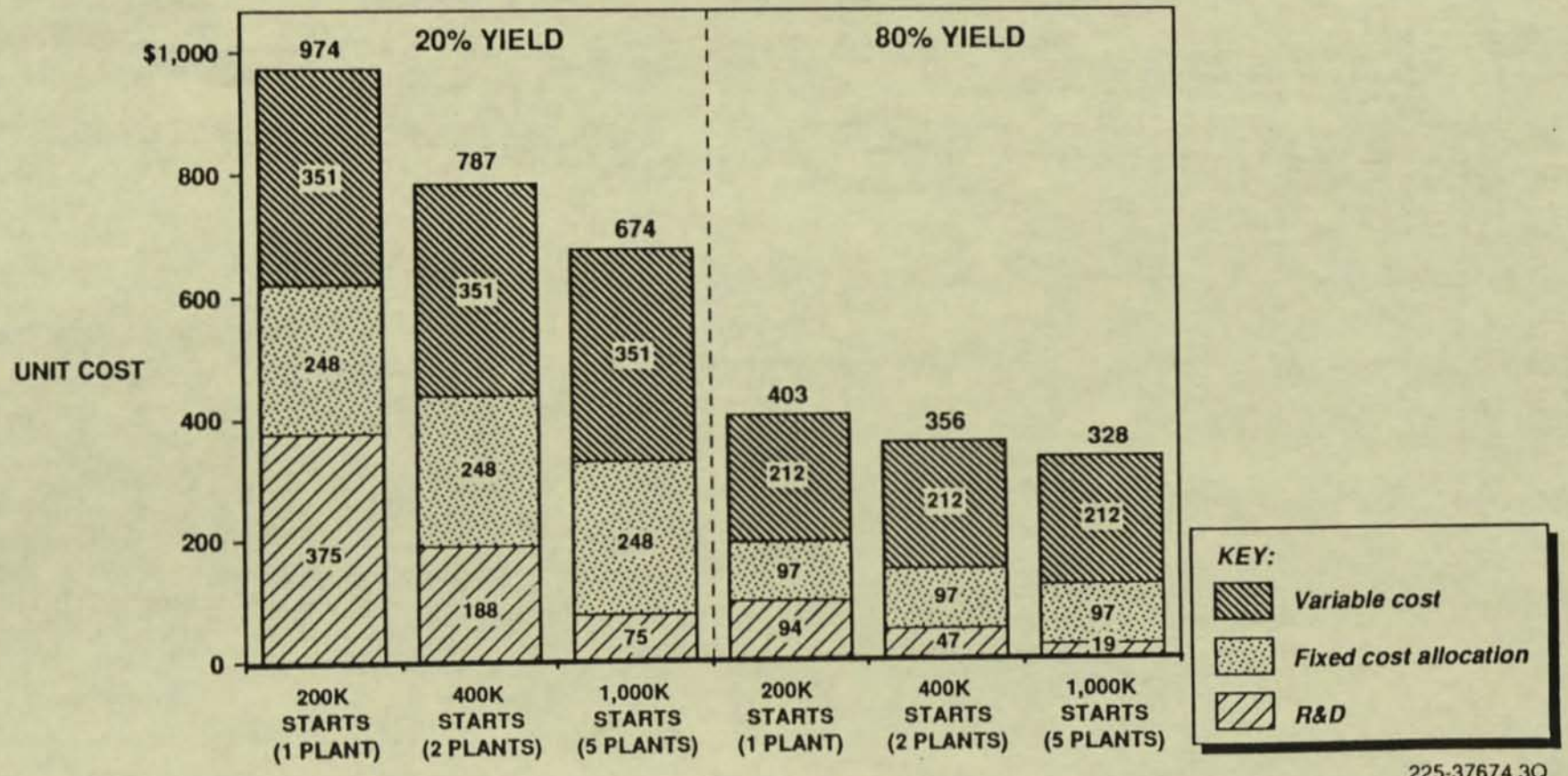
SOURCES: BAH analysis, Dataquest

KEY:
Estimated flat panel demand

225-37746.1S

HOWEVER THE HIGH ONGOING COST OF R&D WILL ADVANTAGE MARKET SHARE LEADERS

EFFECT OF $15 MILLION R&D EXPENSE AT VARYING YIELDS AND MANUFACTURER VOLUMES



225-37674.3Q

NOTE: This data is for an AMLCD 6x8 inch panel manufacturing facility

SOURCES: Stanford Resources, BAH analysis

In Summary ...

NONPARTICIPATION BY THE U.S. IN FLAT PANEL DISPLAY MANUFACTURING IS LIKELY TO SIGNIFICANTLY HOLLOW THE ELECTRONICS FOOD CHAIN

- The U.S. may lose a substantial share of manufacturing value added, since FPD plants are likely to be clustered around overseas R&D centers, at least in the short term.

- Higher levels of system integration onto the display will reduce the potential for U.S. manufacturing value-added and substantially reduce local component procurement.

- Unlike CRTs, there will be few incentives toward local manufacture of FPDs, and therefore little reason to source material or components locally.

- U.S. systems companies may be substantially affected by restricted access to advanced FPD technology

  - Merchant supply will be restricted or nonexistent.

  - Systems companies may find themselves dependent on competitors for FPD supply.

  - The inability to integrate systems onto the display module may lead to a substantial cost and performance disadvantage.

HOWEVER THERE APPEARS TO BE A REAL AND CURRENT OPPORTUNITY FOR THE U.S. TO PARTICIPATE

- Entry must occur soon, in order to minimize any deficit in process and product technology.
- The venture must have sufficient resources to sustain the ongoing investment required to remain competitive in R&D and overall scale.
- There are opportunities available in the U.S. to achieve viable production volumes
  - In the short term, via the strong U.S. presence in PC and workstation manufacture
  - And in the long term, via the strong U.S. manufacturing base in televisions

FINAL REPORT

PHASE ONE

COMPETITIVE AND ECONOMIC IMPACT OF HDS TECHNOLOGIES ON THE U.S. ELECTRONICS INDUSTRY

American Electronics Association AEA

AEA HIGH DEFINITION SYSTEMS TASK FORCE

FEBRUARY 21, 1990

BOOZ •ALLEN & HAMILTON INC.

PREFACE

In support of a strong and viable electronics food chain for the United States, the AEA has convened a taskforce to focus on the issues of High Definition Systems (HDS). Advanced displays were selected as a focal point since they represent a critical element of any high definition system and of the overall set of issues faced by American firms in this dynamic high technology area.

This report—prepared by Booz, Allen & Hamilton—is the final report for Phase I. The objective of the Phase I effort was to describe the likely economic and competitive impact of advanced displays on the U.S. electronics food chain. This report is intended to provide an analytical baseline for future recommendations by the AEA HDS Taskforce.

A brief Phase II report is planned. The objective of Phase II is to collect explicit feedback on the findings of Phase I from key stakeholders and corporate policy-makers in the industries most affected.

At the conclusion of Phase II, the AEA HDS Taskforce will publish under separate cover its recommendations and proposed initiatives for how the American electronics industry can ensure successful participation in this major technological area.

AEA MACROECONOMIC PERSPECTIVE

To ensure a healthy business environment for the U.S. electronics industry, AEA has long fostered macroeconomic remedies, such as:

- Improved availability of low cost, patient capital
- Permanence of the R&D tax credit
- Reduction in the capital gains tax
- Relaxation of antitrust legislation for joint manufacturing
- Strengthened funding of basic R&D

Solutions within this macroeconomic environment are essential to the future well-being of the United States. At stake is not only the future of the electronics industry itself, but the many basic U.S. industries, such as banking, steel, and autos, whose quality and productivity improvements are underpinned by electronics processes and technologies.. Ultimately, the quality of life for American citizens will be affected. Concomitant to the erosion of world markets is the loss not only of numbers but—more importantly—the quality of U.S. jobs.

Within the framework of larger economic issues, attention is also merited in microeconomic situations when the issue is a critical, fundamental emerging technology, such as high definition systems, and where non-U.S. competitors have the advantage of industry structure, government support, time, and financial resources.

AEA, February 1990

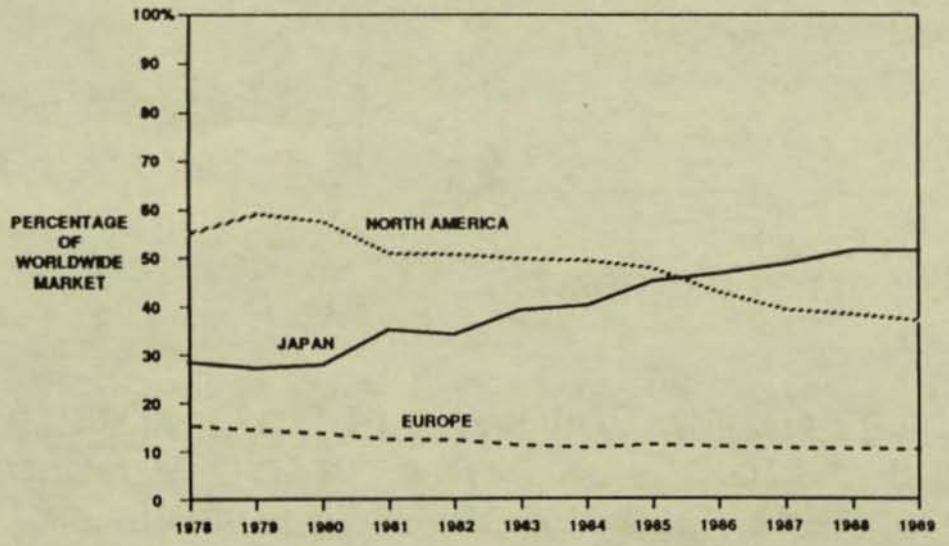
TABLE OF CONTENTS

I. INTRODUCTION

THE CONTINUING EROSION OF U.S. SHARE IN THE WORLDWIDE ELECTRONICS MARKET IS A WELL DOCUMENTED THREAT TO U.S. GLOBAL COMPETITIVENESS

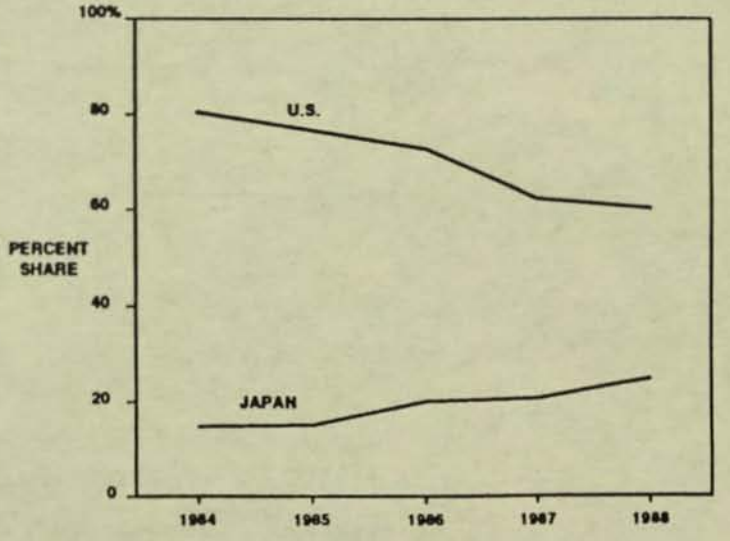
- Initial share losses at the component level are now being followed by losses at the systems level.
- Emergence of HDS technology and flat panel displays (FPDs) in particular provides a new opportunity for U.S. firms.
- If FPD manufacture is left to non-U.S. competitors, the U.S. market share in electronics, telecommunications, and computers will be affected.

REGIONAL SHARES OF WORLDWIDE SEMICONDUCTOR MARKET



SOURCE: Dataquest

U.S. AND JAPANESE SHARE OF WORLDWIDE DATA PROCESSING SYSTEMS REVENUES

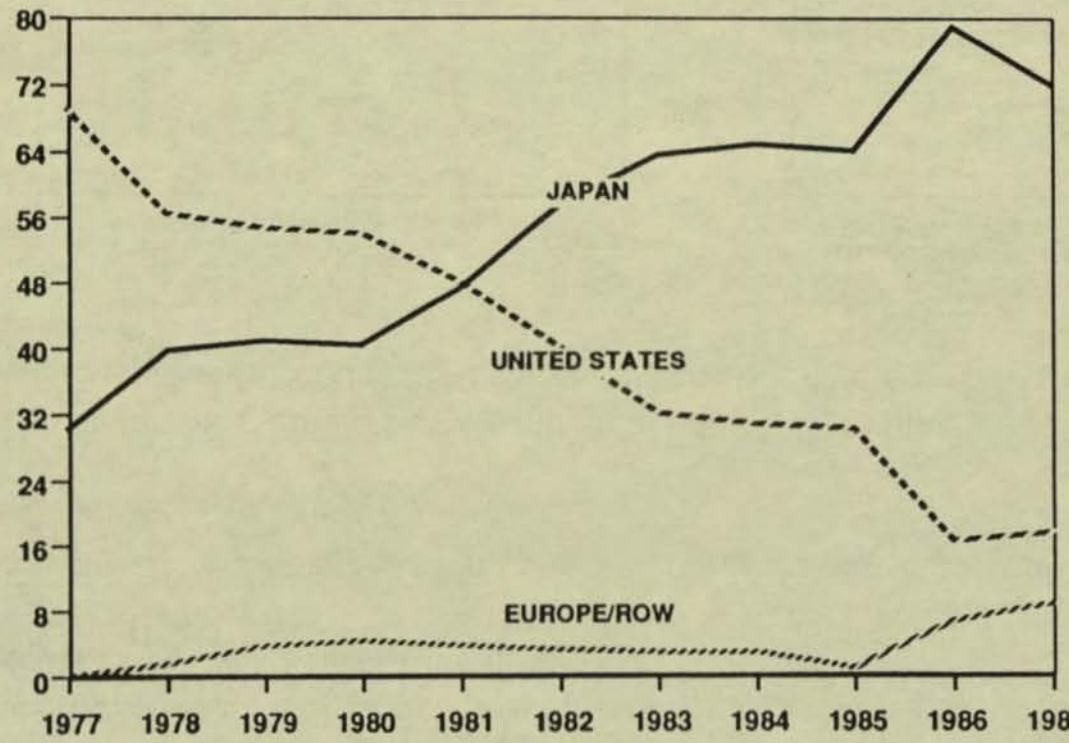


SOURCE: SIA

225-37730 1X

THIS EROSION IN SHARE HAS BEEN PARTICULARLY DRAMATIC IN HIGH GROWTH, CAPITAL INTENSIVE SECTORS SUCH AS DRAMs, TARGETED AS STRATEGIC BY OUR MAJOR COMPETITORS

WORLD DRAM MARKET SHARE
(PERCENT)



SOURCE: Dataquest

137-37684.1Q

AS ONE MEANS TO ENSURE A STRONG U.S. ELECTRONICS INDUSTRY, THE AEA HAS CONVENED THE HIGH DEFINITION SYSTEMS TASKFORCE

- High Definition Systems (HDS) involves an evolution and revolution in the importance of video technology to key industries and markets. While the consumer market will be affected in the long term (through IDTV, EDTV, and HDTV), the effects on industrial/ commercial/government markets will be felt much sooner.

- The taskforce has elected to focus initially on advanced displays, and particularly on the consequences for the U.S. electronics food chain of the shift from CRT to FPD technologies.

- Displays provide a powerful base on which to build a long-term HDS strategy. They are:

  - A critical element in the development of HDS systems.

  - Indicative of trends that are occurring throughout HDS.

  - Representative of the full set of issues faced by U.S. competitors in all high technology sectors, from components to systems.

II. EXECUTIVE SUMMARY

OVER THE NEXT 10–15 YEARS CRTs WILL BE REPLACED IN MOST APPLICATIONS BY FLAT PANEL DISPLAYS

CRTs currently dominate the market for high information content displays, in dollar terms the largest sector of the overall display market.

However, by the end of the decade flat panel displays are expected to compete with CRTs in every major application segment.

- CRT technology is approaching basic limitations in key areas, particularly screen size and resolution.
- While flat panel display technology is rapidly improving.
  - Current trends suggest that flat panel displays will approach CRT performance levels at reasonable cost within the next ten years.
  - FPD technologies may ultimately allow the manufacture of larger and higher resolution displays than are economically possible with CRTs.

Once flat panel displays have achieved comparable size and performance to CRTs, their intrinsic advantages in both form factor and power consumption will result in penetration constrained only by their price premium over CRTs.

ADVANCED DISPLAYS WILL BE IMPORTANT TO GLOBAL U.S. COMPETITIVENESS IN SEVERAL KEY INDUSTRIES

Military

The continued development of advanced weapons systems requires information systems made possible only through flat panel technology.

- CRT displays are seriously inadequate for advanced military requirements.
- Advanced display technology can operate as a force multiplier on overall weapons performance.

Computers

Access to the most advanced flat panel displays will be necessary if U.S. PC and workstation manufacturers are to offer a complete and competitive range of products.

- As product differentiation via processor and software becomes more difficult, other bases of competition will assume greater importance, including
  - Other forms of product differentiation
  - Manufacturing costs and quality control
  - Design cycle time and time to market

- Access to display technology will play an increasingly important role.
  - In differentiation, via portable and small footprint products
  - In manufacturing, as an important part of overall costs
  - In time to market, through access to leading display technologies
- FPDs may allow the integration of major system elements onto the display, providing a substantial cost advantage to a systems producer with internal FPD capability.

Television

Competitiveness in flat panel display technology will be crucial if the U.S. is to retain its strong domestic manufacturing base in large screen receivers.

- FPDs pose a strong long-term challenge to CRT televisions, by
  - Revolutionizing form factor in direct view TVs
  - Allowing smaller, lighter, and potentially cheaper projection TVs
- Competitiveness in TV manufacture is strongly affected by position in displays.
  - The display is typically more than 50% of total manufacturing cost.
  - FPDs may allow major system integration onto the display element.

ACCESS TO FLAT PANEL TECHNOLOGY MAY BE RESTRICTED RESULTING IN SERIOUS EROSION OF THE POSITION OF U.S. SYSTEMS MANUFACTURERS

The availability of advanced flat panel displays will be constrained for several years.

- High entry costs ($50 to over $100 million) and substantial technological barriers to entry will restrict the number of suppliers.
- The risk of rapid process obsolescence will retard increases in plant scale.
- Manufacturing yields are still extremely low for larger screen size devices.

Since the manufacture of flat panel displays is dominated by Japanese firms with large internal needs, any merchant supply will be restricted and uncertain.

- Demand for advanced FPDs should substantially exceed supply for several years.
- Internal demand for FPDs will remain strong.
- Manufacturers are having difficulty in meeting even single customer requirements.

These same companies also compete in global systems markets and can use control of display technology to gain competitive advantage.

Simultaneously, any increase in system integration onto the display element will hollow out the U.S. electronics food chain, by reducing the value-added available to nonintegrated systems producers.

HOWEVER IF PROMPT ACTION IS TAKEN, SUCCESSFUL U.S. ENTRY INTO FLAT PANEL DISPLAY MANUFACTURE IS POSSIBLE

A successful strategy for participation in flat panel displays must build on four broad critical success factors:

- Access to competitive technology
- Sufficient financial resources to stay the course
- Access to sustained volume sufficient for scale manufacture
- Appropriate skill base and supply infrastructure

In the short term a competitive cost position will depend on achieving competitive yield at the facility level; in the long term it will depend on achieving competitive scale at the manufacturer level.

Viable short-term volume is achievable within the U.S. computer markets; in the long term, viable scale will probably require access to the consumer electronics market. This suggests some form of strategic alliance for most U.S. players.

A U.S. entrant must move rapidly if it is to be successful.

- Late entrants will lag badly in process and product technology.

- Manufacturers who secure high volume production will have a cost advantage in R&D

III. STRUCTURE OF THE DISPLAY INDUSTRY

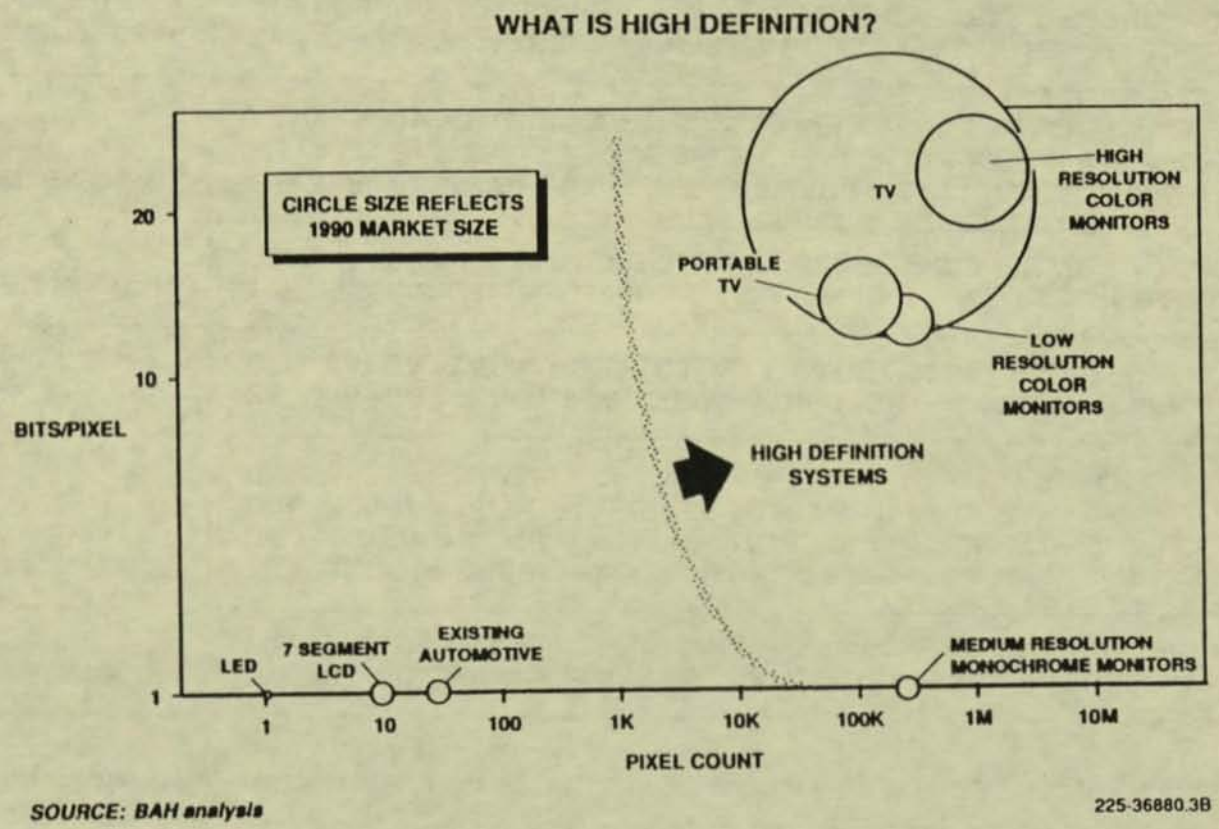
DIMENSIONS OF DISPLAY PERFORMANCE

SCREEN SIZE	RANGES FROM 1" OR LESS FOR SPECIAL PURPOSE APPLICATIONS TO GREATER THAN 30" FOR COLOR TV DISPLAYS
PIXEL COUNT	AS LOW AS 7 FOR A SINGLE DIGIT DISPLAY, UP TO GREATER THAN 4 MILLION FOR A CAD DISPLAY
PIXEL DENSITY	300 DPI WOULD BE NECESSARY TO MATCH THE DENSITY OF CURRENT LASER PRINTERS. CURRENT HIGH-END COLOR CRTs ACHIEVE AROUND 120 DPI
GREY SCALE	THE RANGE OF GRADATIONS IN BRIGHTNESS WHICH A PIXEL CAN ASSUME BETWEEN ITS FULLY ON AND ITS FULLY OFF STATE. IDEALLY SHOULD BE AT LEAST 3 BITS PER COLOR, WITH 8 BITS OR MORE REQUIRED FOR PHOTOGRAPHIC QUALITY. ANALOG CRT DISPLAYS ARE CAPABLE OF ESSENTIALLY INFINITE GREY SCALE.
COLOR CAPABILITY	RANGES FROM ZERO (MONOCHROME) THROUGH 8-16 COLORS (CURRENT GENERATION FLAT PANELS) TO FULL ANALOG COLOR CRTs
FORM FACTOR	THE RELATIONSHIP BETWEEN A DISPLAY'S DEPTH AND ITS SCREEN DIAGONAL SIZE. SHOULD BE AS LOW AS POSSIBLE IN ORDER TO PRODUCE A SLIM DISPLAY MODULE.
CONTRAST	THE BRIGHTNESS RATIO BETWEEN A PIXEL'S FULLY ON AND ITS FULLY OFF STATE. SHOULD BE AS GREAT AS POSSIBLE. CRT DISPLAYS HAVE A VALUE OF AROUND 70:1. ACTIVE MATRIX LCD DISPLAYS SHOULD ACHIEVE 40:1, WHICH IS ACCEPTABLE
LONGEVITY AND RELIABILITY	CAN BE AN ISSUE IN CERTAIN APPLICATIONS. CRTs, FOR EXAMPLE, HAVE A LIFETIME OF AROUND 10,000 HOURS, OR A LITTLE OVER ONE YEAR OF CONTINUOUS USE

SOURCES: Interviews, BAH analysis

225-36811.1T

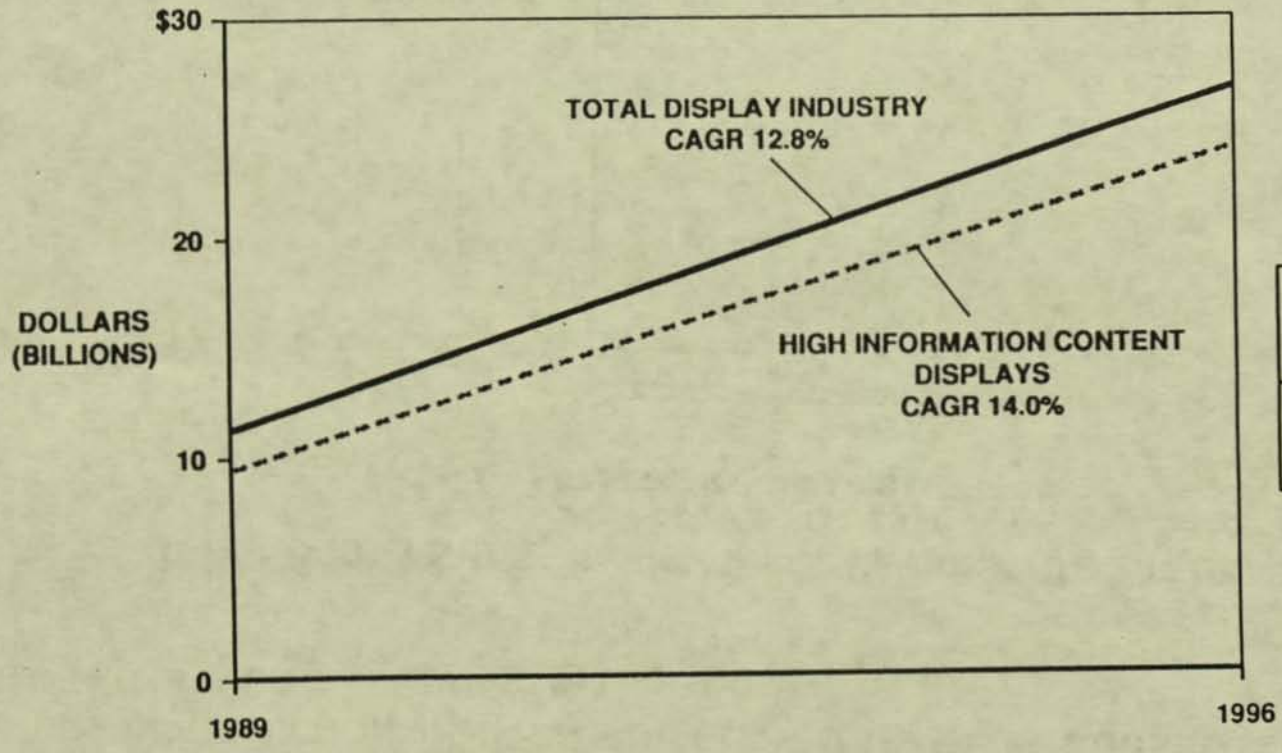
AT MATURITY THE HIGH DEFINITION SYSTEMS MARKET WILL ALLOW THE DISPLAY OF LARGE AMOUNTS OF INFORMATION IN FULL COLOR OVER A WIDE RANGE OF SCREEN SIZES



PARTICIPATION IN THIS HIGH GROWTH MARKET WILL REQUIRE PRESENCE IN TODAY'S DEVELOPING DISPLAY TECHNOLOGIES, AND PARTICULARLY IN FLAT PANEL

THE TOTAL DISPLAY INDUSTRY IS LARGE AND RAPIDLY GROWING, AND THE HIGH INFORMATION CONTENT SECTOR IS ALREADY THE MAJORITY OF ITS TOTAL VALUE

WORLDWIDE MARKET FOR HIGH INFORMATION CONTENT DISPLAYS
(> 100,000 PIXELS)



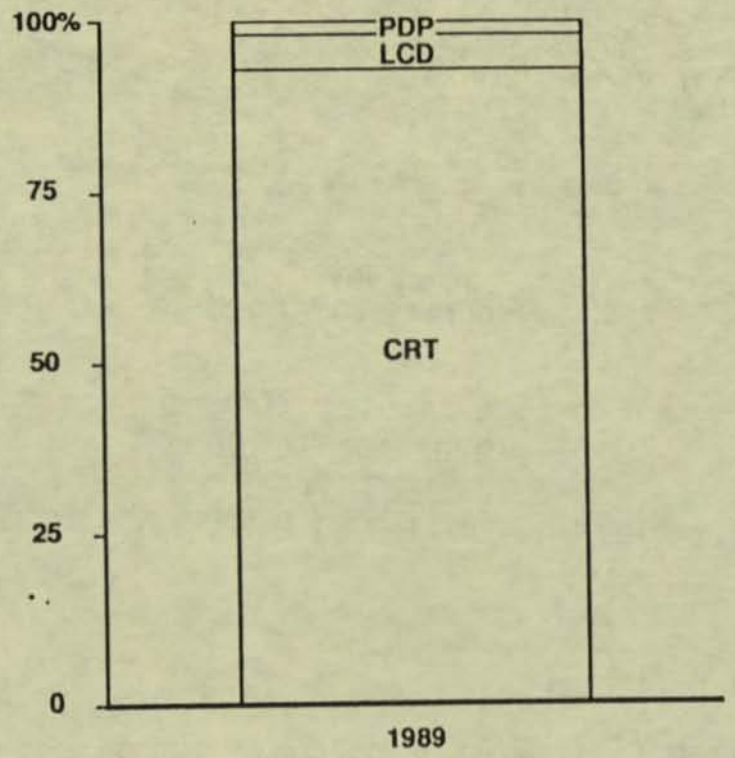
HIGH INFORMATION CONTENT SHARE OF DISPLAY MARKET	
1989	1996
83%	90%

225-36840.3B

SOURCE: Stanford Resources

THE HIGH INFORMATION CONTENT DISPLAY MARKET IS CURRENTLY DOMINATED BY CRT TECHNOLOGY

TECHNOLOGY SHARE IN HIGH INFORMATION CONTENT DISPLAYS
(>100,000 PIXELS)
BASED ON DOLLAR SALES



TOTAL HIGH INFORMATION CONTENT DISPLAY
MARKET = $9.6 BILLION

SOURCE: Stanford Resources

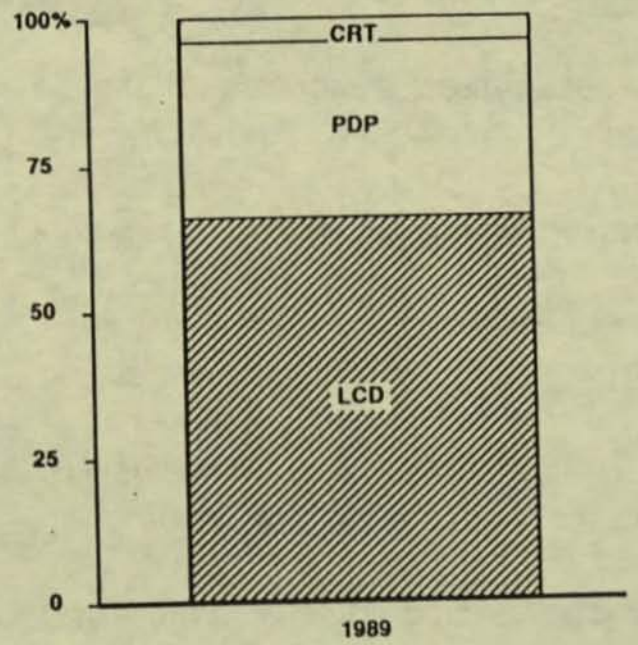
225-36841.1T

HOWEVER FLAT PANEL DISPLAYS ARE EXPECTED TO COMPETE WITH CRTs IN EVERY MAJOR APPLICATION SEGMENT BY THE END OF THE DECADE

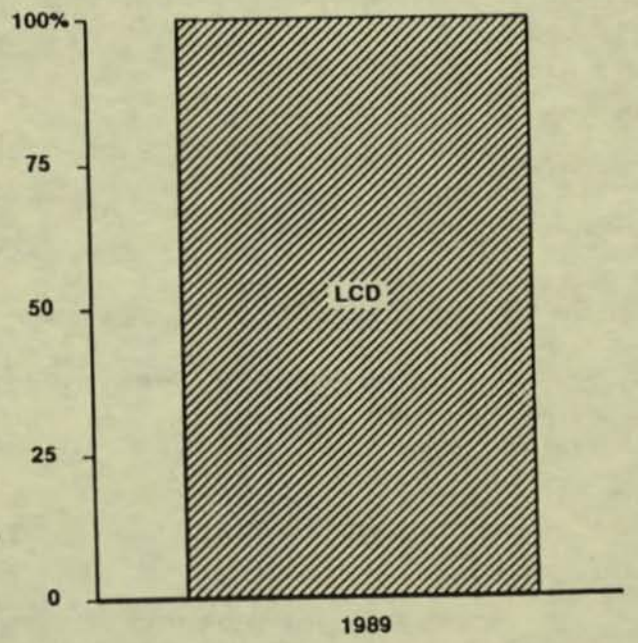
- CRT technology is approaching basic limitations in screen size and resolution.
  - Larger screen sizes mean substantially heavier CRTs and exponentially increasing costs.
  - Fabrication and alignment of CRTs becomes increasingly difficult as pixel densities and pixel counts continue to climb.
- Flat panel display technology is developing rapidly.
  - Current trends suggest that flat panel displays will approach CRT performance levels within the next ten years.
  - Scale manufacture and yield improvements will reduce FPD cost disadvantage over CRTs in the medium term.
  - FPD technologies may ultimately allow the manufacture of larger displays than are economically viable with CRTs.
  - FPDs have major intrinsic advantages over CRTs in both form factor and power consumption.

IN FACT, FLAT PANEL DISPLAYS (PRINCIPALLY LCDs) ALREADY DOMINATE THE DISPLAY MARKETS IN PORTABLE COMPUTERS AND PORTABLE TELEVISIONS

DISPLAY TECHNOLOGY UNIT SHARES
IN PORTABLE COMPUTERS



DISPLAY TECHNOLOGY UNIT SHARES
IN PORTABLE TELEVISIONS



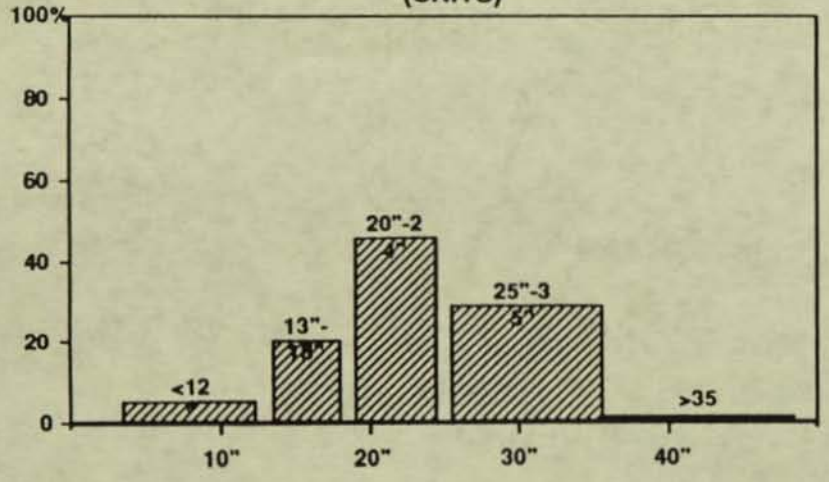
SOURCE: Stanford Resources

225-36842.2B

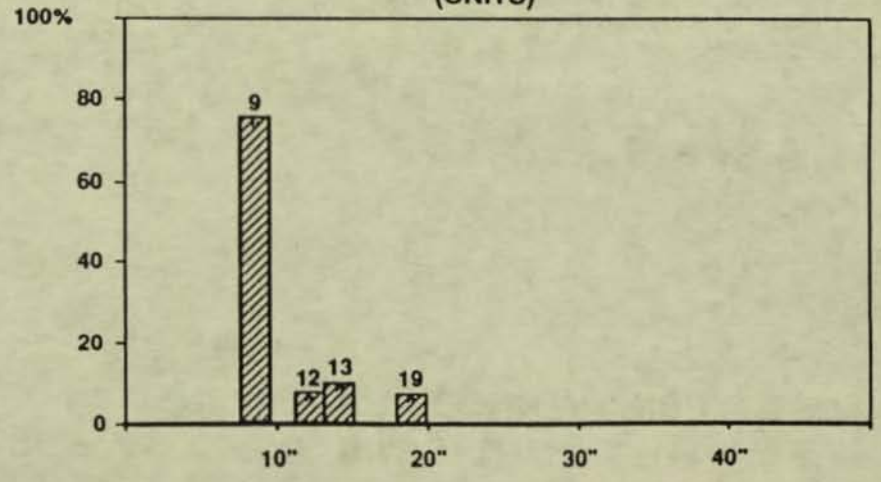
SCREEN SIZE EMERGES AS AN IMPORTANT FACTOR IN THE FUTURE PENETRATION RATE OF FPDs INTO THE DISPLAY MARKET

- The move to large scale manufacture of small screen FPDs is primarily one of driving down process experience curves on existing technologies.
- The move to competitive scale manufacture of large screen FPDs will, however, require breakthroughs in a number of critical process technologies.
- As a consequence, the penetration rates of FPDs into the consumer and computer markets may differ widely because of the differing screen size distributions in the two markets.

1988 U.S. TELEVISION SCREEN SIZE DISTRIBUTION
(UNITS)



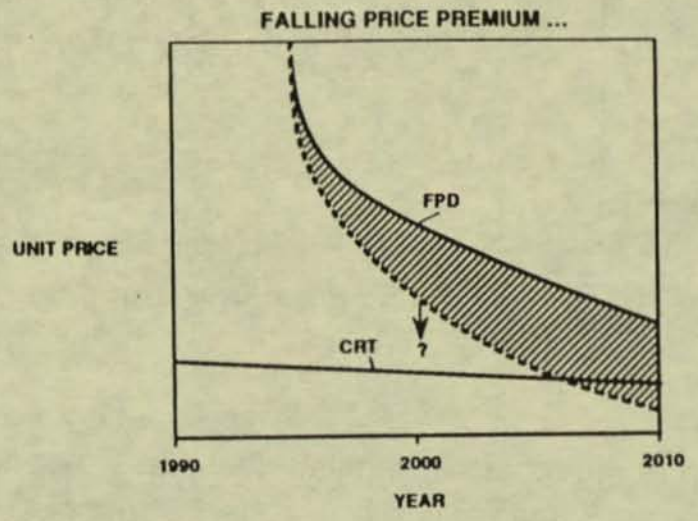
1988 APPLE MACINTOSH SCREEN SIZE DISTRIBUTION
(UNITS)

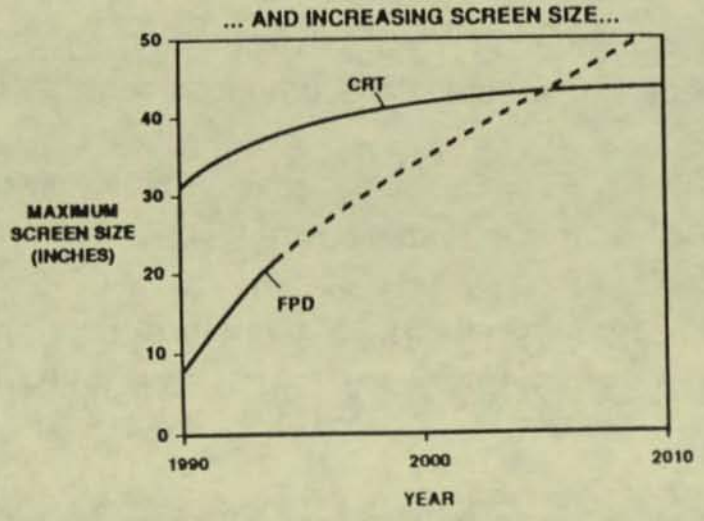


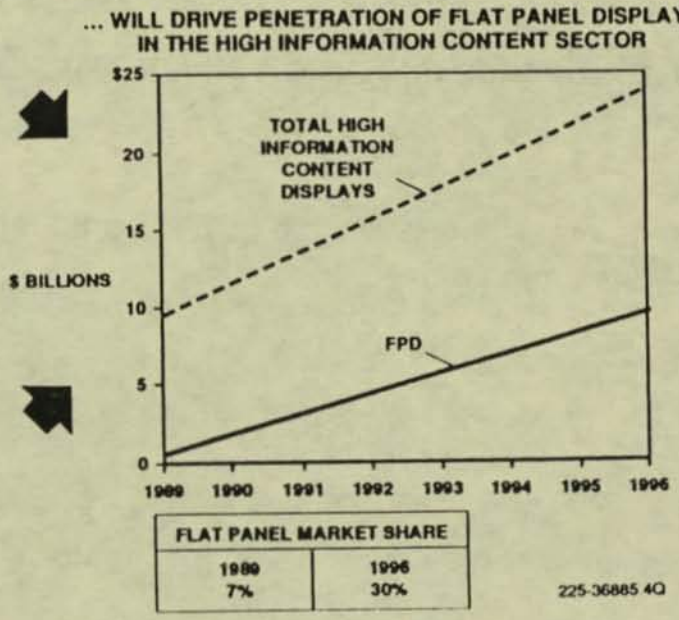
SOURCES: Dataquest, Thomson Electronics

225-36909.5Q

ONCE FPDs HAVE ACHIEVED COMPARABLE SIZE AND PERFORMANCE TO CRTs, THEIR INTRINSIC ADVANTAGES WILL RESULT IN PENETRATION CONSTRAINED ONLY BY THEIR RELATIVE PRICE PREMIUM VERSUS CRTs







FLAT PANEL MARKET SHARE	
1989	1996
7%	30%

225-36885 4Q

SOURCE: Stanford Resources

IN SUMMARY ...

- While the flat panel display market is already substantial and rapidly growing, the longevity of CRTs in the marketplace should not be underestimated.

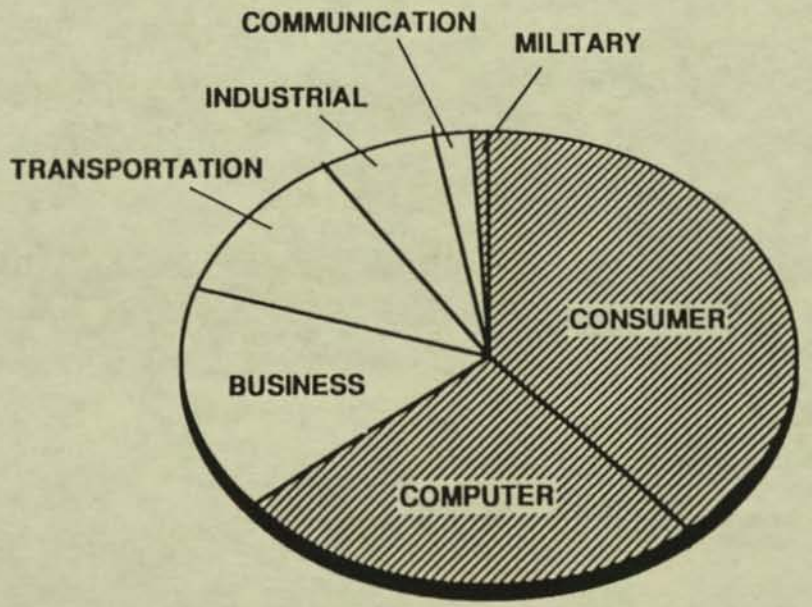
- FPDs will gain significant share of the high information content display market within the next decade, particularly in applications that require small to medium size screens—including the bulk of the computer market and the small screen TV market.

IV. IMPLICATIONS FOR KEY PRODUCT/SYSTEM SEGMENTS

- Military
- Computers
- Consumer TVs

THIS PROGRESS REPORT PROVIDES AN OVERVIEW OF THREE KEY APPLICATION SEGMENTS FOR FLAT PANEL DISPLAYS—MILITARY, COMPUTERS, AND TELEVISION

WORLDWIDE DISPLAY MARKET FORECAST
FLAT PANEL TECHNOLOGIES - BY APPLICATION



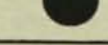
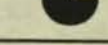
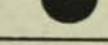
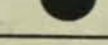
1989
$3.2 BILLION

SOURCE: Stanford Resources, Inc.

225-36900.1Q

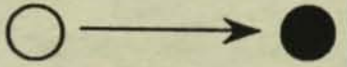
Military

CURRENT CRT PERFORMANCE IN MILITARY APPLICATIONS

	DISPLAY PERFORMANCE ATTRIBUTES						
	BRIGHTNESS & CONTRAST	SCREEN AREA	DEFINITION	DURABILITY	MEAN TIME BETWEEN FAILURES	WEIGHT/ VOLUME	POWER CONSUMPTION
COCKPIT							
SHIPBOARD							
GROUND VEHICLES							
PORTABLE COMMUNICATIONS							

SOURCES: Frost & Sullivan, BAH analysis

KEY:



Increasing performance gap relative to mission requirements

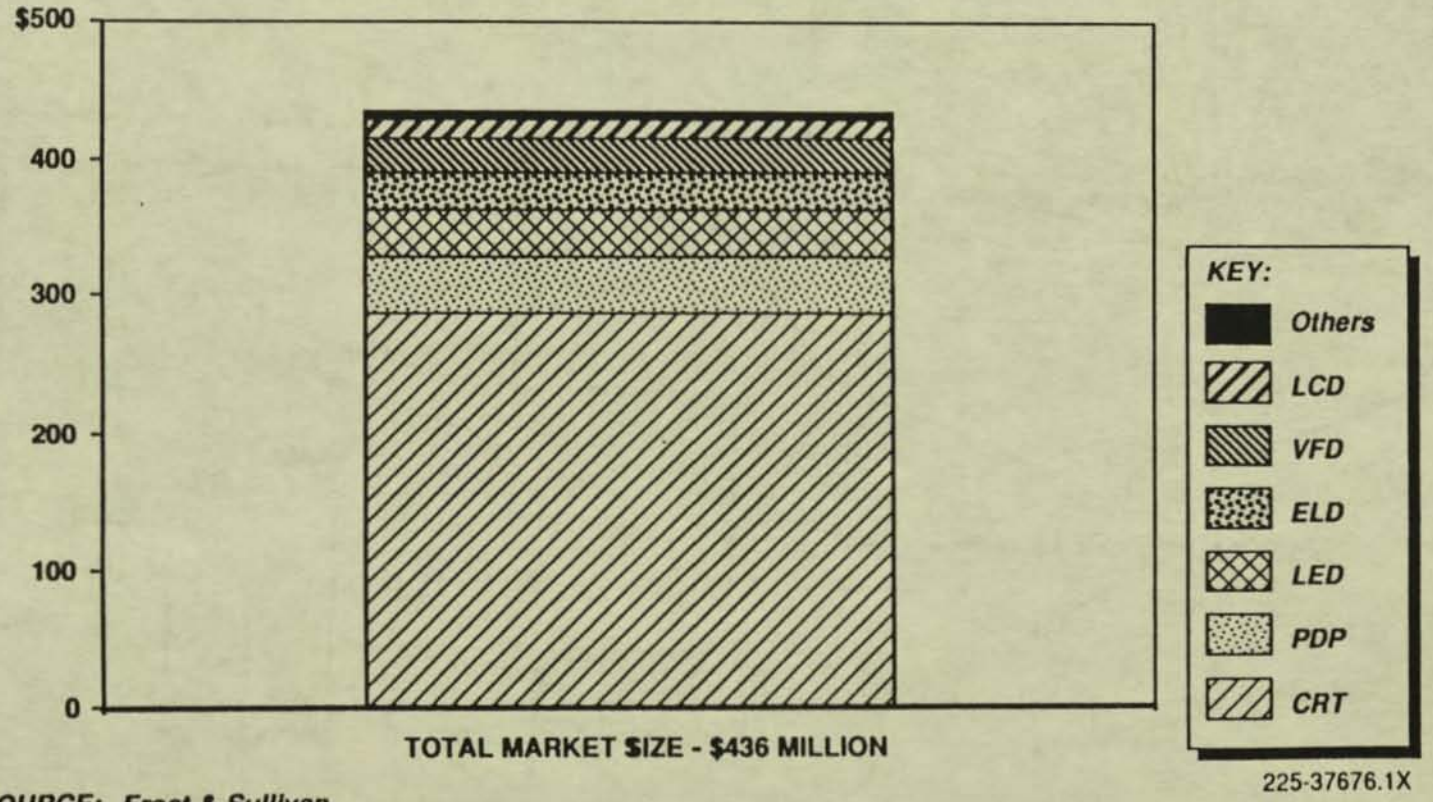
225-37680.3X

CRT TECHNOLOGY IS SERIOUSLY INADEQUATE FOR ADVANCED MILITARY SYSTEMS

- Limitations in brightness, definition, and screen size severely constrain performance in key areas:
  - Aircraft cockpit displays
  - Shipboard and land-based command centers
  - Command, Control, Communication and Intelligence (C^3I) systems
- High power consumption, short life cycle, and fragility limit systems' reliability.
- Weight/volume is a disadvantage in many applications.

BUT THE LACK OF VIABLE ALTERNATIVES HAS ALLOWED CRTs TO REMAIN DOMINANT IN THE MILITARY MARKET

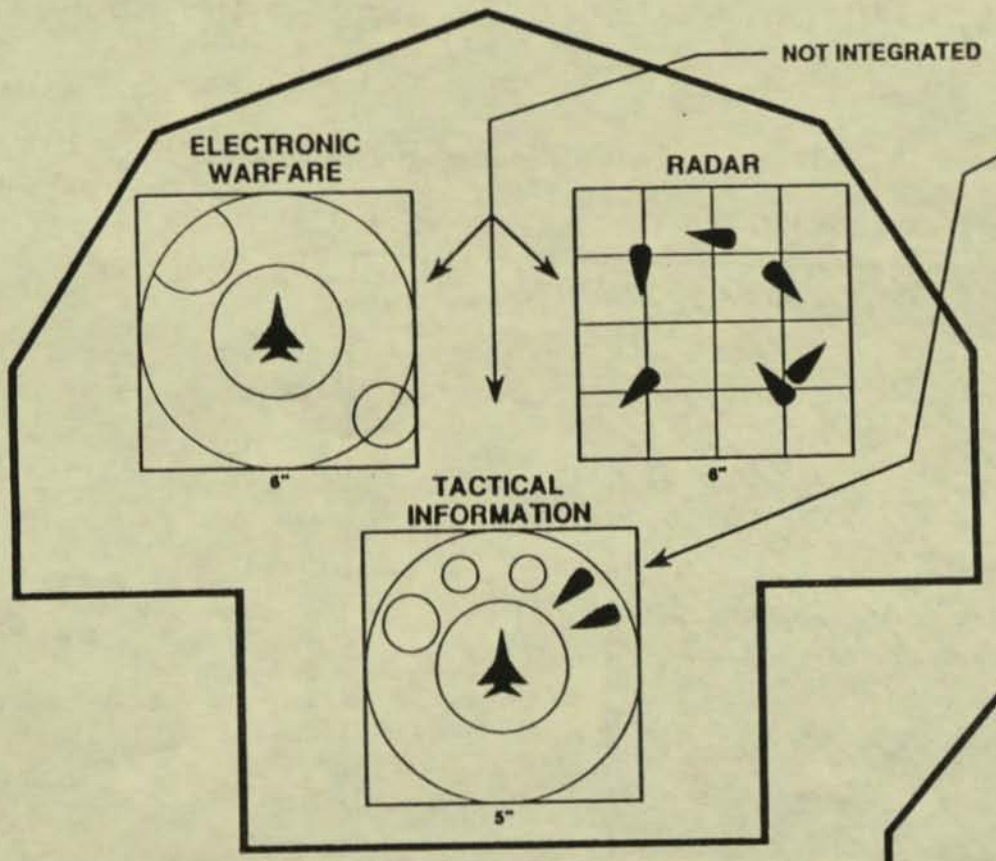
ESTIMATED 1989 U.S. MILITARY DISPLAY MARKET BY TECHNOLOGY
(DISPLAY COMPONENT VALUE ONLY)



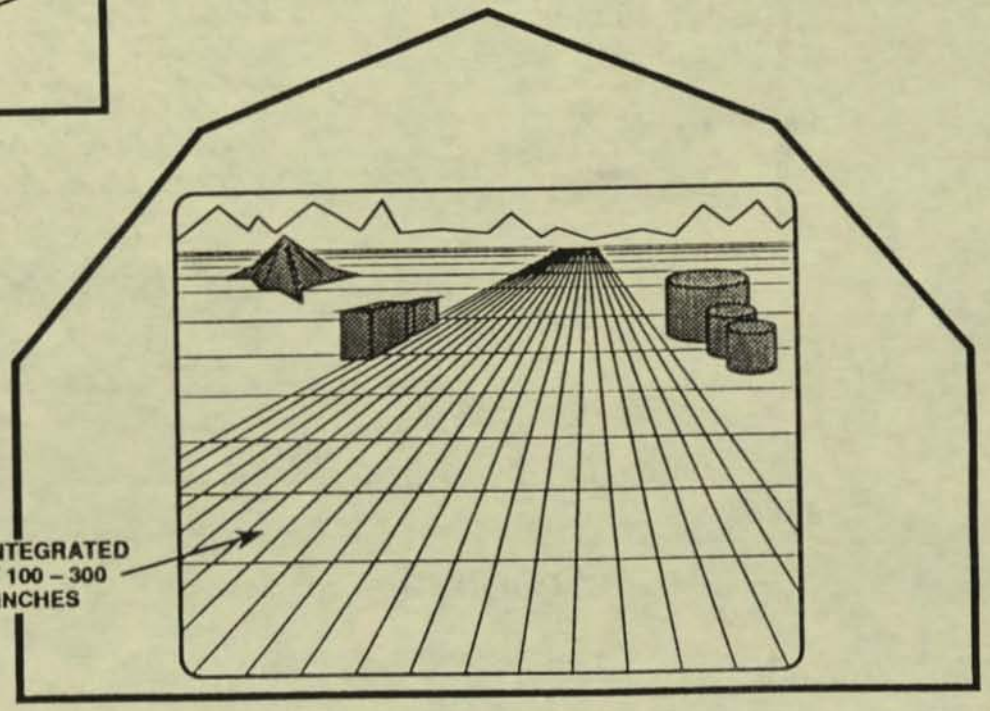
SOURCE: Frost & Sullivan

AND THE WIDE RANGE OF MILITARY OPERATING REQUIREMENTS HAS RESULTED IN FRAGMENTATION AMONG FLAT PANEL TECHNOLOGIES

CURRENT FIGHTER COCKPIT



FUTURE FIGHTER COCKPIT



SOURCE: McDonnell Douglas

225-37668-3X

ADVANCED FLAT PANEL TECHNOLOGY HAS THE POTENTIAL TO ADDRESS ALL CURRENT DISPLAY DEFICIENCIES, WITH CONSIDERABLE IMPACT ON OVERALL WEAPONS PERFORMANCE

- High definition and large screen areas allow integration of multiple displays into a complete situation awareness system which

  - Improves tactical decision making.
  - Shifts processing burden from personnel to support systems.
  - Reduces potential for operator error.

- By improving operator effectiveness advanced display technology can operate as a force multiplier for the entire weapons system.

A VIABLE DOMESTIC SUPPLY FOR ADVANCED FLAT PANEL DISPLAYS MAY NOT ARISE SOLELY TO SERVICE MILITARY REQUIREMENTS

- Military demand alone may be inadequate to drive a viable flat panel display venture.
  - Although unit costs are high, typical production volumes for the more advanced devices are very low.
  - Varied operating requirements will limit quantities demanded for a number of FPD technologies.
- Military cannot wait for the militarization of commercial displays, as their performance requirements far outstrip those of mainstream commercial markets.

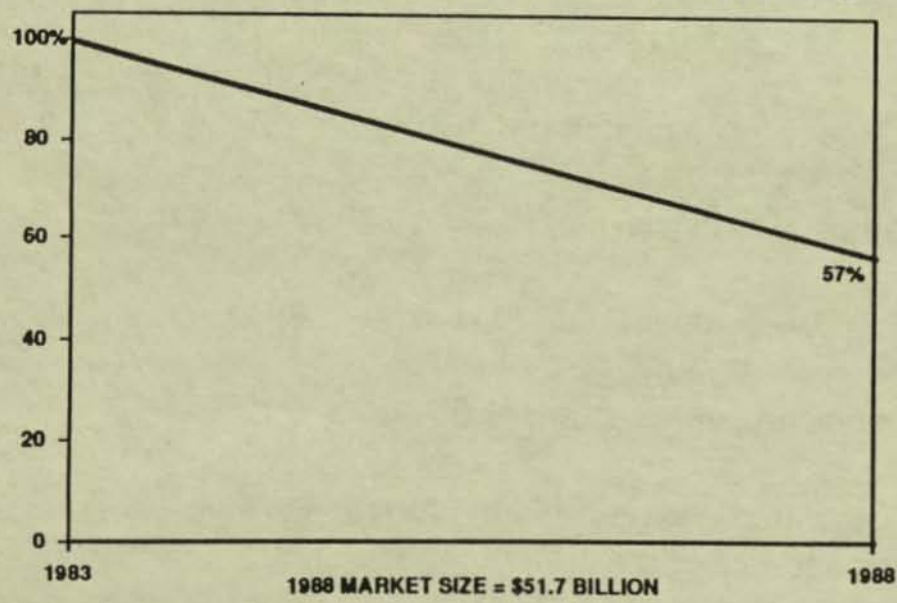
Computers

FLAT PANEL DISPLAYS WILL BE OF GREAT STRATEGIC IMPORTANCE TO THE PC AND WORKSTATION SEGMENTS OF THE COMPUTER INDUSTRY

- The display will be an important element of overall value-added, and therefore a basis for competitive cost differentiation.
- The display will increasingly be a basis for product differentiation, and thereby greater profit capture.
- Display supply is increasingly uncertain, as the market moves from merchant supply (for CRTs) to supply from systems competitors that are vertically integrated into displays (for FPDs).

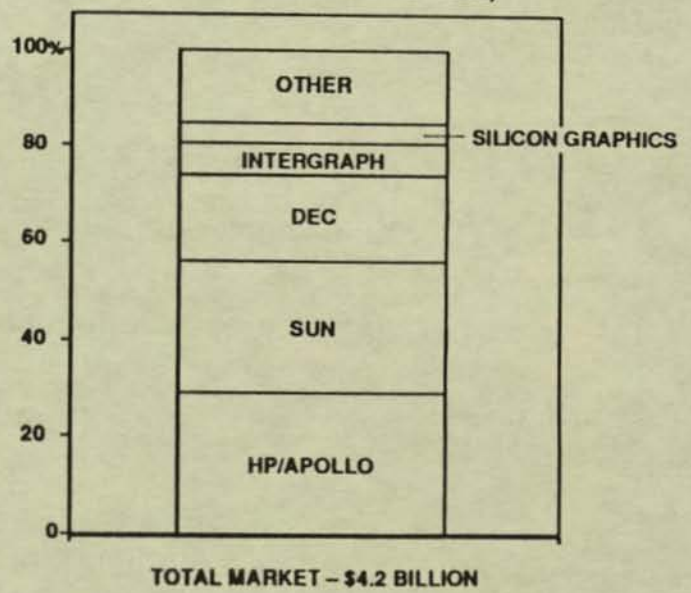
PCs AND WORKSTATIONS ARE THE FASTEST GROWING SEGMENTS OF THE COMPUTER INDUSTRY, AND WHILE THE U.S. HAS LOST SHARE, THEY REMAIN AN EXTREMELY IMPORTANT MARKET

U.S. SHARE OF WORLDWIDE PC MARKET REVENUES



SOURCE: Dataquest

ESTIMATED 1988 WORLDWIDE MARKET SHARES IN TECHNICAL WORKSTATIONS (BASED ON DOLLAR SALES)



SOURCE: Dataquest Inc.

225-37687.Q

THE BASES OF COMPETITION IN THE PC AND WORKSTATION MARKETS ARE SHIFTING ... WITH DISPLAYS EXPECTED TO PLAY A MORE SIGNIFICANT ROLE

- Product differentiation via processor and software is increasingly difficult.
  - The CPUs come from independent semiconductor companies or can be licensed from the system companies.
  - The operating systems are increasingly standard.
  - The great bulk of application software comes from independent suppliers.
- Other bases of competition will thus assume growing importance, including:
  - Other forms of product differentiation.
  - Design cycle time.
  - Manufacturing costs and quality.
- Access to display technology will play an increasingly important role.
  - In differentiation, via portable and small footprint products.
  - In manufacturing, as an important part of overall costs.
  - In time to market, through access to leading-edge display technologies.

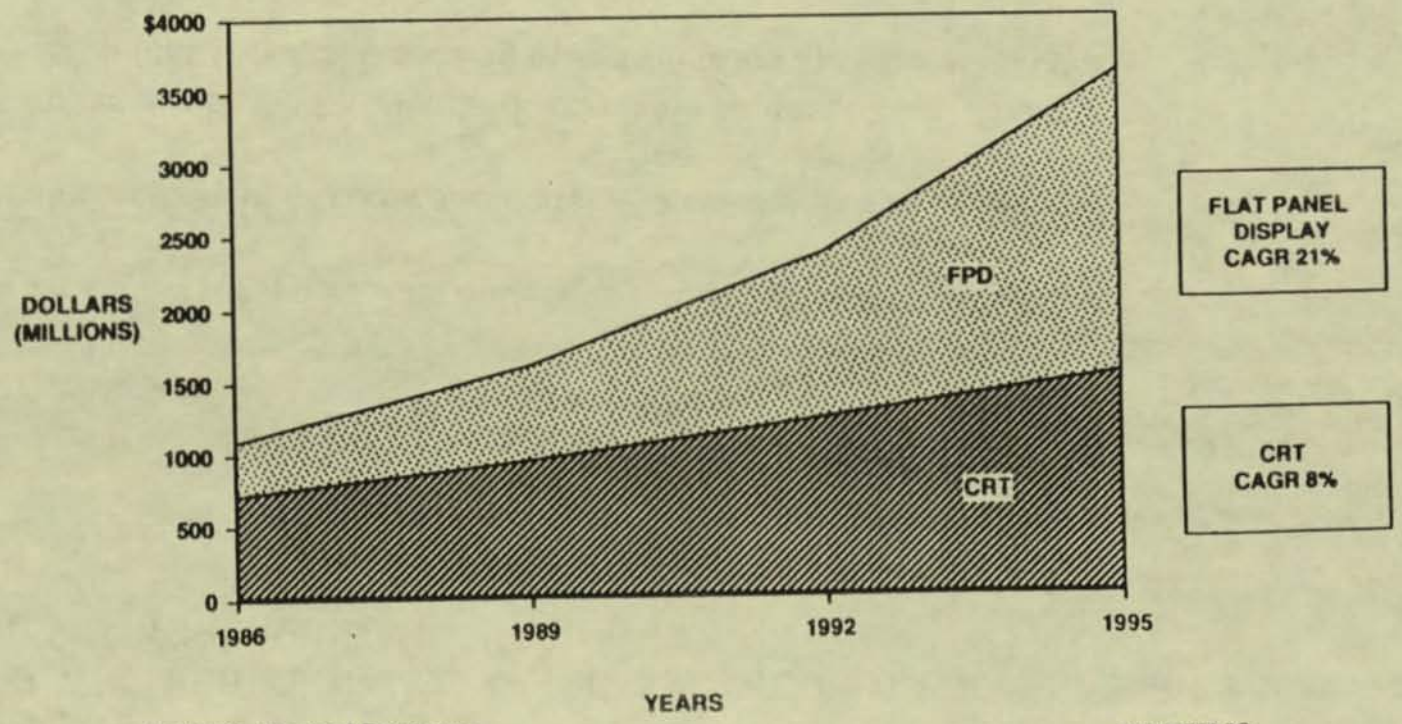
MOREOVER, THE PERFORMANCE OF PC AND WORKSTATION DISPLAYS IS CONTINUALLY INCREASING

- Color is increasingly important.
  - Sun now sells 70% of its machines with color displays, and this percentage is increasing.
  - DEC now sells more than 60% of its screens with color displays.
- Resolution (both pixel count and density) is continually increasing.
  - Apple, which initially standardized on medium resolution displays for its Macintosh product, is moving increasingly to high resolution color technology.
  - In the IBM compatible market, the medium resolution VGA standard is superseding the older and less powerful CGA and EGA standards.
- Average screen size in PCs is likely to increase as windowing software becomes more common.

FLAT PANEL DISPLAYS ARE PROJECTED TO MAKE SIGNIFICANT INROADS INTO THE COMPUTER MARKET

- The portable section of the marketplace will continue to grow, as their performance deficit diminishes.
- FPDs will begin to encroach into the mainstream market, initially in those sectors where transportability, footprint, and lifetime are of particular importance.

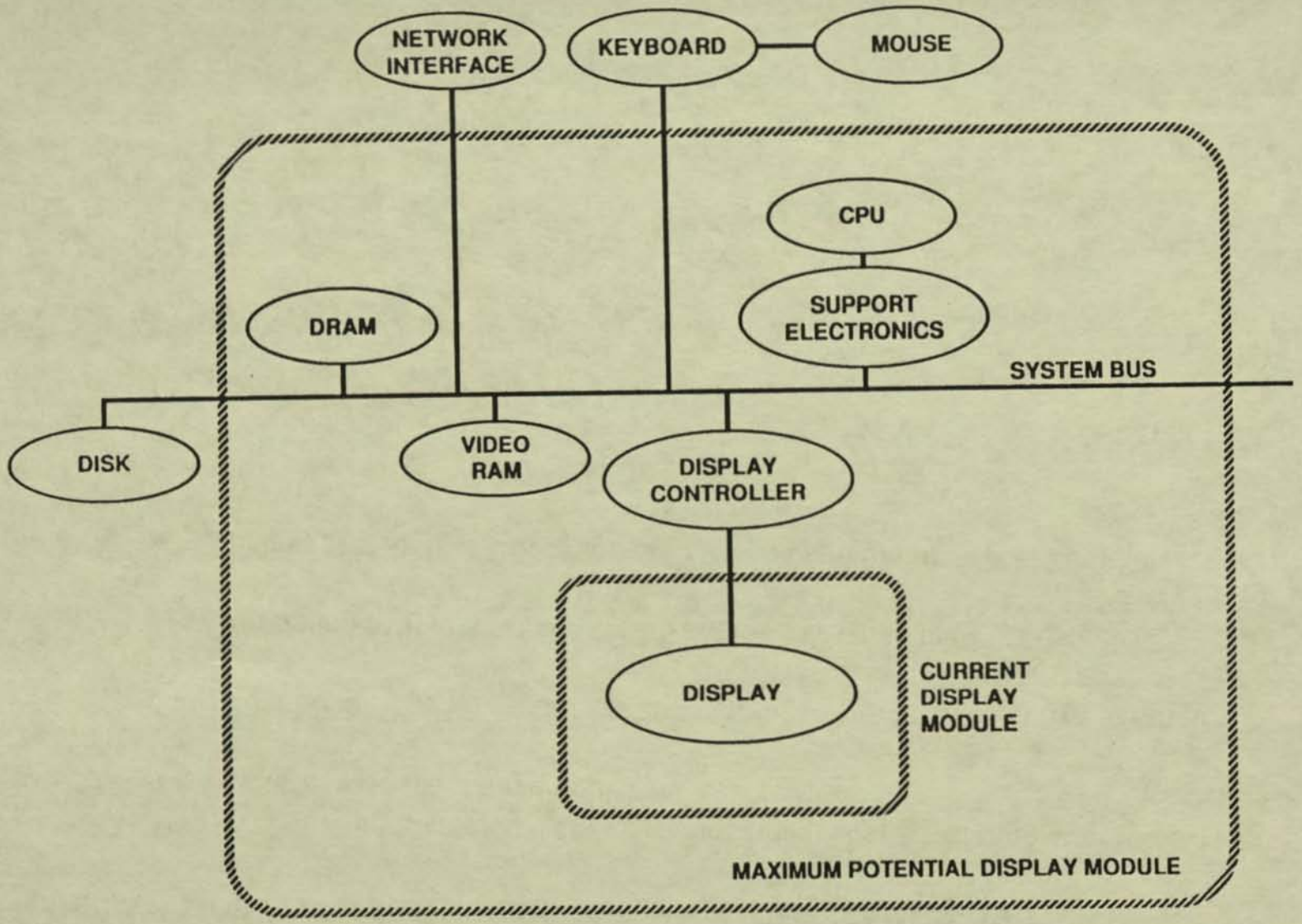
WORLDWIDE MARKET FOR DISPLAYS IN COMPUTER PRODUCTS



SOURCE: Stanford Resources

225-36776.2G

POTENTIAL FOR INCREASED INTEGRATION INTO DISPLAY



225-36911.2S

IN ADDITION, FLAT PANEL DISPLAY TECHNOLOGY MAY PERMIT THE INTEGRATION OF SOME OR ALL MAJOR SYSTEM ELECTRONICS INTO THE DISPLAY MODULE ITSELF, POSSIBLY ONTO THE SAME SUBSTRATE

- This level of integration could confer a substantial cost advantage over the system manufacturer who must buy the display as a component.

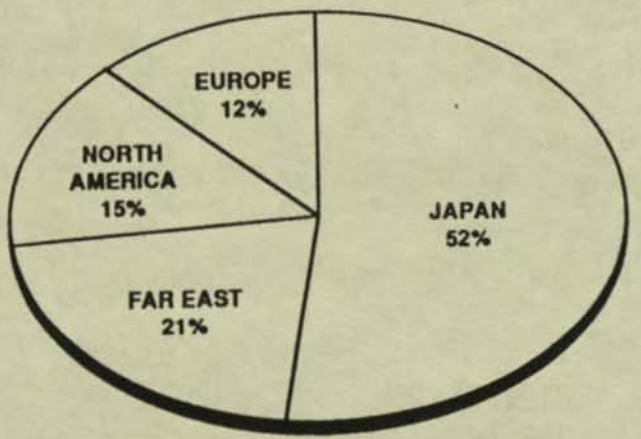
- If this cost advantage emerges, a manufacturer will be faced with two alternatives:

  - Competing with an ongoing disadvantage in manufacturing cost.

  - Shifting system unit fabrication over to the plant of the display supplier.

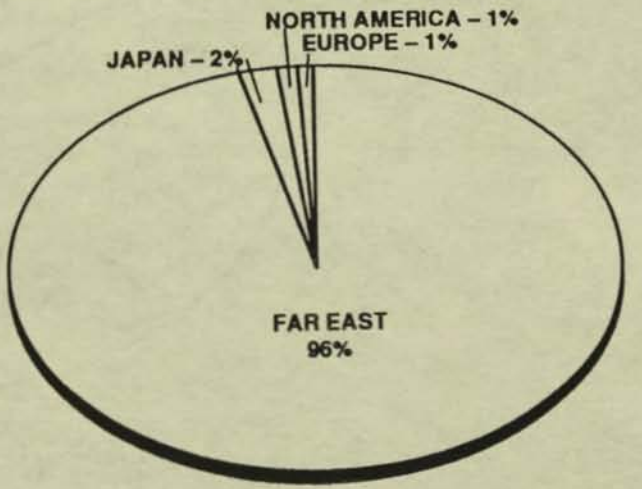
CURRENTLY THE MANUFACTURE OF COMPUTER MONITORS IS DOMINATED BY JAPANESE AND FAR EAST SUPPLIERS THAT ARE ALSO ACTIVE IN THE CONSUMER VIDEO MARKET

REGIONAL SHARES OF HIGH RESOLUTION COLOR MONITOR PRODUCTION (IN UNITS)



TOTAL MARKET 1989 = 10 MILLION UNITS

REGIONAL SHARES OF MONOCHROME AND LOW RESOLUTION COLOR MONITOR PRODUCTION (IN UNITS)



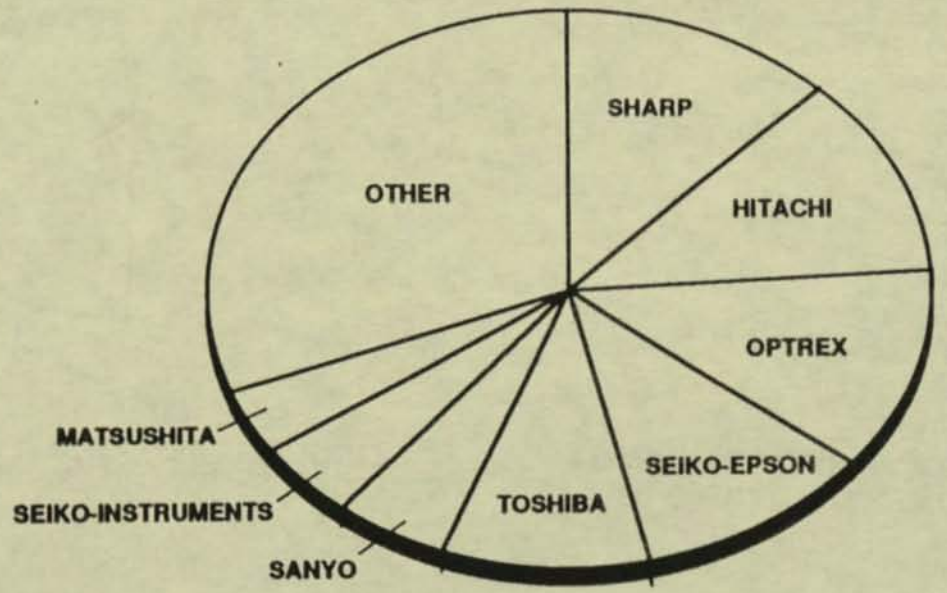
TOTAL MARKET 1989 = 14 MILLION UNITS

SOURCE: Stanford Resources

225-36810.2X

A SIMILAR POSITION IS EMERGING IN THE SUPPLY OF HIGH INFORMATION CONTENT LCD DISPLAYS

WORLD SHARE IN HIGH INFORMATION CONTENT LCD MARKETS BY 1989 DOLLAR SALES



SOURCE: Stanford Resources

225-36803.2G

FLAT PANEL SUPPLIERS ARE ALREADY ACTIVE IN PCs ... AND INCREASINGLY IN WORKSTATIONS

VERTICAL INTEGRATION BY LCD PRODUCERS INTO END PRODUCT MARKETS

LCD PRODUCER	PRESENCE IN END PRODUCT MARKET	
	PCs	WORKSTATIONS
SHARP	▨	▨
HITACHI	▨	▨
OPTREX	▨	▨
SEIKO EPSON	▨	▨
TOSHIBA	▨	▨
SANYO	▨	▨
SEIKO INSTRUMENTS	▨	▨
MATSUSHITA	▨	▨

SOURCE: BAH analysis

KEY:
▨ *Indicates presence in end product market*

225-37725.1X

DEPENDENCE ON COMPETITORS FOR DISPLAYS COULD BE A MAJOR THREAT TO US SYSTEMS COMPANIES

- In rapidly evolving sectors, the bulk of product earnings typically comes in the first six to nine months. Thus, any delay in access to critical component technologies such as displays will have a crucial effect on product profitability.

- Early access to internally developed technologies allows a head start in the design process, conferring a substantial time-to-market advantage for the company in the systems marketplace.

- The expected slow ramp-up in yield for FPDs will mean that supply for merchant customers from vertically integrated competitors will be severely constrained, if available at all.

- Early in the product life cycle of any given subsystem, prices are at a premium level. These premiums, when paid to competitors for supply of subsystems, enhance competitors' profitability.

Consumer TVs

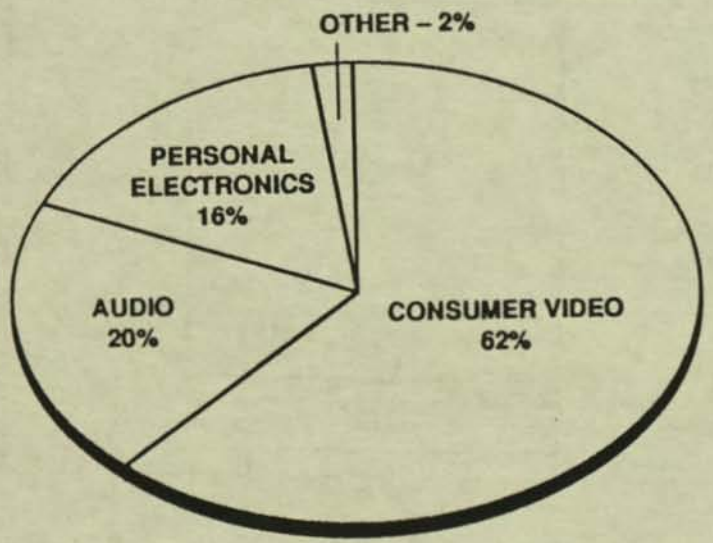
THE CONSUMER TV MARKET IS OF GREAT STRATEGIC IMPORTANCE FOR ADVANCED DISPLAYS

- Eventually a high proportion of advanced displays will be used in the consumer TV market, potentially resulting in a major decline in demand for the U.S. electronics food chain.

- The large production volumes in television will critically influence:

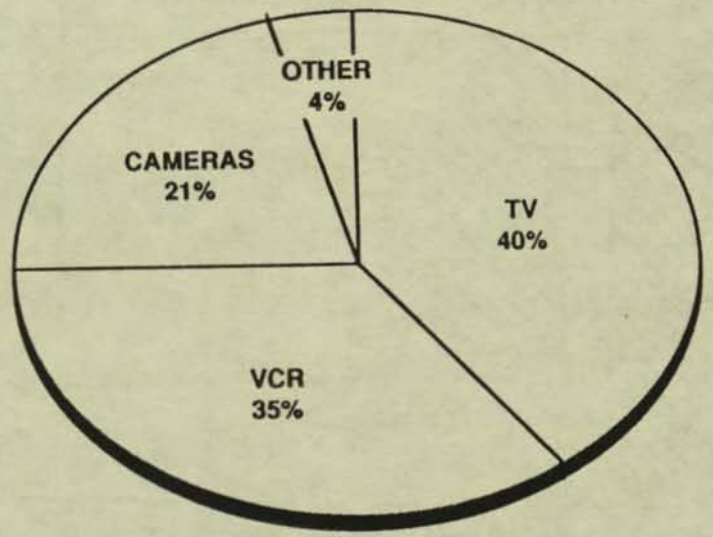
  - Definition of worldwide scale for FPD manufacturing
  - Competitive cost dynamics of the industry

WORLDWIDE CONSUMER ELECTRONICS MANUFACTURING REVENUE



1989 TOTAL SIZE (EXCLUDING APPLIANCES)
$ U.S. 85 BILLION

WORLDWIDE CONSUMER VIDEO SALES BY PRODUCT



1989 TOTAL SIZE = $U.S. 52.8 BILLION

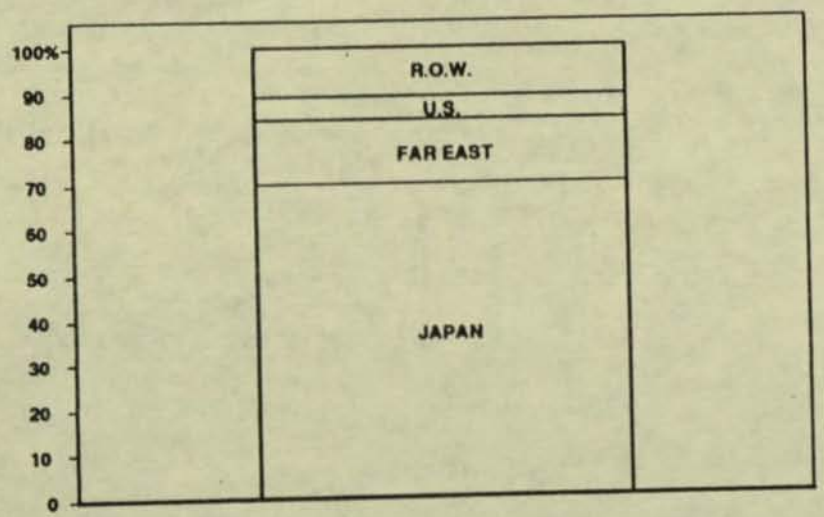
225-37697.3J

NOTE: Charts only include Japan, U.S., and Europe

SOURCE: Dataquest

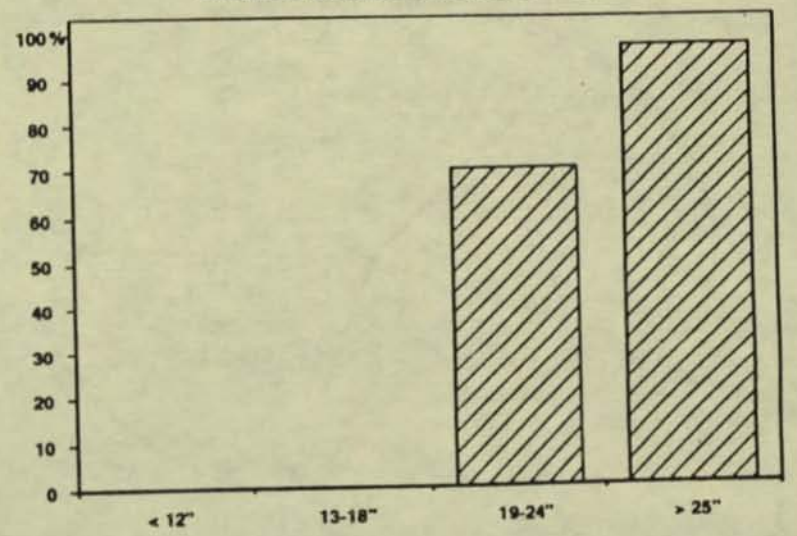
UNLIKE VCRs AND CAMCORDERS (PRIMARILY SOURCED IN JAPAN AND THE FAR EAST), THE UNITED STATES HAS A SIGNIFICANT DOMESTIC MANUFACTURING BASE IN LARGER SCREEN TVs

1988 VCR PRODUCTION BY REGION
(IN UNITS)



SOURCE: BEP data services

PERCENT OF U.S. TELEVISION RECEIVERS MANUFACTURED DOMESTICALLY IN EACH SCREEN SIZE SEGMENT
OVERALL DOMESTIC PERCENT = 60%



SOURCE: Thomson Electronics

225-37673.1Q

THE STRONG U.S. PRESENCE IN TELEVISION MANUFACTURE IS BASED ON BOTH HISTORY AND ECONOMICS

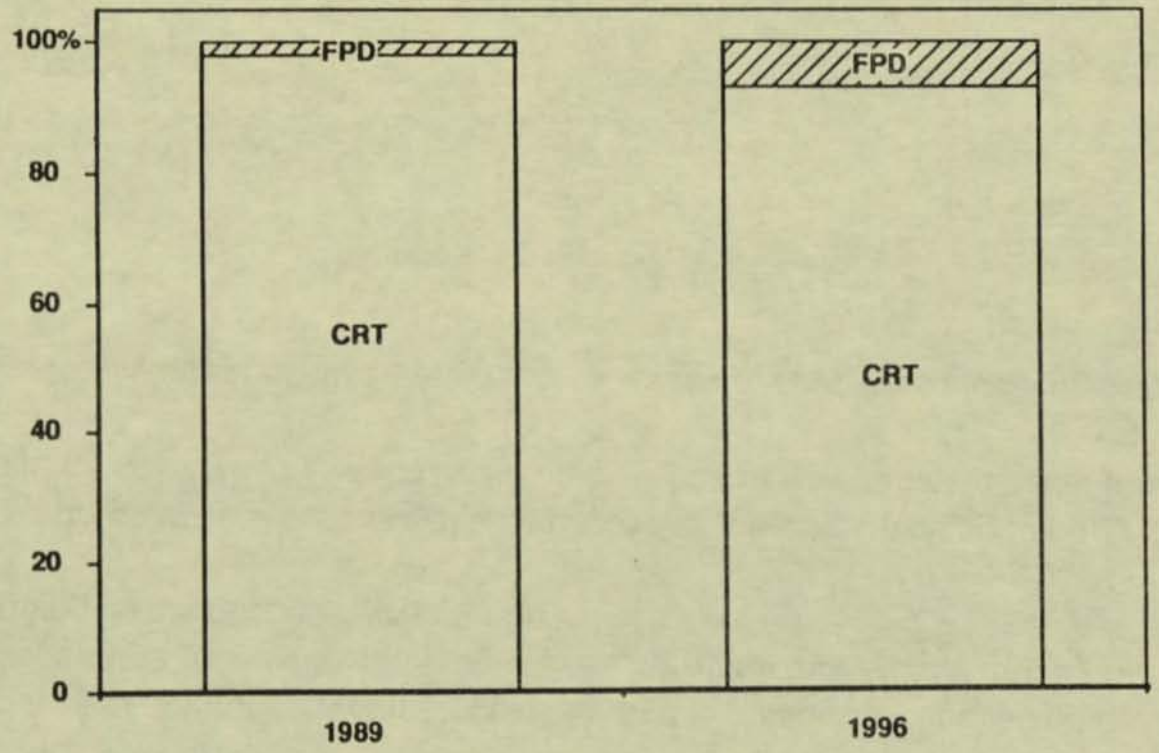
- U.S. manufacturers developed color TV and its associated technologies, resulting in today's large domestic infrastructure, an infrastructure maintained by high and ongoing levels of capital investment.

- Transportation is a substantial cost for CRTs, thereby inhibiting imports, particularly in the large screen sizes which make up over half of the market in dollar terms.

- Uncertainty over possible trade restrictions is an incentive to local manufacture.

CRT TECHNOLOGY IS EXPECTED TO REMAIN DOMINANT IN CONSUMER ELECTRONICS FOR AT LEAST THE NEXT TEN YEARS, DUE TO ITS STRONG COST ADVANTAGE

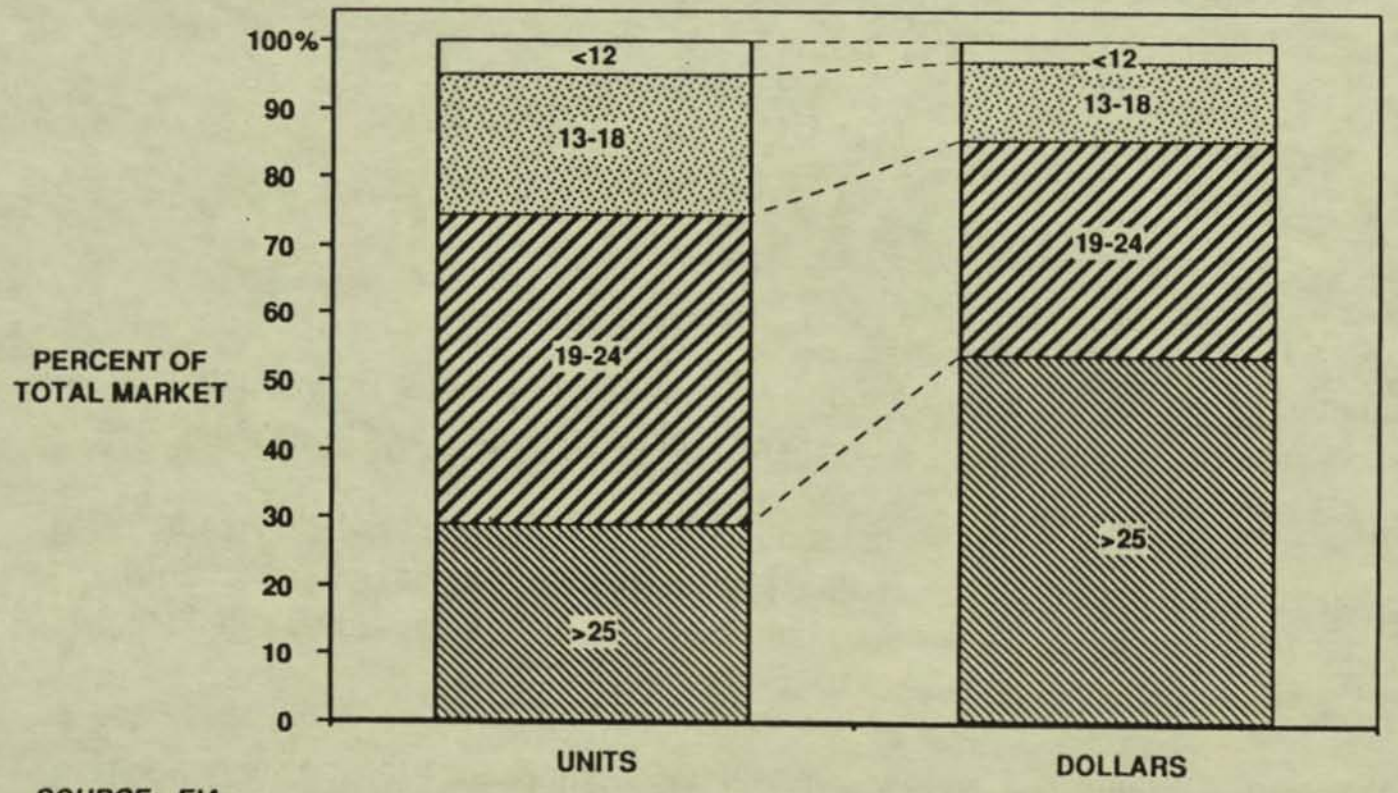
CONSUMER ELECTRONICS TECHNOLOGY SHARES (UNITS)



SOURCE: Stanford Resources

225-36897.1X

1988 U.S. COLOR TV SEGMENTATION BY DIAGONAL SCREEN SIZE



SOURCE: EIA

225-36804.3B

HOWEVER, FLAT PANEL DISPLAYS POSE A LONG-TERM CHALLENGE TO CONVENTIONAL CRT RECEIVERS

- A flat panel display allows the construction of a much thinner and lighter receiver. The size and bulk of conventional TVs is a major drawback, particularly in large screen sets.

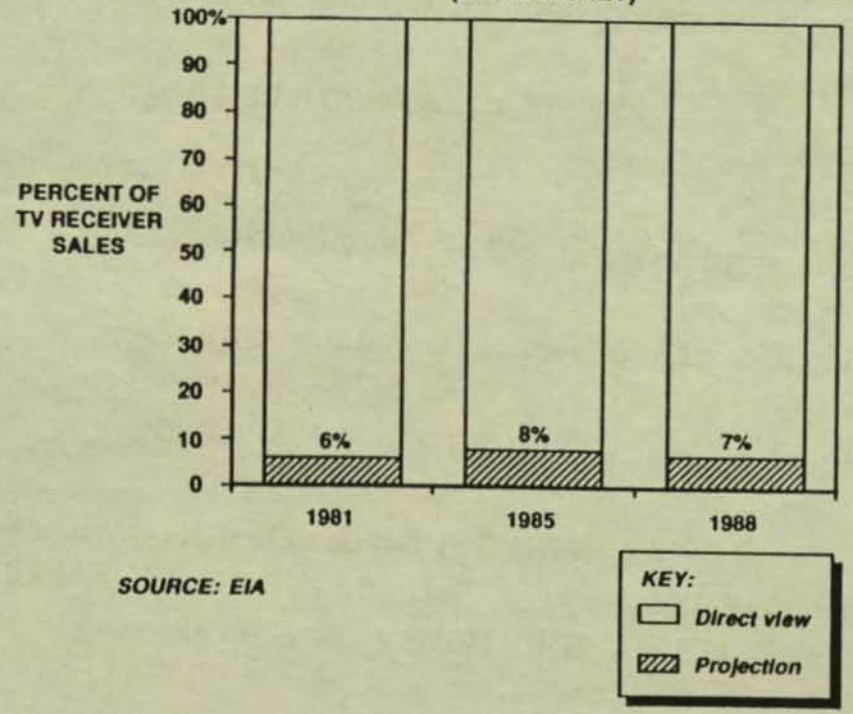
- A flat panel display may eventually allow the construction of larger screen sets. The large screen market, both direct view and projection, is relatively small in unit volumes but makes up more than 50% of total video sales.

- Flat panel allows the construction of a much smaller, lighter, and potentially cheaper, projection TV. This may redefine the role of projection in the overall TV marketplace.

CRT PROJECTION RECEIVERS CURRENTLY REMAIN A LOW-GROWTH NICHE IN THE TELEVISION MARKET

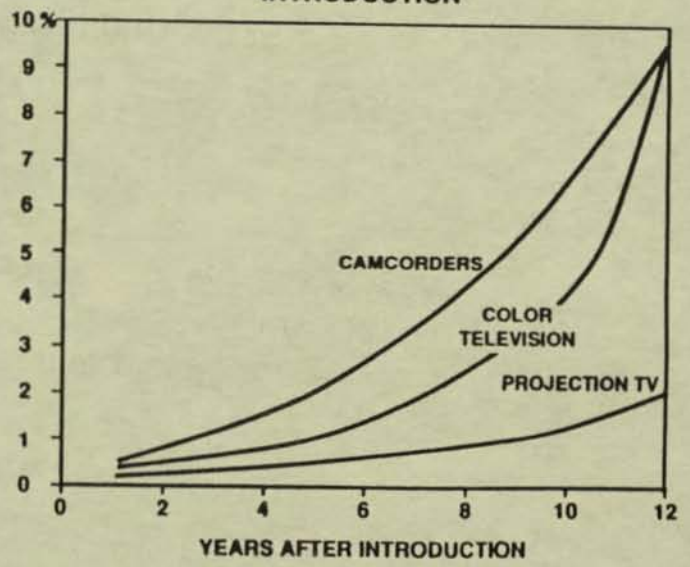
- The receivers are bulky and expensive.
- Picture quality—particularly brightness and resolution—is relatively poor.
- The low resolution of the NTSC standard limits the appeal of very large screen displays.

PROJECTION TV AS A PERCENTAGE OF TOTAL U.S. TV SALES IN DOLLARS (U.S. MARKET)



SOURCE: EIA

ESTIMATED PENETRATION INTO U.S. HOUSEHOLDS RELATIVE TO YEAR OF INTRODUCTION



SOURCE: Thomson Consumer Electronics

225-37698.1X

DEVELOPMENTS IN ADVANCED VIDEO STANDARDS AND FLAT PANEL TECHNOLOGY HAVE THE POTENTIAL TO SUBSTANTIALLY INCREASE THE IMPORTANCE OF PROJECTION TV

- Advanced video standards—IDTV, EDTV and HDTV—
  - Considerably improve the appeal of large screen displays.
  - Front projection avoids "dead glass" problems with differing aspect ratio standards.
- Flat panel projection technology
  - Considerably reduces footprint and weight, and improves reliability.
  - Has strong potential to reduce cost and to improve overall picture quality.
  - Will be commercialized well in advance of comparable large area direct view screens.

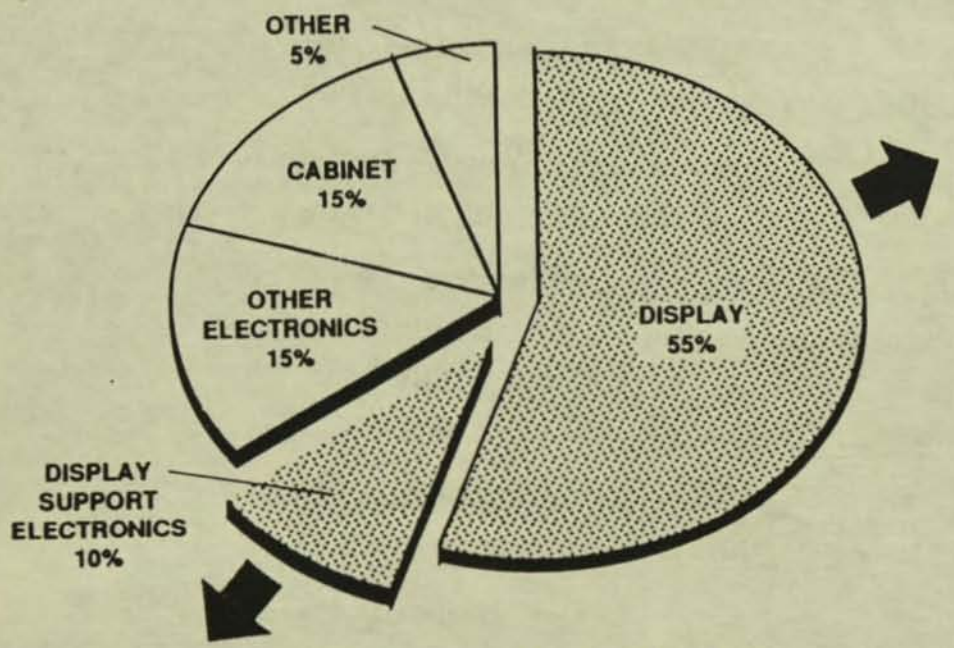
HOWEVER, THE POTENTIAL DISRUPTION TO THE U.S. ELECTRONICS FOOD CHAIN BY PROJECTION DEVICES IS LIKELY TO BE LESS THAN BY DIRECT VIEW

- While the fundamental technology is similar to direct view, supply of projection devices is likely to be less restricted.
  - Device areas are small, thereby easing fabrication, increasing throughput and improving yield.
  - Current technologies allow monochrome flat panel elements, simplifying design and fabrication.
- Merchant availability of projection LCDs is likely to improve as plant capacities and yields increase.
- The potential for systems integration onto a projection display element is substantially lower than in direct view.
- The LCD elements in a projection system form a much smaller part of overall value added.

PENETRATION OF FLAT PANEL DISPLAYS INTO THE MAINSTREAM DIRECT VIEW TV MARKET WILL BE RELATIVELY SLOW TO DEVELOP

- The cost premium for FPDs is expected to remain high through the 1990s.
- The medium and small screen size segments of the receiver market, where flat panel displays can first compete, are particularly price sensitive.
- Since the display represents a large cost element in the receiver, the resulting large differential in total set cost will inhibit overall penetration.

POTENTIAL THREAT TO U.S. VALUE-ADDED IN TELEVISION RECEIVERS

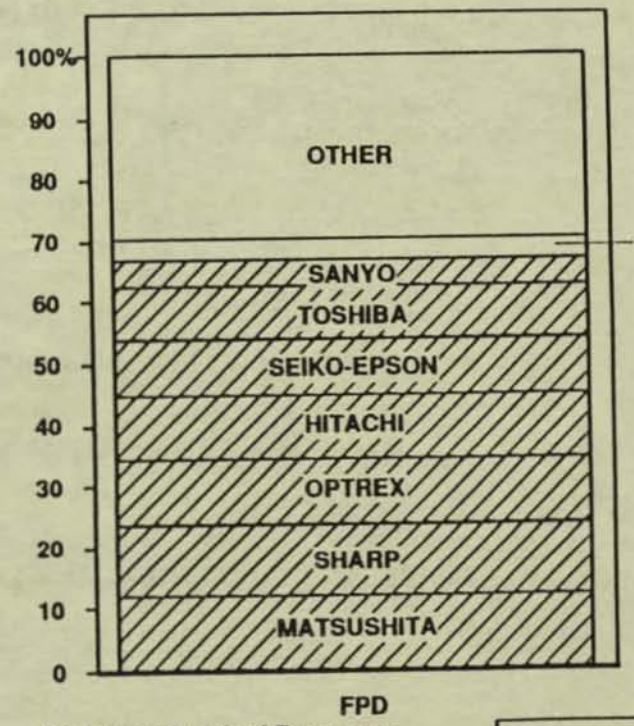


SIZE = $U.S. 6 BILLION

NOTE: About 70% of U.S. value in a typical television is in the display component

SOURCE: BAH estimates

WORLD SHARE IN FLAT PANEL DISPLAYS BY 1989 DOLLAR SALES



SOURCE: Stanford Resources

KEY:

Also involved in nonportable TV manufacture

225-37729B

HOWEVER, LARGE SCREEN SETS, THE MOST PROFITABLE SEGMENT OF THE DOMESTIC TV INDUSTRY, WILL EVENTUALLY BE THREATENED BY FOREIGN SUPPLY

- Advanced displays will be a strong element in product differentiation.
  - Form factor
  - Image quality
- Japanese companies currently have a substantial lead in the commercialization of FPD technology.
  - Japan currently holds 85% of the world's flat panel display market (by value), with the Far East in second place at approximately 8% worldwide share.
  - Share in the low information-content LCD display market confers valuable process experience for large screen monolithic FPDs.
- Any merchant market in FPDs will be dominated by companies that produce primarily for their own receiver lines.
- The change to FPD technology will seriously threaten the U.S. electronics food chain, including components.
  - Much higher value to weight ratio of FPDs will make international production attractive, even in large screen sizes.
  - For the foreseeable future, production facilities are likely to remain near R&D centers, thus denying significant manufacturing value-added to the U.S.
  - The potential for integration of support electronics onto the display elements will pose a substantial threat to local component sourcing.

IN THE LONG TERM, THE THREAT TO THE U.S. ELECTRONICS FOOD CHAIN MAY BE EVEN GREATER IN TV MANUFACTURING THAN IN COMPUTERS

- A large, healthy portion of the U.S. electronics food chain—the manufacture and assembly of large screen TVs—is under threat.
- The display and its associated electronics, forming over 50 percent of the overall product cost of a TV, is subject to production outside the U.S.
- While a merchant market for advanced television displays may continue to exist, nonvertically integrated companies may be forced to source their displays from competitors.

V. POTENTIAL FOR A U.S.-BASED DISPLAY INDUSTRY

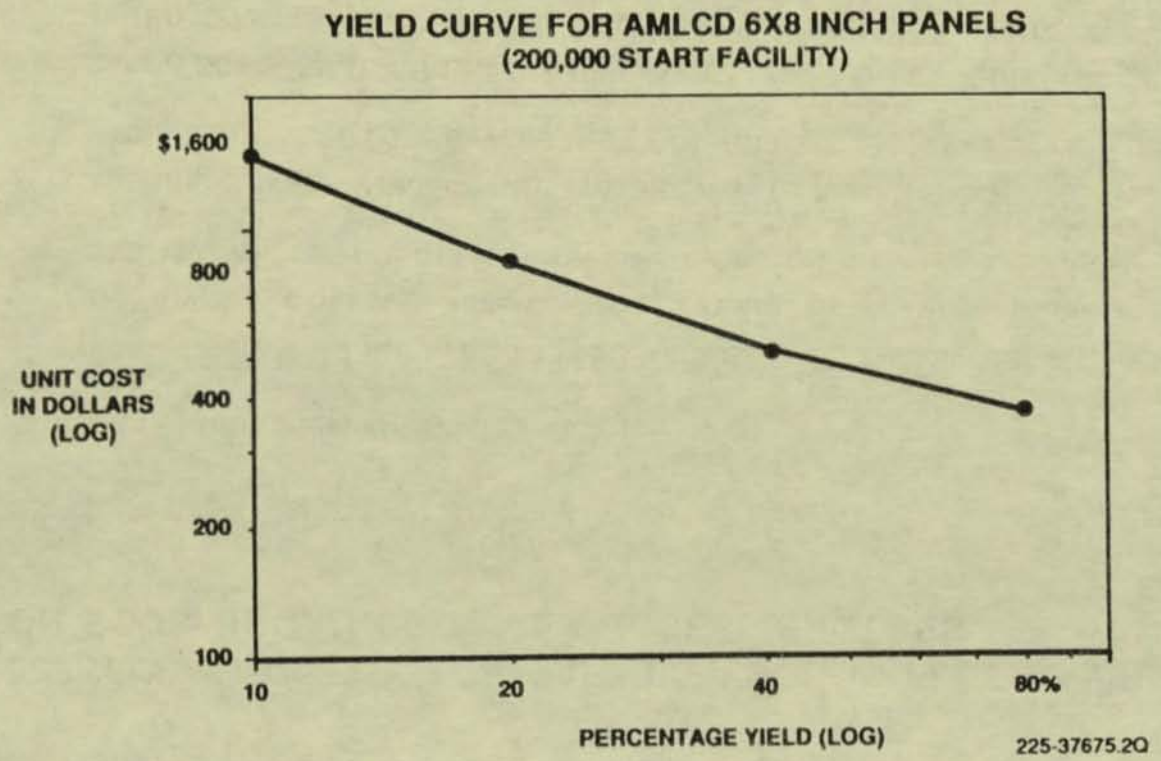
A SUCCESSFUL STRATEGY FOR PARTICIPATION IN FLAT PANEL DISPLAYS MUST BUILD ON FOUR BROAD CRITICAL SUCCESS FACTORS

- Access to competitive technology.
- Sufficient financial resources to stay the course.
  - Start-up investment is large ($50 to over $100 million, depending on technology) but not prohibitive at current scale. However, expected rapid growth in scale will require sustained investment to remain competitive.
  - Closing any competitive gap in yields will require the ability to accept lower profitability (and possibly losses), potentially over an extended period.
  - Since both Japan and Korea have targeted FPDs as "strategic", current participants may be willing to accept low or negative returns in pursuit of long-term share.
- Sustained access to volume markets.
- Access to necessary engineering skills and to a world-class industry infrastructure.

OF THESE FACTORS, SUSTAINABLE ACCESS TO VOLUME IS PERHAPS THE MOST CRITICAL FOR A U.S. ENTRANT

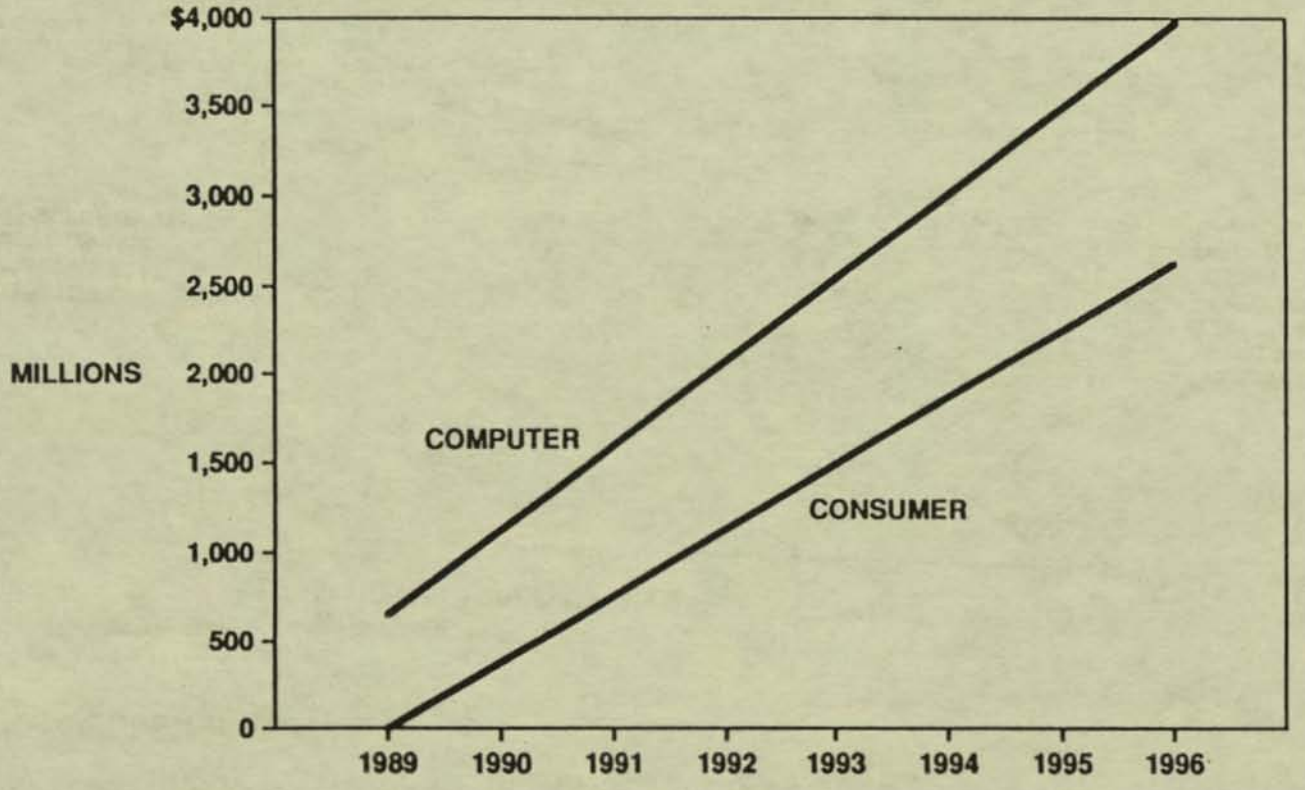
SCALE WILL NOT BE A MAJOR COMPETITIVE FACTOR IN FLAT PANEL MANUFACTURE IN THE SHORT TERM

- Yield is the crucial cost driver, but is broadly insensitive to scale.
- There will be few facilities and their maximum scale is limited by equipment technology and the rapid rate of change in manufacturing process.



SOURCES: BAH analysis, Stanford Resources

COMPARISON OF HIGH INFORMATION CONTENT FLAT PANEL DISPLAYS BY MAJOR APPLICATIONS



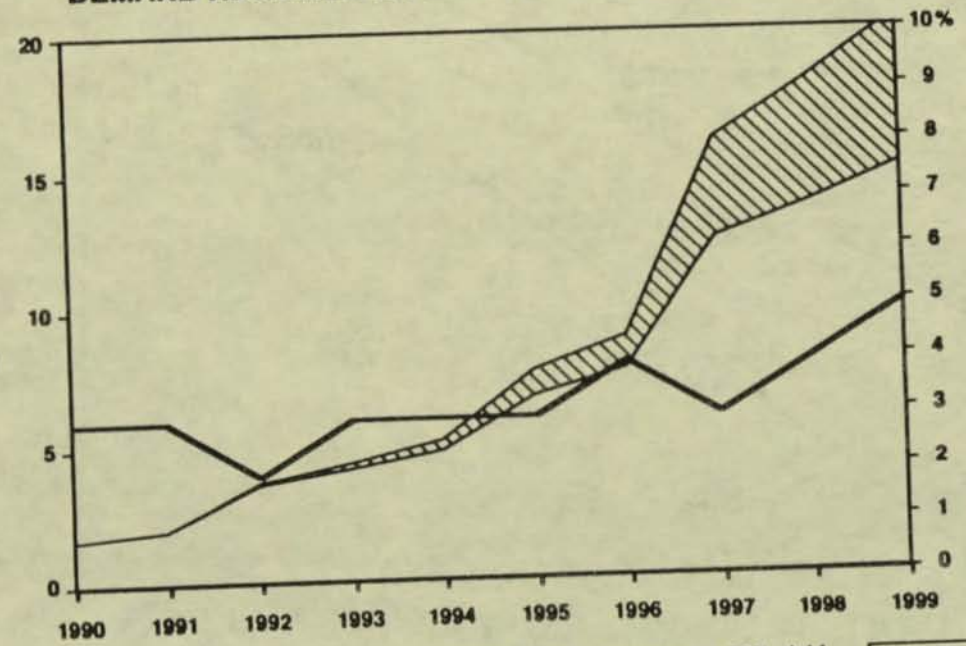
SOURCE: Stanford Resources

225-36920B

ACCESS TO SUFFICIENT VOLUME FOR VIABLE MANUFACTURE IN THE SHORT TERM CAN BE ACHIEVED IN THE COMPUTER MARKET ALONE

- The market for advanced FPDs will develop in computers well in advance of mainstream TV.
- Yielded output from an optimally sized facility will be a small fraction of overall computer demand.

SHARE OF WORLDWIDE COMPUTER FLAT PANEL DEMAND REQUIRED BY AN EFFECTIVE SCALE FACILITY



FACILITY SCALE ASSUMPTIONS: 1990 - 200K starts, 20% yield
1995 - 500K starts, 40% yield
1999 - 1,000K starts, 80% yield

KEY: *Estimated flat panel demand*

SOURCES: BAH analysis, Dataquest

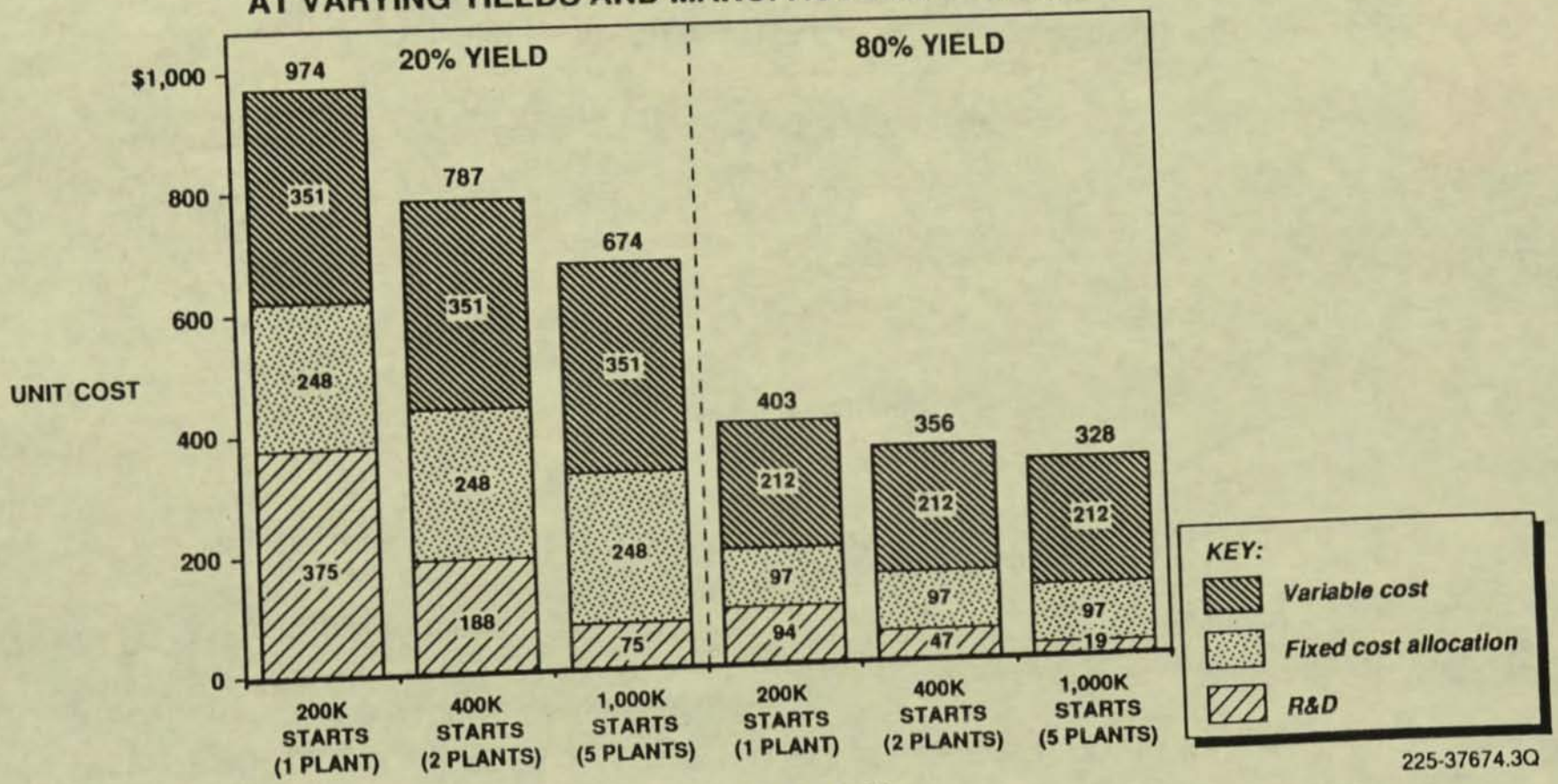
225-37667.4S

AS YIELD PROBLEMS ARE RESOLVED, SCALE AT THE FACILITY LEVEL MAY INCREASE IN COMPETITIVE IMPORTANCE

- Fixed costs may increase.
  - New deposition and stepper equipment, developed specifically for the FPD market, may change capital requirements.
  - A switch from amorphous to polysilicon technology increases capital equipment needs.
- Variable costs may fall.
  - Material costs will fall with improving yield.
  - Glass prices may fall as new suppliers enter the market.
  - A switch from amorphous to polysilicon or cadmium selenide technology eliminates the need for separate drivers, representing around 30% of total variable costs.
- Stabilizing process technology will diminish the risks of larger plants.

HOWEVER THE HIGH ONGOING COST OF R&D WILL ADVANTAGE MARKET SHARE LEADERS

EFFECT OF $15 MILLION R&D EXPENSE AT VARYING YIELDS AND MANUFACTURER VOLUMES



NOTE: This data is for an AMLCD 6x8 inch panel manufacturing facility

SOURCES: Stanford Resources, BAH analysis

In Summary ...

NONPARTICIPATION BY THE U.S. IN FLAT PANEL DISPLAY MANUFACTURING IS LIKELY TO SIGNIFICANTLY HOLLOW THE ELECTRONICS FOOD CHAIN

- The U.S. may lose a substantial share of manufacturing value added, since FPD plants are likely to be clustered around overseas R&D centers, at least in the short term.
- Higher levels of system integration onto the display will reduce the potential for U.S. manufacturing value-added and substantially reduce local component procurement.
- Unlike CRTs, there will be few incentives toward local manufacture of FPDs, and therefore little reason to source material or components locally.
- U.S. systems companies may be substantially affected by restricted access to advanced FPD technology
  - Merchant supply will be restricted or nonexistent.
  - Systems companies may find themselves dependent on competitors for FPD supply.
  - The inability to integrate systems onto the display module may lead to a substantial cost and performance disadvantage.

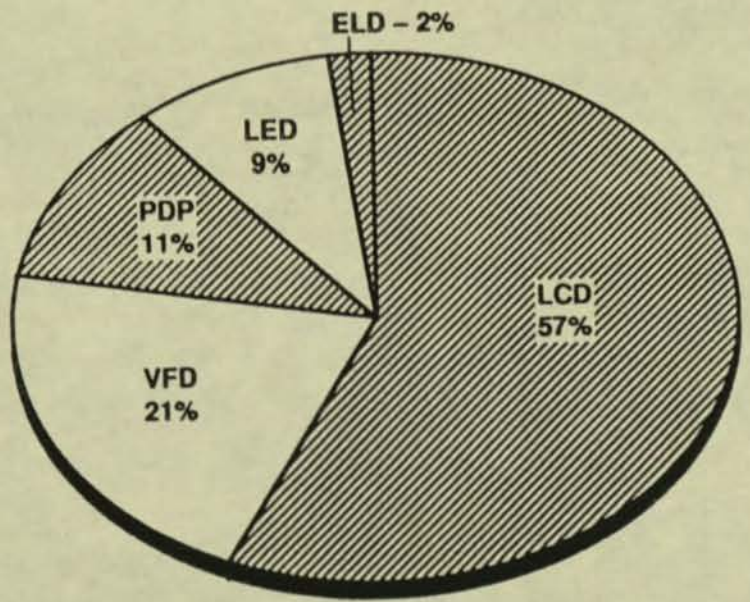
HOWEVER THERE APPEARS TO BE A REAL AND CURRENT OPPORTUNITY FOR THE U.S. TO PARTICIPATE

- Entry must occur soon, in order to minimize any deficit in process and product technology.
- The venture must have sufficient resources to sustain the ongoing investment required to remain competitive in R&D and overall scale.
- There are opportunities available in the U.S. to achieve viable production volume.
  - In the short term, via the strong U.S. presence in PC and workstation manufacture.
  - And in the long term, via the strong U.S. manufacturing base in televisions.

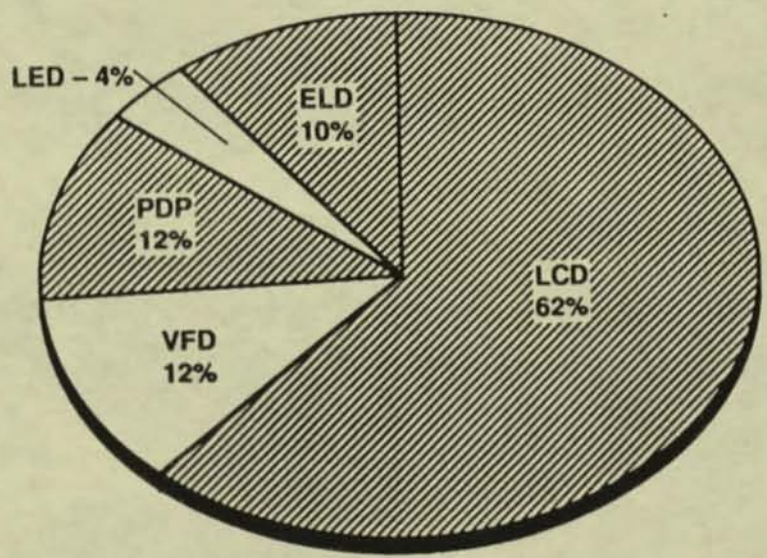
VI. APPENDIX—OVERVIEW OF FLAT PANEL DISPLAY TECHNOLOGIES

THERE ARE A LARGE NUMBER OF POTENTIAL TECHNOLOGIES FOR THE FABRICATION OF ADVANCED FLAT PANEL DISPLAYS

WORLDWIDE DISPLAY MARKET FORECAST
FLAT PANEL TECHNOLOGIES



1989
$3.2 BILLION



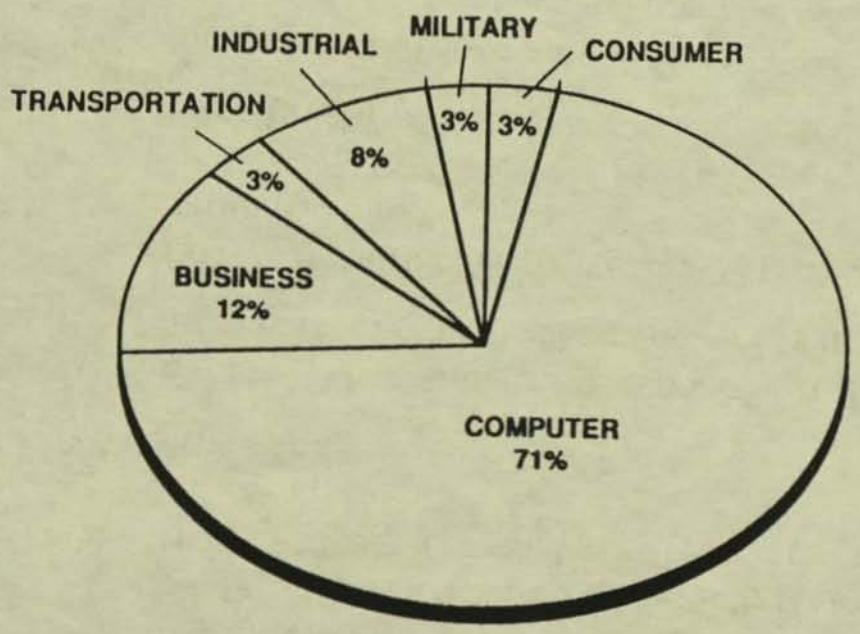
1996
$11.7 BILLION

225-36785.2T

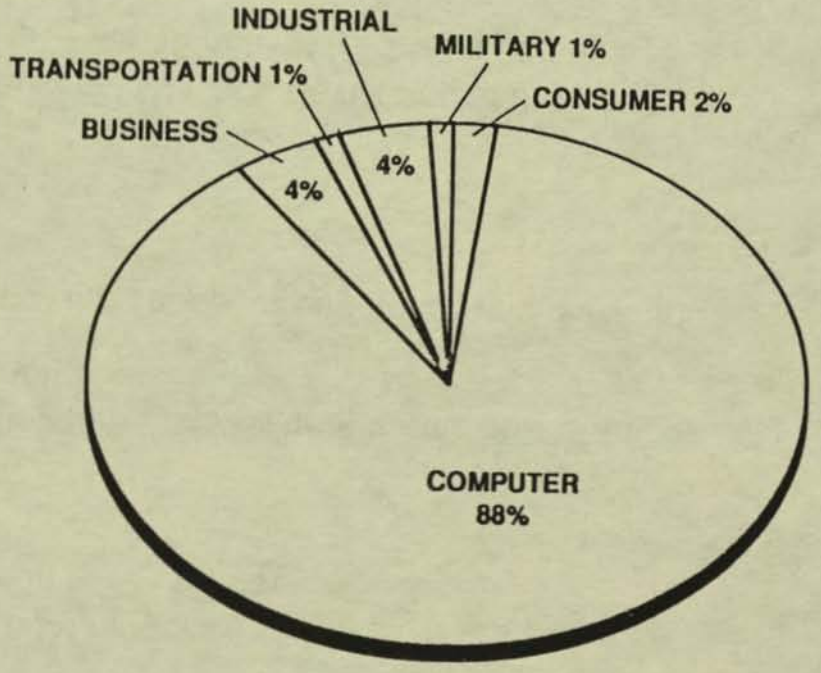
SOURCE: Stanford Resources, Inc.

... OF THESE, THREE ARE PROJECTED TO BE OF GREATEST IMPORTANCE— LIQUID CRYSTAL DISPLAYS (LCDs), ELECTROLUMINESCENT DISPLAYS (ELDs), AND PLASMA DISPLAY PANELS (PDPs)

WORLDWIDE PDP DISPLAY MARKET BY APPLICATION



1989
TOTAL SIZE = $U.S. 0.4 BILLION



1996
TOTAL SIZE = $U.S. 1.4 BILLION

SOURCE: Stanford Resources

225-36794.1G

PERFORMANCE REVIEW—PDPs

Strengths

- Simple manufacture and construction
- Highly reliable
- Large screen size possible (currently up to 1.5M diagonal)
- High information content possible (currently up to 4M pixels)

Weaknesses

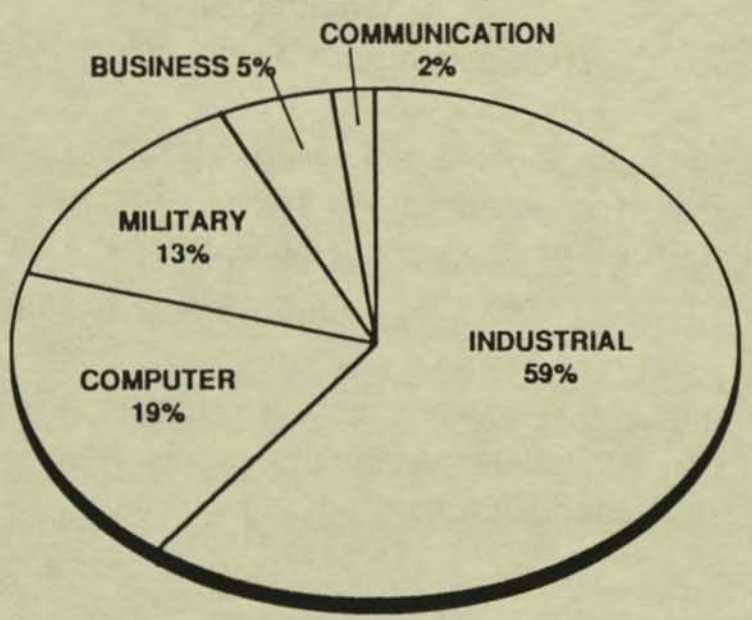
- Expensive to manufacture, especially in high information content forms, due to the large number of high voltage driver ICs required
- Full color difficult to achieve, due to problems with phosphor brightness and discharge spreading effects

Recent Developments

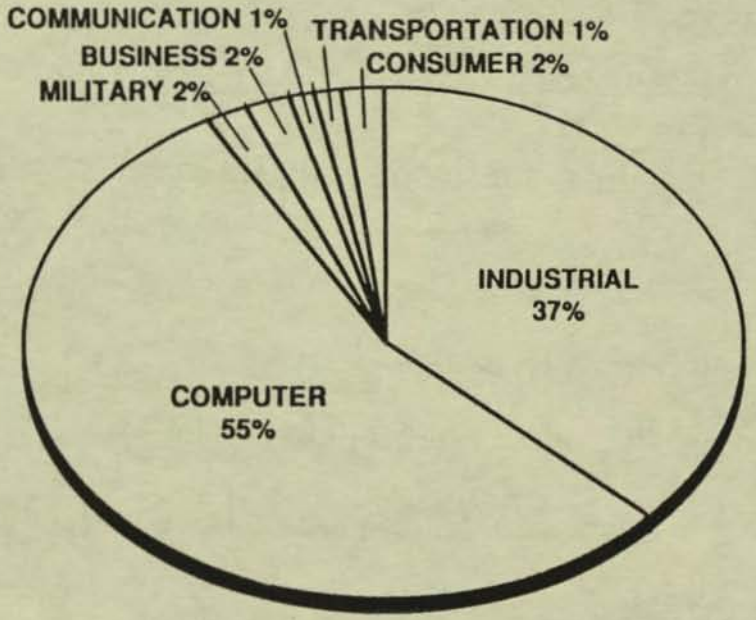
- Independent Sustain and Address (a new design technique developed at the University of Illinois) has the potential to reduce the number of IC drivers and thus manufacturing costs
- Multicolor displays are under development for the military by Magnavox and Photonics Technology
- Fujitsu has demonstrated a 15", eight color computer display

Source: Stanford Resources Inc.

WORLDWIDE ELD DISPLAY MARKET BY APPLICATION



1989
TOTAL SIZE = $U.S. .1 BILLION



1996
TOTAL SIZE = $U.S. .9 BILLION

SOURCE: Stanford Resources

225-36795.1G

PERFORMANCE OVERVIEW—ELDs

Strengths

- Extremely thin and compact
- Extremely good contrast; gray scale capability
- Thick film technology simplifies manufacturing
- Large screen sizes possible (currently up to 19" diagonal)
- High information content possible (currently 900K pixels)

Weaknesses

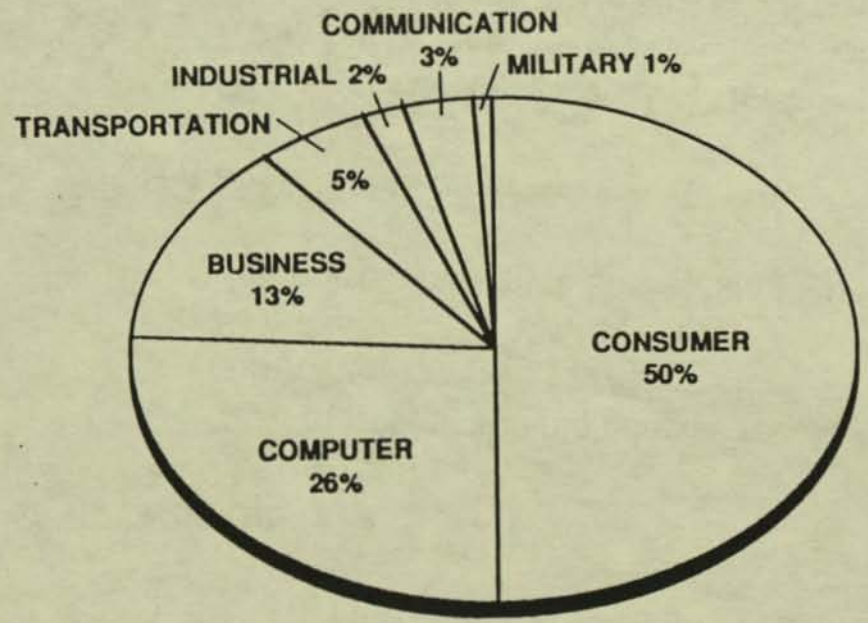
- Expensive to manufacture, especially in large information content forms, due to the large number of high voltage driver ICs required
- Full color difficult to achieve, largely due to problems with blue phosphor brightness

Recent Developments

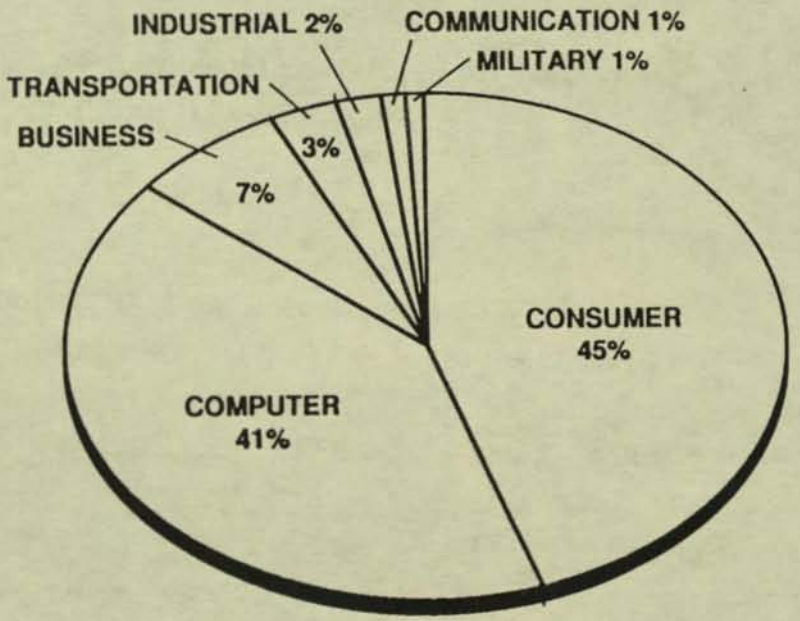
- Planar Systems has developed a 19" ELD
- Matsushita has demonstrated a 10" multicolor (yellow, orange, green) ELD
- Planar has developed techniques to reduce ELD power consumption by more than 50%
- Lohja/Finlux has demonstrated a 7" monochrome ELD TV display; a color version is under development
- Nippon Sheet Glass and Phosphor Products have jointly demonstrated a 640x400 pixel display

Source: Stanford Resources Inc.

WORLDWIDE LCD DISPLAY MARKET BY APPLICATION



1989
TOTAL SIZE = $U.S. 1.8 BILLION



1996
TOTAL SIZE = $U.S. 6.3 BILLION

SOURCE: Stanford Resources

225-36787.1G

PERFORMANCE OVERVIEW—LCDs

Strengths

- Extremely low power consumption
- Low voltage requirement lowers driver costs
- Full color technology already available
- Active matrix designs have good contrast and viewing angle performance

Weaknesses

- Yield problems and high capital requirements mean that active matrix devices are currently expensive to manufacture
- Manufacturability of large screen sizes (20" and greater) has yet to be demonstrated
- Color displays require backlighting thus increasing power consumption

Recent Developments

- Sharp has demonstrated a 14" full color, active matrix panel for TV
- A number of firms have shown full color, active matrix panel suitable for computers and avionics, up to 10" in size
- Full color, Active Matrix TV panels with 5" and 6" screens are now in commercial production

Source: Stanford Resources Inc.

Cross filed-DARPA + f: HDS

AMERICAN ELECTRONICS ASSOCIATION
1225 EYE STREET, NW
SUITE 950
WASHINGTON, D.C. 20005
202-682-9110
FAX: 202-682-9111

TO: AEA High Definition Systems Task Force

FROM: Denise Michel

RE: DARPA HDS Funding -- Good News!

In response to efforts of AEA's High Definition Systems Task Force, the $20M appropriated by Congress for FY90 DARPA high definition display R&D has been released.

The Conference Report accompanying H.R. 4404, the supplemental appropriations bill, states:

> "The Conferees are disappointed that the Administration has not responded to the Appropriations Conference report requirement for submission of a government wide plan to develop high definition display technology. The conferees agree with the Senate report which reiterates the need for such a policy and program. The conferees further agree that there are no longer any restrictions on DARPA from obligating the additional $20,000,000 which Congress appropriated in fiscal year 1990 for research of this technology."

H.R. 4404 was signed into law on May 25 and DARPA is proceeding with the expenditure of these funds.

This action demonstrates Congress' continued support for HDS R&D and the impact of HDS Task Force members' Congressional visits. Now that we succeeded in releasing the FY90 money, we must turn our attention to FY91 --

* Meetings are being scheduled with Administration officials and Members of Congress on June 12 to lobby for continued funding. Please call me at 202-682-9110 if you will be able to participate.

* Next week you will receive a letter (for your signature) to a key Member of Congress in support of FY 1991 DARPA funding. Please sign (or draft your own letter) and mail ASAP. Congress will soon begin the FY 1991 appropriations process and, as you have seen, industry contact helps get results.

American Electronics Association AEA

5201 Great America Parkway, Santa Clara, California 95054. Telephone: (408) 987-4200
1225 Eye Street N.W., Suite 950, Washington, D.C. 20005. Telephone: (202) 682-9110

May 23, 1990

To: AEA HDS Task Force

From: Pat Hubbard

Re: Various and Sundry

Enclosed are two papers presented by task force members, a new article announcing Korea's positioning in HDTV, and various and sundry other background materials that may be of interest to you.

Also enclosed is a list of the "Interim Recommendations of the AEA HDS Task Force" [latest version dated May 1]. This list has now been reviewed by the three public affairs committees of AEA. We will spend the next three months trying to determine the level of support for this list from computer systems companies, with the intent of taking final recommendations back to the three public affairs steering committees and then to the Board on September 13 for approval.

The process we will follow over the next several months is the one we previously laid out:

> From a target list of computer systems companies, we will first pilot-test the waters by going to these companies locally: Hewlett-Packard, Sun, Apple, Tandem. As the meeting dates are set up, we will contact one or more members of the flat panel display working group and ask that person to accompany a BAH person to the meeting.

Paul Low, Chairman of the Education and Science Policy (ESP) Committee [the committee to whom the AEA HDS Task Force reports to the AEA Board of Directors] emphasized the need for the HDS Task Force to educate all members of ESP prior to their September 12 meeting. Towards this end and the additional necessity of having as many of the AEA Board members as possible "up to speed" by the September 13 Board meeting, I will contact you in early August and ask you to contact 3 to 5 either ESP or Board directors and discuss the role of flat panels, the role of AEA and its HDS Task Force, and the proposed actions that will be recommended for Board approval.

Will you also consider how many of the BAH Executive Summary Reports you would like (up to 5 each) and make your request known on the attached form and mail to Sue Weir. If you would like to duplicate yourself, feel free to do so. If anyone wants the larger report, the charge is $75 and can be ordered through Sue.

Denise may also be contacting you regarding lobbying over the next few months as well. Hope you have sent your comments to NIST on the ATP regulations, with copies to Jim Hurd. Jim will compile and frame into a combined AEA position.

Call if you have questions. Regards!

May 1, 1990*

AEA High Definition Systems (HDS) Task Force
INTERIM Recommendations for HDS Flat Panel Displays

GOAL for U.S. ELECTRONICS COMPANIES

TO MANUFACTURE IN THE U.S. BY 1996
GREATER THAN 20% OF THE WORLDWIDE
REQUIREMENTS FOR LARGE AREA DOT MATRIX DISPLAYS

PRIVATE SECTOR INITIATIVES

A. Continue to articulate and educate our membership and public officials [using Booz-Allen Hamilton report] with respect to the strategic importance of high definition flat panel displays as a critical link in the HDS "foodchain" impacting an increasing number of electronics systems.
   - CEO level Lobbying
   - AEA Public Affairs Committees--IPASC, DPASC, ESP
   - Board of Directors

B. Promote a high level dialogue via a series of high level briefings and information gathering meetings with major computer systems companies and other large users of displays.
   - Explore and encourage the formation of a high volume production consortium
   - Include results in final report to AEA Board of Directors September 1990

C. Encourage the formation of a working group of flat panel manufacturers/developers to:
   - Support/participate in the formation of a high volume production consortium
   - Develop proposals of joint government-industry initiatives such as NIST's Advanced Technology Program

D. Encourage start-up of new companies and existing companies to develop/manufacture flat panel displays, critical subcomponents, and equipment used in the development/ manufacture of flat panel displays.

PUBLIC/PRIVATE SECTOR INITIATIVES

A. Actively participate, with the support of the U.S. government, in foreign government-industry technology consortiums in related areas.
   - Provide the necessary industry personnel
     [Note: AEA initiative underway to send industrial researchers to Japan, dependent on DoC's ability to secure positions in key industrial consortia related to flat panel R&D and with NSF financial support.]

B. Encourage the purchase of U.S. made displays and sub-components.
- Federal purchases
- Commercial purchases
- Display manufacturers

C. Encourage foreign manufacturers who will manufacture in the United States to do so with the formation of joint ventures with U.S. display manufacturers and provide reciprocity of market access in their home markets.

PUBLIC SECTOR INITIATIVES

A. Fund critical federal programs in the area of high definition display technology.
- Defense Advanced Research Projects Agency - $100M
- National Institute for Standards and Technology - $100M

B. Establish a national center for Electronics Display Research.
- Increase the availability of qualified researchers

C. Monitor foreign trade practices of displays. Enforce and strengthen anti-dumping laws where violations are found.
- Propose changes in tariff classifications to more accurately monitor trade practices

D. Remove all foreign tariffs on U.S. made displays or ask U.S. Department of Commerce to monitor dumping.
- Place flat panel displays on the agenda of the current Uruguay Round
- Include flat panel displays on retaliation list of any other trade disputes

*Review Process:
- IPASC: AEA HDS Task Force document reviewed by IPASC on April 26; reached consensus with HDS Task Force recommendations and strengthened several trade related items.

THE CRITICAL ROLE OF THE DISPLAY FOR HDTV AND MORE

Presented to the *HDTV Conference* in Arlington, VA on February 14, 1990 by James M. Hurd, Planar Sytems, Inc.

THE CRITICAL ROLE OF THE DISPLAY FOR HDTV AND MORE

I. THE HDTV DISPLAY, SYSTEMS AND TECHNOLOGY

The cost and performance requirements for the high definition display to be used in future computer products and High Definition Television (HDTV) are difficult hardware challenges. They are some of the most difficult and important technological challenges in the set of technologies which comprise the future high definition system (HDS). The display element in future high definition systems will most likely be the most expensive single cost item. Because of the competitive advantage the display will provide the manufacturer of the high definition system, the competition to establish a proprietary position in high definition displays has become the strategic topic of a wide set of companies, industry associations and even governments. The high definition display will not only have application in HDTV products for consumer and communication products, but will also be a key building block for future military, industrial and computer-based products which will use HDS technologies. The resolution and optical requirements for these non-HDTV applications will require many of the same performance features as the HDTV display, but not necessarily the same size requirement. For maximum viewing benefit, the size and resolution of the HDTV display must more than double that of today's typical NTSC display, as illustrated in Figure 1. Independent of the standards debate for format, it can be assumed that the format required for HDTV will have a minimum of 2000 addressable columns and 1000 addressable rows; for maximum viewing benefit it will be greater than 40" diagonally. The exact format or size does not substantially alter the technological challenge to display developers and/or manufacturers.

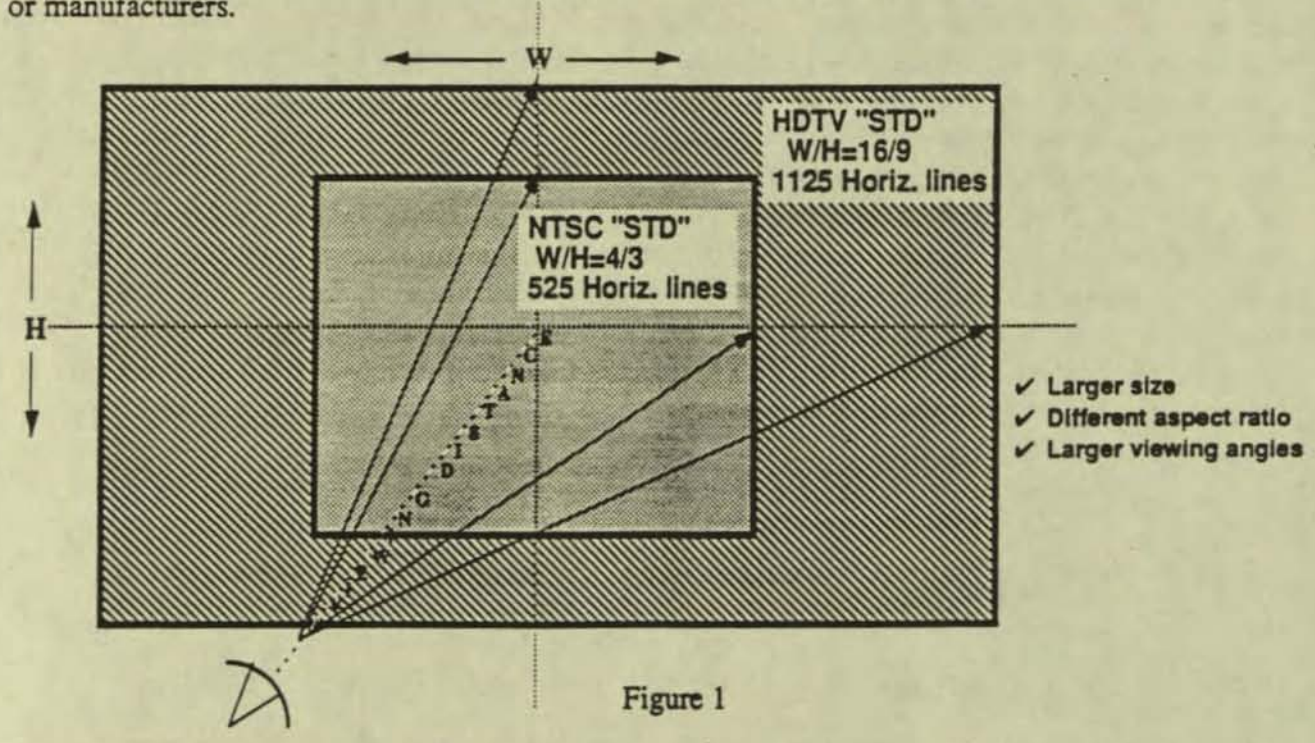


Figure 1

There are three general approaches shown in Figure 2 which are being pursued in order to satisfy the need for an HDTV display: 1) The conventional direct-view cathode ray tube (CRT); 2) The projection display, and 3) The direct-view flat panel display. None of these approaches totally satisfies the cost and performance requirement today for an HDTV display. The future success of any of these approaches is heavily dependent on the inherent characteristics of each approach and the developer's ability to enhance the performance and decrease the cost in order to satisfy all, or a portion, of the market driven requirements for a high definition display.

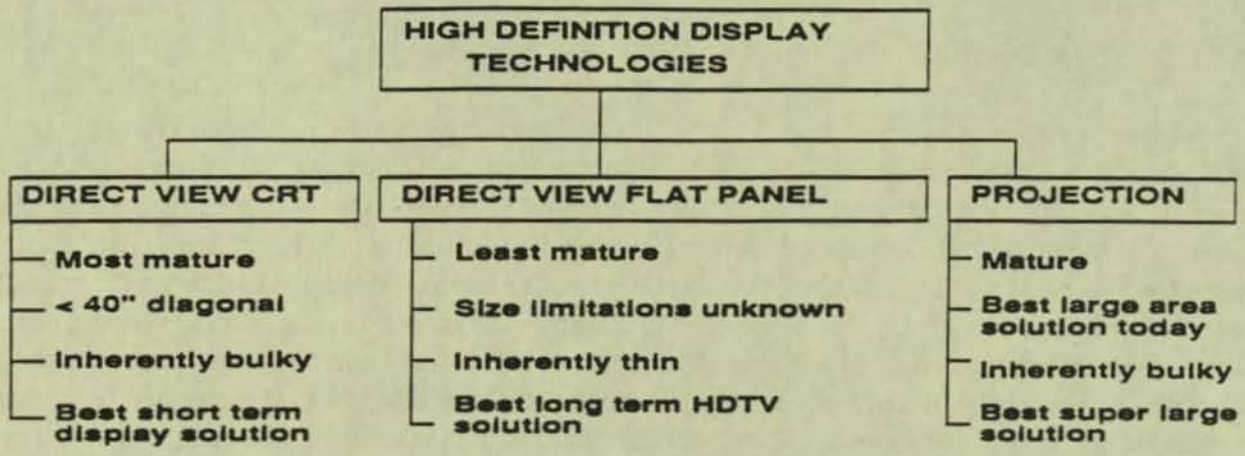


Figure 2

DIRECT-VIEW CRT DISPLAY

Direct-view CRT technology, with which most consumers are familiar, is used in the vast majority of displays for television entertainment, computer graphics, and high resolution imaging applications. Conventional CRT technology, when extended to the size and resolution requirements of future HDTV systems, encounters unresolvable disadvantages, most notable of which are physical size limitations. Figure 3 shows some of the physical attributes of conventional CRT technology when used in a 40" diagonal class display. As the display diagonal increases with conventional CRT technology, the depth also increases proportionally. The inability to move a 40" plus diagonal CRT through a standard 30" door opening will limit its usability in many HDTV applications for home and office. Due to this inherent limitation, the direct-view CRT will not be able to satisfy the large area HDTV requirement; however, because of its dominant position as the most mature technology, it will satisfy the need for high definition displays of less than 40" diagonal. Competitive pressure on direct-view CRTs will increase from the direct-view flat panel displays as they progress toward satisfying the HDTV requirement.

Parameter / Company	Diagonal	Depth	Weight
Matsushita	40"	25"	170 lbs.
Sony	42"	26"	230 lbs.

Figure 3

THE CRITICAL ROLE OF THE DISPLAY FOR HDTV AND MORE

PROJECTION DISPLAY

Today, none of the direct-view technologies, CRT nor flat panel- based, are producing a full color display with a diagonal viewing dimension of greater than the required 40"; however, projection displays are available with that size capability. Various types of technologies have been used to demonstrate large area projection TV capabilities using approaches based on lasers, CRTs, LCDs, etc. All of the projection systems on the market today or currently in development, tend to be space consuming and heavy. Additionally, costs have not come down as originally projected. Current development efforts in projection systems for HDTV is focused at increasing the capability of today's technology to address the increased resolution requirement for HDTV, having already achieved the diagonal requirement while increasing brightness and viewing angle. Opportunities for significant size reduction for projection-based systems seems improbable when competing against the potential large sized direct-view flat panels. Likewise, the inherent bulk of the projection system provides no advantage in the area of high definition displays in applications that can be satisfied with displays less than 40" in diagonal with the direct-view CRT.

DIRECT-VIEW FLAT PANEL

The great advantage of the newer flat panel display technologies is that they offer solutions to the inherent space and bulk problems which characterize the direct-view CRT and projection systems in all diagonal sizes. There are several candidate flat panel display technologies being pursued; these technologies have made impressive progress in the last ten years. In the early 1980s, flat panel electronic displays accounted for only a few percentage points of the overall market for electronic displays; today flat panel displays account for over 25% of worldwide display sales. We now see flat panel displays in a wide variety of products from aircraft cockpits to pocket TVs. Flat panel display sales are growing at nearly twice the rate of CRTs in virtually every application sector of displays, indicating the transition from a CRT technology dominated market. During the 1980s, various types of flat panel display technologies demonstrated sufficient market acceptance to drive significant manufacturing volumes which, in turn, allowed manufacturing economies to reduce costs. Currently, flat panel displays in volume production are limited to monochrome up to 20" in diagonal and color to 6". The ability to project when any or all of the candidate flat panel display technologies will be capable of progressing from the size and performance levels of today, to where they must be in order to produce an HDTV display at an acceptable cost, is difficult to judge and is filled with technological, manufacturing and market risks. The current status of each of these technologies represents somewhat different positions in terms of the level and types of risk involved to achieve high definition display performance as depicted in Figure 4.

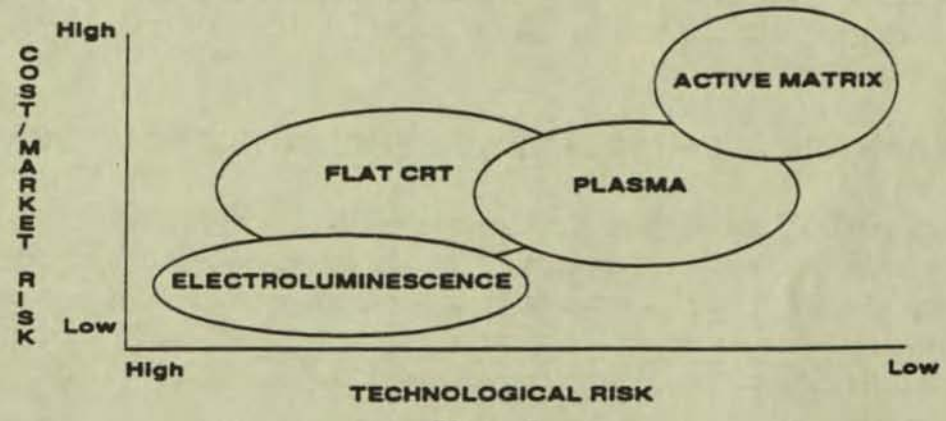


Figure 4

THE CRITICAL ROLE OF THE DISPLAY FOR HDTV AND MORE

The active matrix liquid crystal display (LCD) technology has been the source of a great deal of publicity and seems to be the "display of choice" for Japan, Inc. Of all the display technologies being considered for HDTV applications, active matrix liquid crystal has the least technological risk having already demonstrated full color capability in the laboratory, but it also has the highest level of risk associated with it from a manufacturing cost standpoint due to its inherent high level of complexity. This manufacturing risk is common to both monochrome and color and increases with size.

Plasma display technology, one of the oldest flat panel display technologies, originally the "display of choice" of Japan, Inc., has apparently fallen from favor with a large Japanese consortia now focusing on active matrix technology. Large area plasma panels have been demonstrated and today are available in small volume monochrome up to 40" in diagonal. Nearly ten years ago, full color plasma displays were demonstrated in the laboratory but have yet to emerge in volume production, due to difficult production and performance problems.

AC thin film Electroluminescence (EL) is a relatively new technology, first emerging in volume production during the mid-1980s and rapidly offering products up to workstation sizes; however, EL has yet to demonstrate a level of full color performance to indicate that a practical commercial product is feasible. EL's comparatively simple manufacturing process suggests the potential of being one of the lowest cost HDTV displays to produce. Although significant progress in EL technology has been in monochrome displays in a relatively short period of time, that now must be translated into full color.

Although the most significant progress in flat panel display technology in the past ten years has been in EL, LCD and plasma, it is much too early to rule out alternatives in the face of the significant HDTV technical challenge. Various flat panel configurations of CRT technology have been evaluated over the last 20 years. The potential advantage of a viable flat CRT would be its ability to leverage extensively off the large existing technology base in CRT phosphor and screen processing technology.

Even with this set of challenges in front of the flat panel developers and manufacturers, most agree that it is not a question of whether or not a flat panel display for HDTV can be produced successfully. It is more a question of when and by whom and which markets will be targeted as vehicles to be used to build economies of scale along the development road to HDTV. The simple extrapolation of the enormous amount of progress seen in all the flat panel technologies in the last 10 years, not only in terms of technology but also in market acceptance and manufacturing, have clearly shown that flat panels can and will compete effectively for use in all high definition systems, including HDTV. If the same amount of progress is made in any or all of the flat panel technologies in the next ten years, as was made in the last ten years, we are assured of an HDTV flat display in this decade.

II. THREAT AND OPPORTUNITY FOR THE U.S. ELECTRONICS INDUSTRY

The importance of HDTV and high definition displays for HDTV goes far deeper and is much broader than just the next generation of television products. The vast majority of electronic products that we use for military, communication, industrial, business, computer or consumer products have an electronic display associated with them. At one time, the U.S. pioneered the development of CRT for television applications. Many of those early pioneers turned further development and manufacturing of the CRT over to foreign

companies due to its labor intensity and their lack of vision that the CRT would be not only a critical component for television, but also a critical component for the then emerging computer revolution. As a result, most U.S. companies are totally dependent upon foreign suppliers of CRTs (Figure 5) as a commodity componenet for our non-consumer products. Although there are now controlled captive operations which have moved back to the U.S. as labor cost became less advantageous for foreign manufacturers and larger tubes increased transportation costs. Overall, due to the abondonment of the CRT business years ago, the U.S. is not a factor in the very large electronic display business which in 1990 will produce nearly $15 billion worth of product.

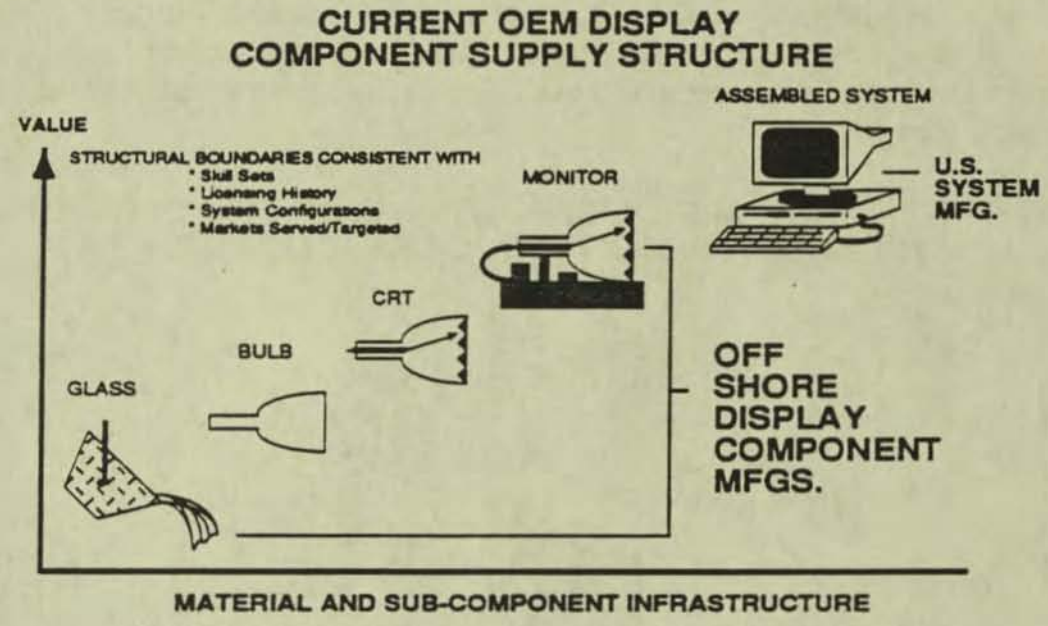


Figure 5

It is clear from current market trends, and over the last ten years, that flat panel displays are competing effectively and will continue to compete in markets which historically have been dominated by the CRT. The fact that the large electronic display industry is transitioning from a basis in CRT technology to the newer flat panel technologies creates an opportunity for the U.S. to re-enter the business and establish a presence as a major transition is taking place within the display industry based on new flat panel technology developments and automated manufacturing.

Parallel with the transition in the electronic display market from CRT-based to flat panel, is the transition in the television industry from NTSC to an HDTV standard. This has now supercharged the interest in flat panels in two ways: 1) The need for an HDTV display larger than CRT technology has accelerated the need and investment interest for a flat panel solution for the future HDTV industry; 2) The level of display performance required for HDTV use will satisfy most future display requirements for electronic displays, not only in HDTV markets, but in many if not all of the non-consumer markets including computers. These high definition display markets will become the target markets for the flat panel manufacturers as they develop their technologies and build production volume.

In the face of this transition in display technology and TV standards, the threat to the U.S. electronics industry is simply: Can the U.S. display user (military, computer, consumer, etc.) expect to be able to source these new generations of flat panel displays as they have for the CRT?

THE CRITICAL ROLE OF THE DISPLAY FOR HDTV AND MORE

Given the large level of development and new plant and equipment costs required by foreign manufacturers for flat panel technology and the ability to integrate a wide variety of system functions onto the display at low cost, why would a foreign manufacturer be interested in supplying a low margin display component to U.S. electronics manufacturers? In order to get the maximum return of that large investment, the foreign manufacturer will likely choose to integrate that display into its own workstation or HDTV production system or receiver. We have already seen this type of vertical integration in the consumer TV industry based on CRTs and with the advent of high definition displays we can expect to see that same trend in other markets, particularly computers (Figure 6). An early example of that is the portable laptop market for which foreign display manufacturers originally supplied displays and now are competing with their own flat panel-based computers. It would be naive to think the Japanese and European mega-dollar consortia now developing displays are driven by a need to better serve the U.S. electronics system manufacturers with state-of-the-art low cost display components.

COMPETITIVE SUPPLY STRUCTURE OF THE EMERGING HIGH DEFINITION DISPLAY INDUSTRY

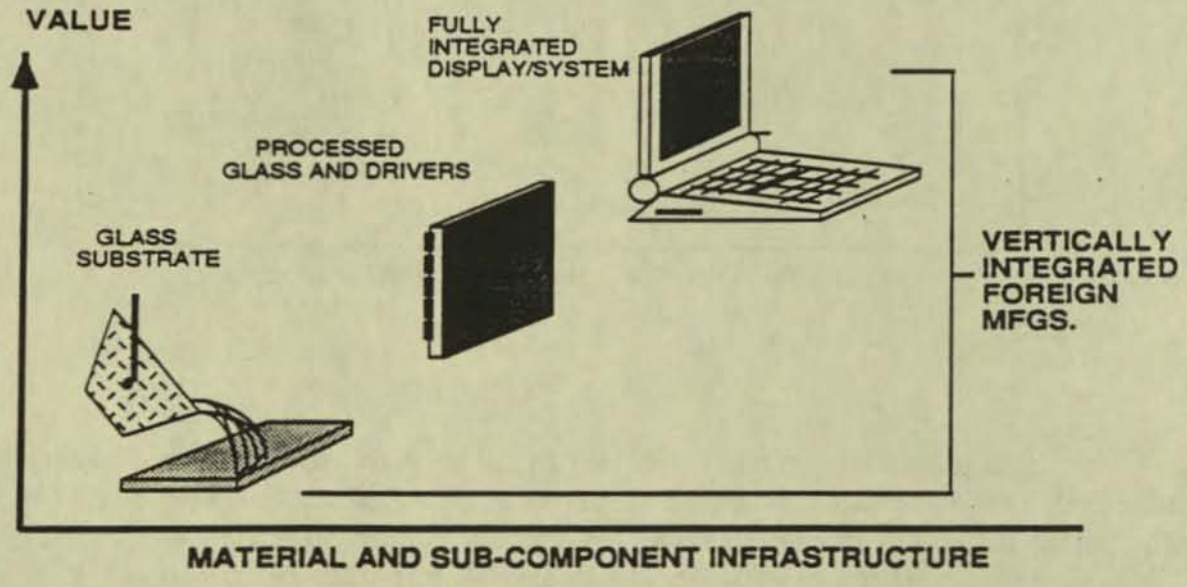


Figure 6

CONCLUSIONS

The new generation of high definition displays is indeed the "missing link," not only to HDTV products, but is also a critical link in the electronic component "food chain" which we now have an opportunity to relink by creating a U.S. supply base of the new generation of high definition flat panel displays that will be critical to a wide range of products. Our actions in the private and public sector over the next few years are critical in order to create an environment in terms of the technologies, investment dollars and fair market practices that are conducive to building an industry from the small entrepreneurial status that now characterizes the U.S. position in high definition display development and manufacturing.

THE SURPRISING ECONOMICS OF FLAT PANEL PRODUCTION (THE CASE FOR MINIFAB PRODUCTION)

Griffith L. Resor III, MRS Technology, Inc
10 Elizabeth Drive, Chelmsford, Massachusetts

ABSTRACT

Forecasts of production cost for active matrix displays generate lively debate. So far confusion, not consensus, has been the result. A complex business model has been developed to understand the issues. Market behavior, unit volume changes, materials costs, yield, line balance, capital needs and after tax discounted cash flow results have been examined. Advantages for large scale production have been included. Strategic choices of national location, factory volume, product pricing and tax policy have been explored.

The model shows that the flat panel business does not resemble the DRAM business, not even closely. A minifab with 550,000 starts per year was found to be optimum. Materials costs, not capital costs, determine this business economics and R&D priorities. Innovation in process will be the key to success. Differences in decision rules and analytical methods, not actual operating results, account for different nations current investment decisions.

BACKGROUND

The United States' trade deficit must be improved dramatically, if the world's trading system is to be maintained. The electronics industry has a major role to play. In fact the USA trade deficit in electronics is a major part of the problem. At MRS Technology, Inc. it was felt that the present failure of the USA to participate in the emerging flat panel display business would be fatal for the USA electronics industry. It was assumed from the start, since other nations were active, that the USA problem lay somewhere in the government created business environment. It was suspected that the high cost of capital was the major problem. But, in fact, it was not known which government policies were important, nor was it clear which policy changes would have the greatest impact on the flat panel production business. A detailed analysis was needed to discover which policy issues were really important, and to learn how much change would be required to really impact free market decision makers.

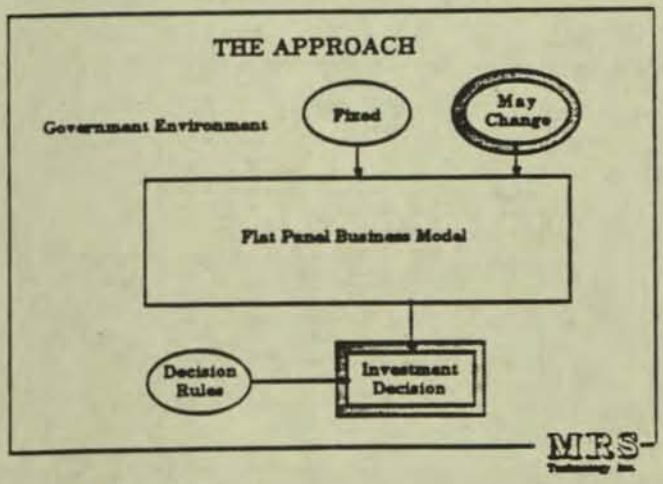


Figure 1. The Approach

THE BASIC APPROACH

A model of the flat panel business was created, which specifically focused on private sector and national policy variables. The model, shown in Figure 1, was created and used to explore the impact of various changes in the political and economic environment on business and investment decisions. From the start it was important to be able to move the business to different national tax and economic environments. It was also important to evaluate the business in after tax terms, since most of the incentive tools available to governments involve changes to the after tax business results. The results of this work provide focus to the government discussion. The results also turn out to have major private sector impact. Several business myths about the flat panel business simply proved, under closer examination, to be untrue. This was a surprise.

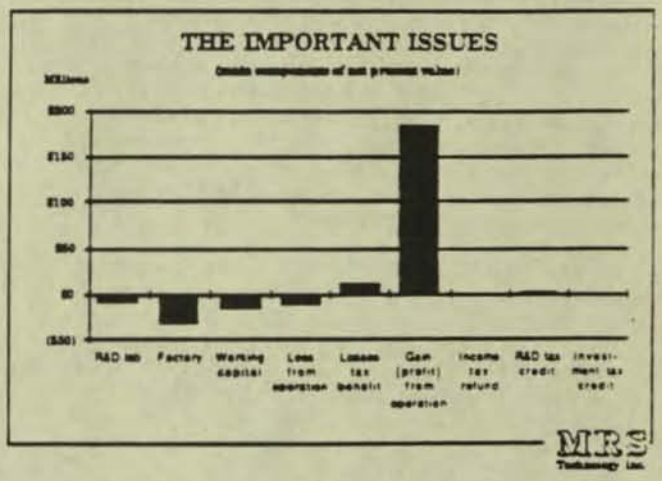


Figure 2. The Important Issues

Implications for Government Action

The model shows four issues account for most of the risk and value in the business. Three of these issues have important political impact.

First, there is a substantial R&D investment to be made, to put the business on a strong technical foundation ($7,000,000 each year plus a $10,000,000 lab). Risk is the major financial issue for this phase. Private sector risk can be significantly reduced by government assistance. In the USA this role is currently played by the Defense Advanced Research Projects Agency (DARPA). Their work will buy precious time for USA technology centers, accelerating their technical progress and giving them time to find production teammates. The R&D tax credit, hotly debated each year in the USA, has no significant impact on this business. This was a surprise.

Second, the factory, and all its associated start up costs, is the largest investment issue. Estimates range from $40 million to $60 million. Availability and cost of capital are the major financial issues. Risk has been reduced by the R&D phase. In the USA it is expected that the States will use their economic development funds to help with this phase. In Japan deferred low interest loans and special accelerated depreciation rules help support the factory investment phase, and lower future capital carrying costs. Reinstating the USA investment tax credit on factory investments would have a major positive impact on this

business. Changing anti-trust laws to specifically allow teaming of smaller volume users for joint manufacturing should also help.

Private sector financing is the most likely method for financing working capital needs and early operating losses. Note, this will require "cross subsidy" within a large corporation, taking profits from one business to fund this investment. Nearly $30 million is needed for these uses in the minifab model. Note, also, the ability to deduct operating losses and R&D from other income provides a significant reduction in this initial investment (depends on corporate income tax rate).

The third area for political focus concerns pricing. **The most important element of the entire business is the profit to be earned. Without the prospect of significant profits, investments will not be made.** When Mr. Kawanishi of Toshiba states publicly he is prepared to take losses for "5 or 6 years" to enter this business, he is protecting his company's investment and scaring off other more timid investors. Only investors who see a way to secure a profit will invest in this business. In the USA existing mechanisms for protecting businesses from predatory monopolistic practices must be strengthened and applied to foreign firms. When these laws were written nearly 100 years ago, foreign competition in USA markets was not an issue. Now it is the issue.

The most startling finding is that geographic location of the business has **no significant impact on the operating results**. The accumulation of cash in the business is nearly the same whether the business operates in the USA or in Japan. While Japan enjoys significantly lower interest rates and inflation rates, it has significantly higher corporate income taxes. These cancel each other. The USA does not appear to be at an economic disadvantage.

The difference in investment decisions lies in the decision making rules. The practice in the USA of using discounted cash flow analysis, coupled with the higher cost of capital in the USA has caused USA based investors to leave their money in the bank. The underlying assumption is that all investments are equally attractive, except for their financial return, so one should choose the highest return investment. The logical goal is to maximize wealth over time. Since the USA appears to be **minimizing** its wealth, including a wholesale selloff of its remaining assets (engines which produce wealth), the USA decision making rules appear to be suspect, and should be reviewed. But reprogramming 500,000 MBA's is beyond the scope of this paper.

Private Sector Impact

Construction of the flat panel business model yielded significant, surprising insights into the operation of the business itself. Prior to this work it was commonly felt that Japan was the only place to make money in this business; the business was just like the DRAM business; huge volumes of product shipments would be needed just to compete. It appeared that the Japanese TV giants would soon rule the display and computer worlds. We find that this need not be so. **We find that the economic realities of the flat panel business will provide significant strategic opportunities for many non-TV players in all regions of the industrial world.**

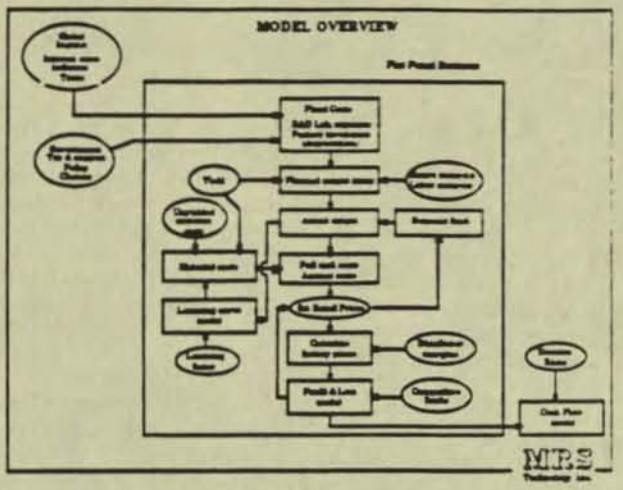


Figure 3. The Model Overview

The "Model"

Figure 3 shows a more detailed flow chart of the model. This will be discussed in limited detail at the conference. A detailed book is available from MRS.

A 15 year time horizon is used in the model. Several items change by a factor of 10 over this time frame. A one year "slice" at the economics, while simple, misses the important dynamics of this business completely.

All costs that are fixed (do not vary with output) are isolated and entered into the model directly as absolute amounts (not ratios). This makes for easier isolation of variables, and provides for the correct mathematics. Normally used rules of thumb for depreciation do not provide accurate results, particularly if the rules are taken from the DRAM business.

The hours of factory operation should be maximized. Competition and economics dictate this. However, it was found that ramping the factory too rapidly ahead of yield produces huge losses and not much useful product. Yield gains will set the pace of this industry's growth.

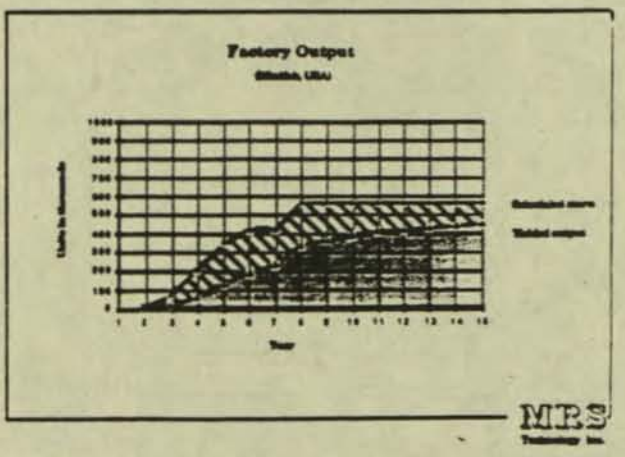


Figure 4. Factory Output

The actual output of the factory shown in Figure 4 is not only limited by scheduled hours, equipment capacity, and yield. A market price elasticity "demand model" provides feedback on market growth as prices decrease. Factory output is limited to the smaller of yielded output or market demand. This feature reflects the benefit of larger scale.

Materials costs increase with inflation, decrease as yields improve, and decrease as a result of a learning curve model. As cumulative unit volumes improve, costs are lowered. This gives added advantages of scale.

Once global assumptions have been set, unit prices are adjusted "on-line" to optimize the business. After much trial and error, generalized pricing rules were developed. In the startup phase, prices should be set to recover out of pocket materials' costs and to gain market design-in goals. The key in this first phase is to **keep supply low** and maximize prices within design-in goals. As the business comes on line, pricing shifts its focus towards lowering price, driving market elasticity to fill the factory and gain learning curve benefits. Finally, as the business matures, pricing shifts to cost plus pricing, driven by competition. In this phase, the demand model shows the market expands rapidly beyond the capacity for this one factory, and it is time to add a new factory.

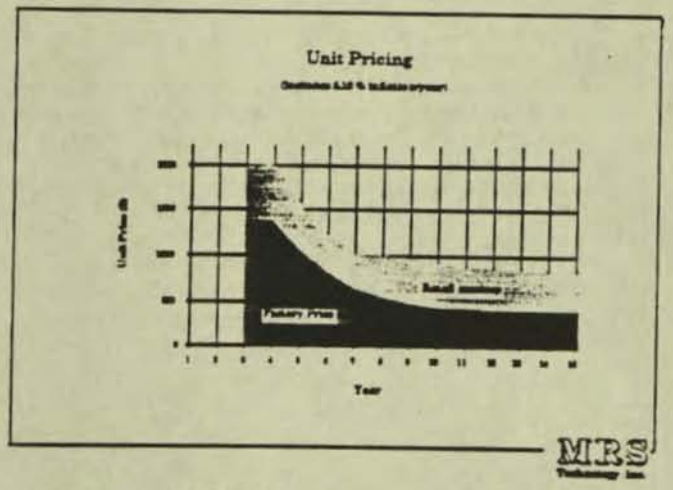


Figure 5. Unit Pricing

Figure 5 shows the retail pricing that results for the minifab model. 5.10% annual **inflation is included in the prices in Figure 5.** In constant dollar terms, the 14" HDTV receiver used in the model will have a factory price of only $200 in 2005.

Implications for Computer Systems

For some users, the flat panel business provides attractive returns, even in the USA, even at the current high cost of capital. The key to this is to have a strategic relationship that offers some price protection. Computer systems makers have this opportunity.

Geographic location (USA or Japan) does not significantly alter the result. The global assumptions on inflation, interest rates and corporate tax rates were changed from those of the USA to those for Japan. The actual operating results were slightly poorer in Japan. The differences found, however, are less than the accuracy of this model. Issues such as infrastructure support, lines of supply, and internal company politics may make a difference, but the economics come out too close to call. **This was a total surprise.** As others have, we assumed the cost of capital would make a significant difference. **The cost of capital impacts the bottom line less than 2%.** Not a factor that can be ignored in such a competitive business, but hardly the show stopper it is alleged to be in the USA.

It is commonly believed that flat panel product prices will remain well above CRT product prices for the next decade or longer. The model shows a much different result. **We find high resolution flat panel product prices will match high resolution CRT product prices within 6 years, even if yields are assumed to be only 45% on the active matrix portion of the TV. Miracles are not required.**

Materials costs drive the cost structure of the business in all years. In the DRAM business it is the capital cost that dominates the business cost structure and makes that business inherently unstable. DRAM's are tiny; so materials costs are small in comparison. This was the expectation for displays. **But the expectation is wrong.** The issue is not even close. Materials costs make up nearly 80% of the factory cost in all 15 years of the model.

This finding has significant business implications. First, innovation in the process, to improve yields and reduce costs, will have the largest payoff. So managers will focus resources on process innovation. This concept is the key to success. The business should also be inherently more stable, since a high materials content enables managers to adjust to volume changes directly, without having to shift pricing to incremental costs to keep the factory full.

Finally, it was discovered that the production line can be balanced at one-quarter the originally assumed superfabsize of 2,250,000 starts per year. A minifab of 550,000 starts per year provides a balanced factory. In fact, because of yield limits, the superfab must be built over 7 years. Low yields and high materials costs prevent any faster ramp-up. Combined with the immature state of processes in the flat panel business, and the need for constant process innovation, the superfab quickly becomes a liability. **Several smaller fabs built over time, each optimized for the process at that time, will be the way this business gets built.** This is, in fact, the pattern now emerging in Japan.

This business will not ramp as fast as new DRAM capacity does today. All forecasts show demand far exceeding supplies for many years. Systems houses will need to have control of their own supply. **Internal captive supply will be the only sure way to have adequate supply of competitive displays.** In fact the unique process skills built by suppliers, coupled with supply shortages, will move profit in the systems business from the system box to the display component. Today the system box is the high margin item, and the CRT display is the commodity. **This situation will soon reverse itself.** To protect profits, display users will want to secure captive supply now.

CONCLUSIONS

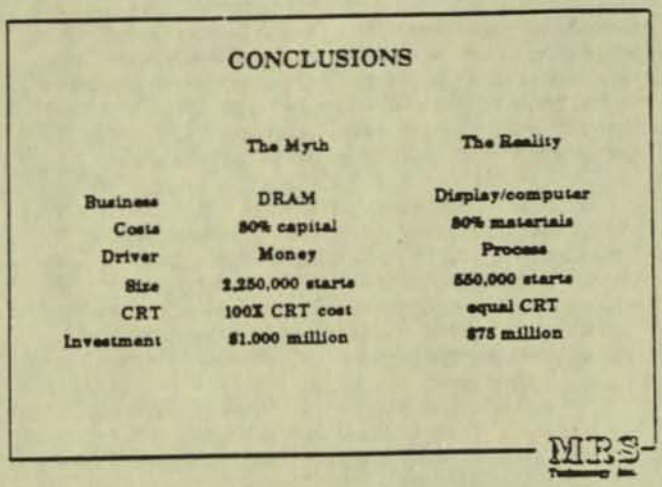


Figure 6. Conclusions

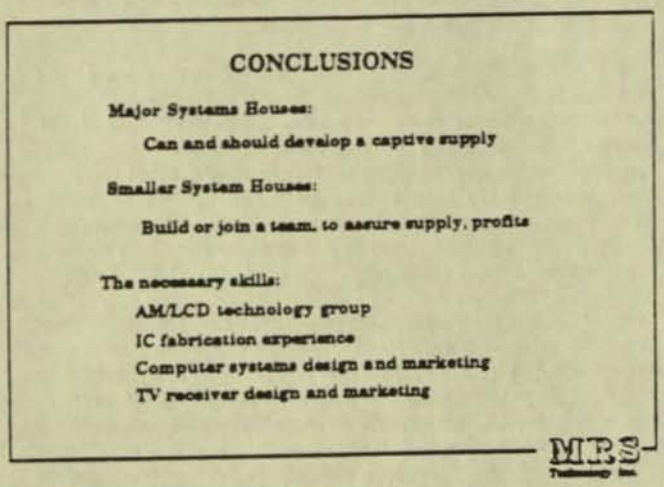


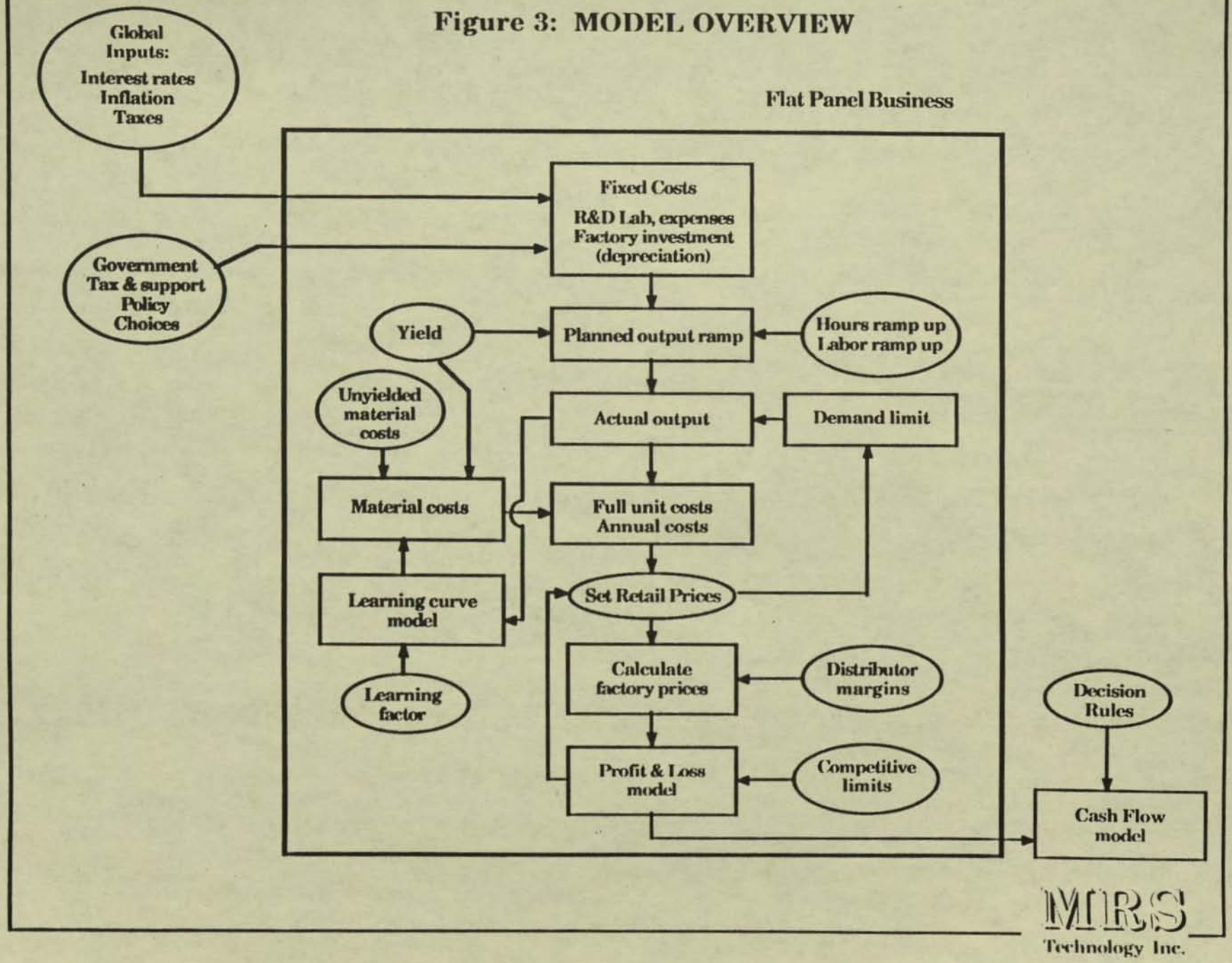
Figure 7. Conclusions

Figure 6 and Figure 7 summarize our findings. The flat panel display business is not the DRAM business. Materials costs, not capital costs, are the dominant cost issue. Process innovation, not brute force capital investment strategies will be the key to future cost reductions, product enhancement and profits. With the process constantly changing, and capital costs less significant, the optimum fab size is quite small (by DRAM standards). An optimum size of 550,000 starts per year was found to be optimum. As yields improve and factory output ramps, product costs will become cost competitive with CRT based products. Miracles are not needed, just normal development of this business. Investment in a minifab business will be approximately $80,000,000. This is not small in absolute terms, but is much smaller than the $1000 million now needed for a DRAM fab.

The minifab business is an attractive investment, when judged on its own merits, wherever the investor's strategic interests provide a reasonable chance of achieving profits. This is particularly true for investors who do not operate by USA based investment decision making rules; but the business is also attractive for a few USA based investors. Supplies will be limited by yields and investment for the next decade or more. Major systems houses who have the necessary unit volumes should build captive supplies. Smaller systems houses will need to team to assure supplies and profits.

In the USA, the model shows that direct R&D support by government will have the best short term impact. Changes in anti-trust laws to enable manufacturing teams will help the smaller systems houses and display makers to join forces and reach the minimum unit volumes needed. Restoring the investment tax credit will have the greatest impact on the factory investments; states are expected to help. The **most important issue is pricing**. As anti-trust laws are being reviewed, means to prevent brute force financial tactics from destroying our entreprenurial industrial base need to be found, without reducing fair competition. This is a tough problem made tougher by inaction in Washington.

Figure 3: MODEL OVERVIEW



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WORLD HDTV RECEIVER, DISPLAY, AND CIRCUITRY MARKETS: Opportunities for Semiconductors and Electronic Components on the Eve of the 21st Century

Code: 536-10 Price: $1695 Date: March 1990

EXECUTIVE SUMMARY

OVERVIEW

High-definition television (HDTV), as it enters the worldwide market in the 1990s, will be a new market for electronic components. The new technology will require considerably more electronic components than conventional television sets: memory devices, digital signal processors, analog/digital and digital/analog converters, and microprocessors, as well as more sophisticated electronic displays.

The focus of this study is high-definition television and the electronic components markets created by the manufacture of HDTV receivers.

WORLD MARKET

The major markets for high-definition television, for purposes of this study, are considered to be Japan, Western Europe, and the United States. Television markets are well developed in these regions and present the most likely areas for the successful introduction of a new, sophisticated, and relatively costly technology.

Unit sales of color television sets in Japan, the United States, and Western Europe totaled nearly 42 million in 1986, and more than 400 million color television sets were in use in the same year. Sales of large-screen sets (over 20 inches) are increasing, and it is anticipated that high-definition television sets will take a portion of those sales.

Estimates of the worldwide market for high-definition television vary greatly; therefore, the estimates in this study are based on conservative assumptions of the television market, the HDTV market, and consequently, the market for HDTV electronic components.

Total sales of HDTV receivers could grow to more than 900,000 units by 1996, with revenues exceeding $3 billion. By 2003, unit sales could reach 4.8 billion, with revenues of $7.1 billion.

Electronic components, for purposes of this study, are defined as the circuitry required by HDTV which is not used in conventional television sets (memory and logic devices, digital signal processors, analog/digital and digital/analog converters, microprocessors) and the display.

Worldwide revenues for circuitry and displays are estimated to reach $1.4 billion by 1996 and $7.9 billion by 2003.

JAPAN

Japan is a mature market for television sets, with at least one in most households and substantial annual sales of large-screen sets. Although the market for HDTV in Japan, where high-definition television was developed, is the smallest of the three

areas under discussion, it will probably be the first in which wide use of the technology is attained.

Because Japanese consumers are being prepared for HDTV so thoroughly, it is anticipated that when the first sets reach the consumer market in about 1991, they will be well received even though the cost will be high.

Based on an early introduction of HDTV in Japan, revenues for display devices could be expected to reach $936.3 million by 1996.

EUROPE

Western Europe is less developed in terms of television broadcasting, but it is a potentially lucrative market for high-definition television. Through Eureka 95, the Europeans are developing their own HDTV system.

Due to the fact that satellite broadcasting will increase accessibility to television programming, where previously programming was limited in time as well as variety, it can be expected that demand for television sets in Europe will grow and that the new technology will be accepted readily.

The market for HDTV circuitry in Europe could be expected to reach $15.1 million by 1996.

UNITED STATES

The United States provides the largest market for color television receivers at present, with the largest number in use and the largest number of units sold annually. Consequently, it provides the largest potential market for HDTV.

Because of the uncertainties as to the type of system which will be adopted in the U.S., and the timetable involved in the setting of standards, it is likely that the introduction of HDTV in the U.S. will start relatively slowly. Consequently, the market will probably lag behind the other two regions.

With a delayed introduction of HDTV, the market for HDTV electronic components (circuitry and displays) could attain $121.5 million in the U.S. by 1996.

MARKET TRENDS

The availability of high-quality programming for HDTV is crucial. HDTV offers superior picture and sound, with a wider screen. Programming material which showcases these qualities is vital to the success of HDTV in the consumer market.

Another factor which could affect the rate at which HDTV is accepted is compatibility. The Europeans and the Americans are adopting systems which are compatible with existing television receivers, so the switch to HDTV will parallel the switch from black-and-white sets to color--a process which was quite slow. The Japanese, on the other hand, are adopting a system which is not compatible with existing equipment, which means that an HDTV set can receive only HDTV broadcasts--and that HDTV broadcasts are available only on the new equipment.

MARKET PARTICIPANTS

The major participants in the high-definition television market share several characteristics: they are committed to global operations, they are committed to long-term research and

development activities, and they are prepared to delay profitable returns for some time.

Major Japanese participants in the market are also major players in the world market, and leaders in the development and successful marketing of consumer electronics technologies. They include Mitsubishi, Matsushita, Sony, Hitachi, and Toshiba.

The major television manufacturers in Europe, Philips and Thomson, are not only committed to the promotion of HDTV in their home markets, but they are important participants in the global marketplace as well. Thomson and Philips control a sizable share of the American television market.

While U.S. manufacturers have abandoned the TV business, with the exception of Zenith, American companies operating globally are an important factor in the area of electronic components. ITT, Texas Instruments, and Motorola operate in many parts of the world, supplying local markets.

Many of the participants are involved in joint ventures or some other sort of cooperative activity to develop components needed for HDTV: Eureka 95, involving some 30 European companies in research; Toshiba and Motorola, manufacturing semiconductors; NHK and Texas Instruments, designing components for HDTV.

FIGURE IV-1

HDTV RECEIVER MARKET:
UNIT SHIPMENT AND REVENUE FORECASTS (U.S.),
1993-2003

(In Thousands of Units and Millions of Dollars)

Year	Unit Shipments (000)	Revenues ($Millions)	Revenue Growth Rate (%)
1993	9.0	40.0	--
1994	17.2	72.3	80.0
1995	37.9	143.1	98.0
1996	83.4	283.4	98.0
1997	191.7	580.2	104.7
1998	450.6	1,213.5	109.2
1999	878.6	2,106.0	73.6
2000	1,537.6	3,280.1	55.7
2001	2,383.3	4,524.9	37.9
2002	3,455.8	5,773.7	27.6
2003	4,838.1	7,113.2	23.2

Compound Annual Growth Rate, 1993-2003: 58.5%

Note: All figures are rounded.

Source: Market Intelligence Research Company

(第3種郵便物認可)

HDTV project confronts knotty issues

Including manpower shortage, desirable skills

Following is the fourth in a series of stories on the electronics industry in Korea. It deals with HDTV which is to be developed. — Ed.

By Choi Nam-hyun
Staff reporter

The domestic consumer-electronics industry looks to high-definition television for its future growth.

HDTV sets worth 20 trillion won are estimated to be sold in the world in 2000, the Korea Academy of Industrial Technology says.

Samsung, Goldstar, Daewoo consumer-electronics companies wish to grab a large chunk of worldwide sales to generate growth.

Hyundai Electronics Industries Co., whose major business line has been industrial electronics, wishes to jump into consumer electronics with the development of HDTV.

It is not the consumer-electronics industry alone that will benefit from HDTV development.

Domestic semiconductor makers lag far behind their U.S. and Japanese rivals in areas other than the manufacture of memory chips.

But HDTV development will provide them with an opportunity to catch up with their foreign rivals in the production of customized ASIC chips and microprocessors.

The technology needed to condense data for HDTV will be applicable to an integrated services digital network of telephones, facsimiles, telexes and other media.

HDTV development will also affect defense, medical-equipment, entertainment and other industries.

The government, not the electronics industry, is playing a leading role in the project of developing HDTV because of its impact that will be felt in many important industries.

Prof. Cho Zang-hee of the Korea Advanced Institute of Science and Technology says the project requires manpower mobilization on a national scale.

"It is like the U.S. Manhattan project (of developing an atomic bomb)," says Cho, who coordinates the HDTV project on behalf of the Korea Academy of Industrial Technology affiliated with the Ministry of Trade and Industry.

At the ministry's prodding, 13 companies, nine universities and two government research institutes, including the KAITECH, are involved in the project.

The government will provide 40 billion won of the 100 billion won needed to develop an HDTV prototype by 1993 with the rest of the money coming from the companies involved.

The Ministry of Trade and Industry plans to allow scientists doing research on digital signal processing, display and semiconductors — the three areas of research on HDTV — to draw money from the project fund beginning next month.

With Korean HDTV standards not determined yet, Cho of the KAIST says, joint research will remain at the basic level, at least until the United States comes up with its standards in September 1992.

"During the period, we will try putting into design what remains conceptual," he says. "It is like solving exercise problems."

The basic research will cover the three HDTV types under development — MUSE of Japan, HD-MAC of the European Community and ATV of the United States, he says.

The Japanese and EC types use satellites for broadcasting while the U.S. type does not.

No one type dominating the others provides Korea with an opportunity to catch up with Japan, the United States and the European Community, Cho says.

"It is a God-given opportunity," he says.

But the project does not appear to be all that auspicious.

With the project not launched yet, scientists heading research teams are worried about a shortage of manpower.

The project needs 918 scientists and technology experts, 570 more than those now available.

Prof. Park Song-bai of the KAIST says what is important in the development of customized ASIC chips is designing skill.

"Where are we going to get all those people skilled in designing?" he says.

Prof. Jang Jin of Kyunghee University, who is responsible for the development of a projection LCD display monitor, also finds fault with the shortage of manpower not only in his area of research but in other related areas.

"It needs people trained in various areas of science to produce an item," he says.

Cho of the KAIST proposes to solve the manpower problem by having graduate-school students and those doing doctorates get involved in high-tech research.

Another problem is the low level of technology supporting industries have.

Prof. Cho Chul-hyung of the KAITECH says it needs the submicron-level processing skill to produce a mold for lenses used in HDTV.

But the machinery industry has not come up to that level yet, he says.

Others voice concern about sharing technology among business rivals participating in the project.

They question if Samsung, which is more advanced in analog-to-digital and digital-to-analog converters than other companies, will be willing to share its technology with them.

The most serious problem, however, appears to be anticipated cost overruns.

"It is expected that we will need more money than is alloted in the second and third years of research," Cho of the KAIST says. "The government may have to spend twice as much as the alloted 40 billion won."

More money is needed to buy test instruments, fabricating facilities, processing equipment and computers, most of them from the United States, he says.

Own technology stressed in HDTV

W100 bil. development project to start next month

Following is the third in a series of stories on the electronics industry in Korea. It deals with HDTV which is to be developed. — Ed.

By Choi Nam-hyun
Staff reporter

Research will start next month on the development of high-definition television, which scientists say will bring about a media revolution.

HDTV to be developed will have an image whose quality will match that of a color picture print, and its sound will be as distortion-free as that of a compact disk player.

To produce an HDTV prototype in 1993, as is scheduled, will need the manpower of more than 900 scientists, most of them holding doctorates in electronics and other disciplines.

The task of developing an HDTV prototype is comparable to that of squeezing 100 black-and-white TV sets or 25 color TV sets into the prototype's space, says Cho Zang-hee, professor of the Korea Advanced Institute of Science and Technology.

To develop an HDTV set requires new technologies for processing signals, displaying images and manufacturing semiconductors which will make all these possible.

The processing of signals for HDTV alone will pose a formidable problem which scientists will have to solve.

It would require larger bands of the spectrum than the six megahertz used for conventional color TV to send the amount of information needed for HDTV if it were not for the frequency-multiplexing technology, Cho says.

The HDTV research team has to develop the technology to compress the amount of information, which would otherwise need more than 30 megahertz, so that it can fit in the band width ranging from six to 13 megahertz, Cho says.

Cho coordinates the whole 100 billion won HDTV project on behalf of the Korea Academy of Industrial Technology while heading a team of researchers working on signal processing under the project.

Korea will be able to develop the frequency-multiplexing and other technologies without much help from abroad, he says.

The basic approach to HDTV development, he says, is "to develop our own original technology."

He says, "Our concern is to develop an HDTV set which will be competitive in price in the world market, not whether or not we will be able to develop one."

Prof. Cho Chul-hyung of the Korea Academy of Industrial Technology is as optimistic about technological development as Cho Zang-hee of the KAIST.

Cho of the KAITECH says, "We will have to detour most patented technologies and develop our own technologies. We will be able to do it."

But it will be impossible for Korea to develop all technologies needed for HDTV, he says.

Korea, he says, will be able to swap some core technologies of its own development with those developed by Japan or the United States.

His mission is to develop a cathode-ray tube for the projection of images on a TV screen, one of the three display monitors to be developed, with other scientists.

Another type for image display is similar to the conventional Braun tube.

The third type is a projection liquid crystal display (LCD) monitor which Prof. Jang Jin of Kyunghee University and his fellow researchers are assigned to develop.

Jang and his team will have to develop a 40mm × 71mm panel with more than 1 million color dots on it, the number of color dots the conventional-looking or projection CRTs for HDTV will have. A conventional color TV set has a quarter of the color dots on the HDTV panel.

Regardless of its type, be it conventional or LCD, an HDTV display monitor will have 1,050 or more scanning lines for high-definition images, twice as many as conventional color TV sets have.

Each dot on the LCD panel will be made to regulate its brightness in accordance with changing voltages, Jang says.

The challenge encountered in the development of an LCD panel may be dwarfed when it comes to the manufacture of semiconductors.

An ASIC chip tailored to specific functions is needed to replace many memory chips for general use and thus reduce the size of an HDTV set, says Prof. Park Song-bai of the KAIST.

"A Japanese ASIC chip would replace more than 40 PCBs (on which many memory chips were placed) which Goldstar Co. would use if it had to produce an HDTV set," Park says.

Even memory chips used for HDTV must have high speed to handle information as fast as is required, Park says.

But major chips used for HDTV are analog-to-digital and digital-to-analog converters, which make it possible to store signals received through the antenna in digital memory and process them for display, he says.

Microprocessors are needed to process signals by means of the digital technology — the one-or-zero coding of computers — rather than the analog technology of sending or receiving signals in the form of waves, Cho of the KAIST says.

"Because of the limited band width for HDTV, you have to intentionally degrade the resolution for a fast moving image and maximize the resolution for a static image with the use of microprocessors," he says.

Digital signal processors are also important chips to be developed for HDTV, says Prof. Lim In-chil of Hanyang University.

Pat Hubbard
VP Education, Science and Technology
American Electronics Association
5201 Great America Parkway
Santa Clara, CA 95054

May 8, 1990

Dear Ms Hubbard,

Your colleagues at AEA said you are the focal point for queries on High Definition TV and suggested I contact you directly. My company, TechSearch, follows R&D developments in Japan and has prepared reports on Japanese Developments in HDTV and Flat-Panel Displays which should be of interest to the AEA. These topics are especially timely given the recent problems at DARPA.

The High Definition TV report is based on TechSearch's unique access to the Japanese HDTV industry. Detailed information is included on technical developments in HDTV both on a component and on a company basis. A detailed Table of Contents is enclosed.

The Japanese believe that HDTV, which involves a wide variety of disciplines, is a major technology driver for the 1990's. Most of the Japanese HDTV technologies currently under development will be fully commercialized by 1995. Opportunities do exist for U.S. companies to acquire Japanese technology through licensing and cooperative agreements. These possibilities are detailed in the report.

The Flat-Panel Displays in Japan Report is a compendium of abstracts of published articles on Japanese developments in flat-panel displays. The following areas are covered:

- Market Trends and Manufactures' Strategies
- Latest Technology Trends from Japan Display '89 Conference
- Application Trends
- Promising Technologies for the Future
- Panel Technologies
- Common Technologies/Peripheral Technologies

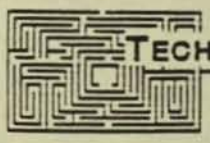
The flat-panel display technology has an impact on applications ranging from HDTV to high resolution computer displays to portable and notebook-size computers. The Japanese industry is focusing on thin film transistor and simple matrix LCDs.

Both reports are available for review. I am in Sunnyvale.

Sincerely,

Bill Stanley

William R. Stanley
(408) 732-2555



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Building 4, Suite 400
Austin, Texas 78759
512-343-4508

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- Clean Room Technology
- High Definition Television
- Tape Automated Bonding

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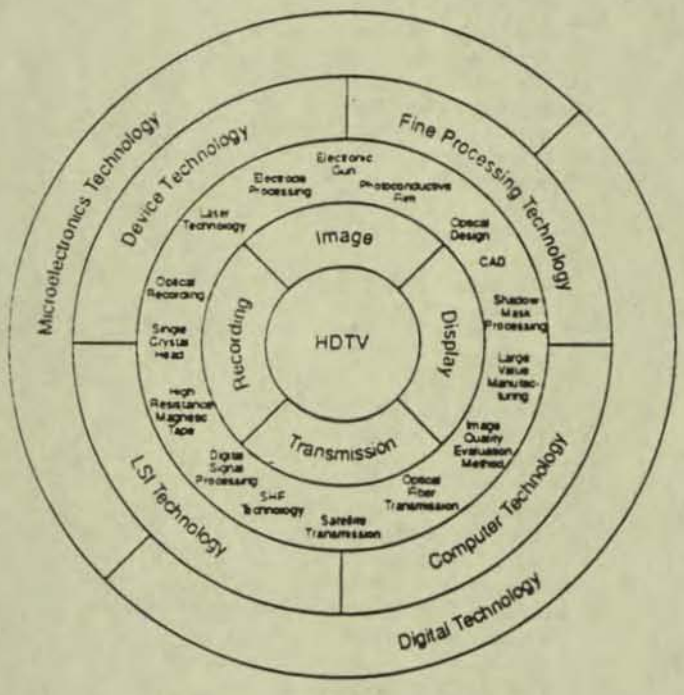
JAPANESE DEVELOPMENTS IN HIGH DEFINITION TELEVISION

High definition television (HDTV) is an entirely new medium, according to the Japanese, not simply a better TV. Called Hi-Vision in Japan, HDTV has been under development there for the last 19 years, and Japanese researchers have been publishing papers describing various developments in HDTV for more than 10 years. The development of HDTV technology in Japan is not limited to one industrial segment but rather spans the entire electronics industry. HDTV combines telecommunications, computers, and all forms of media entertainment with technologies including semiconductors and displays to create something more than just another consumer electronics product. HDTV application areas include broadcasting, computers and workstations, telecommunications, motion pictures, education, medical equipment, and printing and publishing.

The HDTV system involves many technologies: digital signal processing, high resistance magnetic tape, optical recording, laser technology, electrode processing, photoconductive film, optical design, computer aided design, optical fiber transmission, satellite transmission, large-size displays, shadow mask processing, and image quality evaluation methods.

HDTV Technologies



Source: *Hi-Vision Technology*, NHK (1988)

The report highlights the efforts of the Ministry of Post and Telecommunications (MPT) as well as the guidance provided by the Ministry of International Trade and Industry (MITI). The role of Japan's Key Technology Center, (a joint effort of these rival government agencies), in the promoting HDTV research is also discussed. Funding and research goals of the recently established project to develop HDTV LCD projection displays and improved graphics capabilities are provided.

The study examines the Japanese production standards for HDTV and compares them with those proposed in the United States and Europe. Both improved definition TV (IDTV) and enhanced definition TV (EDTV) are discussed.

According to U.S. press reports, Japanese industry executives say that US efforts to initiate an HDTV industry are "surprisingly late and far too small". This study explains this reasoning and details some of the major industry research efforts and technological developments that have been underway in Japan for a period of years. The report focuses on efforts by industry in developments that lower the cost of HDTV systems. Developments in areas including multi-processor architectures for HDTV signals, receivers for satellite network transmission, optical transmission, and video RAMs are discussed. A detailed outline of companies involved in the Japanese HDTV industry is provided in the appendix to the report.

The report also examines HDTV technologies that are available for licensing. These technologies include technologies developed for NHK's MUSE system, as well as technologies developed by other Japanese companies. Potential cooperative agreements are also discussed.

The authors, J. G. Parker and E. J. Vardaman, have visited Japan numerous times over the last five years. The first author is fluent in Japanese and most of the sources for the report are Japanese language documents and interviews with Japanese officials. Report reviewers include Sheridan Tatsuno, a noted author on Japanese industry and government affairs, and Andrew Donoho, a physicist and graphics software developer. The report is priced at $1800.

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Flat Panel Display 1990

Articles published by Nikkei Business Publications Electronics Group, November 1989
Abstracted by James G. Parker, TechSearch International, Inc., April 1990

Sam Fuller
copy to GUROVAC
f: HDTV

d i g i t a l

Interoffice Memo

TO: See Below

CC: See Below

DATE: 1 November 1991
FROM: Dick Fishburn
DEPT: Corp. Operations
EXT: 223-4225
LOC/MAIL STOP: MLO12-2/T81

SUBJECT: Digital TV White Paper

DIGITAL INTERNAL USE ONLY Document

The way individuals use technology in 2020 will create substantial opportunities! Our challenge is to understand how changes in technology will enable new uses and position our Company to take advantage of those opportunities where we can provide competitive advantage. These opportunities are likely to require us to learn new skills and operate differently as an organization, both internally and as we deal with other companies regarding distribution and technology capability.

Many of these opportunities will be extensions of the capability of existing business units. Many others, however, will develop only with the cooperation of multiple business units or the creation of new business units. As part of the architecture of business development, therefore, opportunities can arise from the business units or from the core corporation. An example of the latter is the potential to participate in the market for HDTV and specifically in its digital application.

The Executive Committee has asked that a White Paper be developed that will aid the Committee in the formulation of a corporate strategy toward the digital TV opportunity. An outline of the Paper is attached. The objective is to combine (a) the work initiated by multiple groups concerning segments of the issue with (b) other potential opportunities that have been identified. I assume the outline is not complete and that I have botched a few of the responsibilities. The first name is an attempt to define organizational responsibility; the second is who I guess will do the work.

What we'd like for sections III to VIII is a ONE-PAGE position from your group on the opportunity/set of issues. We shall combine them for presentation. In my absence from November 4-15, Bill Styslinger can answer any questions. Please feel free to have others help or do the work; I shall assume, however, that someone is doing it if I or Bill do not hear from you.

We are aggressively trying to review this with the Executive Committee on 25 November. I'd appreciate your input by 20 November. Please also accept my apologies for not being able to speak to each of you personally prior to this note.

RJF:fc
Attachment

Distribution:

TO: Sam Fuller
Bill Johnson
Branko Gerovac
Mike Thurk
Peter Brown
Bill Hawe
Grace Hinchman
John Smith
Mike Glazer
Bob Palmer
Jim Pappas
Bill Heffner
Bruce Mann
David Stone
Hans Gylstrom
Max Mayer
Jim Neumann
Jack McCredie
Jack MacKeen
Rose Ann Giordano
Willow Shire
Glen Armbruster
Mike Taylor
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Bill Steul
Jim Albryght
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Bill Demmer
Bill Strecker
Pete Smith
Ken Senior
Dan Infante
Dom LaCava
Don Gaubatz
Ed Caldwell
Al Mullen

DIGITAL TELEVISION AND COMMUNICATION

A white paper recognizing the emergence of digital television (circa 1995) and broadband digital public networks, and their implications for Digital, as global provider and user of information technologies.

I. White paper introduction and objective
(Dick Fishburn)

II. Executive summary
- Technology (Sam Fuller)
- Market (Bill Johnson)

III. Status of digital HDTV and other HDTV initiatives
(Branko Gerovac)

IV. Status of digital public networks
(Mike Thurk/Peter Brown/Bill Hawe)

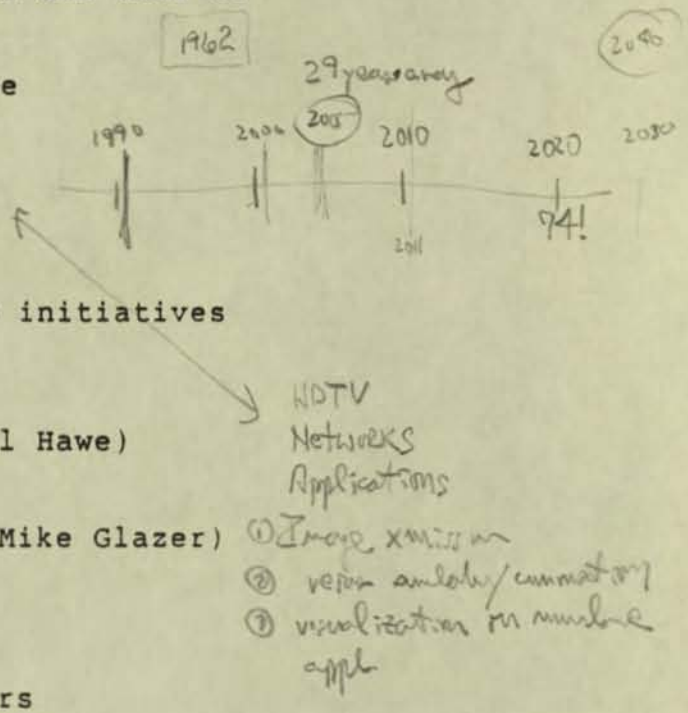
V. Regulatory issues
(Grace Hinchman/John Smith/Mike Glazer)

VI. Digital product opportunities:
- Television Components
(Bob Palmer/Jim Pappas)
- Multimedia Workstations and Servers
(Bill Heffner/Bruce Mann)
- Networks
(Mike Thurk/Bill Hawe)
- Information Utility Software
(David Stone/Hans Gylstrom)

VII. Digital services opportunities:
- Network Services
(Max Mayer/Jim Neumann)
- Added Value Network (i.e. Imaginet)
(Peter Brown)
- System Integration Services
(Max Mayer)

VIII. Market implications
- o Education (Jack McCredie)
- o Government (Jack Mackeen/Rose Ann Giordano)
- o Healthcare (Willow Shire)
- o Manufacturing (Glen Armbruster and Mike Taylor)
- o Telco's (Ernst Wellhoener)
- o Cable and Fiber (Bill Steul/Jim Albryght/ Bill Styslinger)
- o Media (Bob Farquhar/Jim Albryght)
- o Banking (Norm Goldberg)
- o Home

IX. Player Landscape (competitors) and possible alliances
(Lucia Quinn/Gil Press)



From: RDVAX::FULLER "Sam Fuller" 22-NOV-1991 12:44:37.98
To: deluca
CC:
Subj: Print and file in HDTV

From: RDVAX::GEROVAC "Branko J. Gerovac 20-Nov-1991 1839" 20-NOV-1991 18:43:18.15
To: RDVAX::FULLER
CC: GEROVAC
Subj: FYI -- Digital TV White Paper -- HDTV Status

Sam/

Attached is a copy of the my section for the White Paper that Dick Fishburn is pulling together. It will look familiar -- it is an update of the memo for the Jerry Heller meeting several weeks ago.

/Branko

HDTV: Not Just About Television
Status of Digital Television

Branko J. Gerovac
Corporate Research and Architecture
Technology Planning and Development

High-definition television (HDTV) is not just about television. For the past few years, it has been realized that derivative technologies from HDTV (e.g., displays, VLSI) would be useful to computing. However in the past 6-12 months, the situation has changed dramatically -- the desired move from an analog to a digital basis for HDTV. Digital processing and digital communication for HDTV are now widely accepted -- the 4 leading proponents to the FCC HDTV trials are digital systems. Imaging, television, video, telecommunication, and computer industries are increasingly based on the same set of digital technologies. The acceptance of the inevitable merging of computing, communications, and video technologies is growing rapidly.

FCC HDTV Trials

In 1988, the FCC formally began the process of selecting a U.S. HDTV standard. An initial selection will be reported in June of 1992. Six proposals are now entering the testing phase of the FCC trials. Two of them don't count because they are analog (Sarnoff ACTV and NHK/Sony Muse) -- everyone agrees that the result will be digital. Sarnoff hopes to make ACTV a backward/forward compatible extension to current television transmissions (NTSC), regardless of the HDTV trials outcome. NHK/Sony has invested so much in developing their analog Muse systems that it is too late to pull out -- they may hope that the digital systems fail altogether. NHK is winding down their Muse project and reassigning researchers to other activities.

The attached table summarizes some of the numerical parameters of the 4 digital proposals. Since the proposals address the same requirements, they are somewhat similar. Looking at picture parameters, shows two general approaches: AT&T/Zenith and MIT are similar, and Sarnoff and GI are similar. The 4 proposals do differ in the corporate strengths that they bring to the process.

AT&T / Zenith

Zenith is the only U.S.-owned consumer electronics manufacture of television sets -- much of their manufacturing occurs in Mexico, though. Zenith, being a small company with stretched resources, joined with AT&T to get big company backing. AT&T brings digital communications and VLSI experience with a large company infrastructure and manufacturing. AT&T gains a foothold in information content delivery.

The AT&T/Zenith proposal was derived from early MIT work. Therefore, many of the picture parameters are the same. AT&T added their compression, codec, and VLSI technology.

AT&T has capitalized on their strong Washington DC lobbying skills to bring the AT&T/Zenith proposal to a perceived leading position.

Sarnoff / Philips / Thomson / NBC / Compression Labs (ADTV)

Sarnoff Labs (nee RCA) was the source (in the 50s) of the NTSC color television system we now use. Sarnoff has a strong background in

terrestrial broadcast technology. Philips and Thomson bring consumer electronics experience with televisions, cameras, VCRs, etc. -- it is their U.S. subsidiaries that are involved. They call themselves "all American", though some people point out the European connection.

The Sarnoff proposal can be thought of as a digital version of the NHK Muse proposal. Sarnoff certainly would not want to characterize it that way, but when looking at a few of the picture parameters (interlace scan, non-square pixels, etc.), it is not too inappropriate. However, Sarnoff is the only proponent that has a packetization scheme that would be somewhat recognizable as a computer network protocol -- it could be much better, but is beyond what the other proponents attempt. Sarnoff derives their compression scheme from MPEG (the ISO standards activity for compression of motion pictures), which gives them support from the MPEG community.

General Instrument (ATVA-Interlace)

GI is a dominant supplier for satellite and cable transmission systems and cable converter boxes. They have used digital encrypted video satellite transmission for some time. They use DEC computers to control their satellite uplink/downlink equipment. A little over a year ago, GI was bought by the venture capital firm Forestman & Little.

GI's picture parameters are similar to Sarnoff's. GI was the first proponent to offer an all-digital HDTV system. (MIT's system was a hybrid digital/analog for a long time.) In many respects, GI broke the ice by going digital that led the other proponents reevaluate their analog approaches and go all digital as well.

GI is planning to use their digital compression scheme to place 4-5 NTSC program channels in a single 6 MHz cable channel, thereby increasing the number of cable channels from ~60 to ~300. The cable TV industry is very interested in this, as evidenced by a recent RFP. Other proponents are beginning to look at this approach as well.

Massachusetts Institute of Technology (ATVA-Progressive)

Last spring MIT joined with GI to form the American Television Alliance (ATVA). MIT continues to develop their own system distinct from GI's. Of course, they are sharing a lot of technology. MIT essentially has adopted GI's digital modulation scheme. MIT has the last FCC testing slot (Spring 1992); thus, they have a longer time to develop the equipment for the test, and can benefit from seeing the other proponents' systems. GI will build the equipment for the test.

MIT is the source of much of the digital video technology that appears in the other proponents' systems. Many of the principal developers at the other proponents were educated at MIT. MIT likely will receive some royalty payments regardless of the outcome of the FCC trials.

In main respects, MIT's system is technically superior to the others.

COHRS Agenda

In the last couple of years, the loosely organized Committee on High Resolution Systems (COHRS) has been extremely successful in establishing the new agenda for HDTV. A year and half ago, there were no digital proposals, and COHRS was considered a technical fringe group. Now, the FCC is asking COHRS for advice on how to proceed in the testing process.

A few of the COHRS objectives are:

- o merger of television, communications, and computing

  In other words, interactive information services. None of the proponents bring this to the full extent. Though, all are positioning themselves as compliant to some extent.

- o all digital systems

  Now, a done deal.

- o architectural goodness criteria

  Interoperability, extensibility, scalability, open systems, etc. The proponents are just beginning to try to understand this.

  - interoperability means the optimal sharing of data streams across generation, carrier, and equipment technologies, and services and applications

  - extensibility means the ability to incorporate future technological advances in encoding and services without obsoleting then existing components and infrastructure

  - scalability permits encodings whereby uniform generation, transmission, and display characteristics can support a range of product quality and cost

- o header / descriptor

  Proper attention to a self identifying data stream protocol is critical to provide interoperability, extensibility, etc. Key here is accommodating a variety of data stream encodings to permit adjusting signal characteristics to meet application needs. In essence, this is a computer network presentation level protocol.

- o square pixels (as opposed to rectangular pixels)

  Best for computer generated images. AT&T/Zenith and MIT have square pixels. Sarnoff and GI have rectangular pixels. It is generally agreed to go with square pixels.

- o progressive scan (as opposed to interlace scan)

  Ten/fifteen years ago, computer displays started out with interlace scan, but quickly found it to be inadequate. Now all computer displays are progressive scan. AT&T/Zenith and MIT are progressive. Sarnoff and GI are interlace. This is still a hot issue of debate.

- o compliance with film / >60 Hz refresh / source flexibility

  Currently, television is 59.94 Hz refresh. Film is 24 frames per second. Computer displays are 66 to 72 Hz refresh. 72 = 3 * 24. All proponents are 59.94 Hz. MIT's and GI's compression algorithm recognize 24 fps source material and alter operation for better picture quality. What's wanted are a separation/independence of source image rate and display fresh rate.

AT&T/Zenith recently are describing how they address the COHRS criteria. In some respects, they do. They are saying -- pick them, they're extensible and can evolve to the right system. Reading between the lines (here and above), AT&T/Zenith is thought by many to be the leading contender at this time.

How does Digital benefit? What does Digital offer?

Still difficult questions to answer. A few items present themselves:

- o VLSI

  Hudson is ready to apply their skills to new areas. Digital HDTV compression is computationally intensive (~1 Bips) that is uniquely suited to Hudson's design and fabrication technology. Very few other semiconductor manufacturers are as well suited.

- o Cable TV / Ethernet on Cable (ETV)

  With ETV, Digital has an entree to and advantage with the cable television industry. ETV provides ethernet communications service on existing community cable systems. Cable TV is looking for new services (e.g., data and telephone bypass) to provide new revenue sources. The cable industry is moving rapidly to install fiber optic cable backbones and spurs. Cable is more like a computer network topology than is proposed telephone fiber optics. (General Instruments is a key cable industry equipment provider and major Digital customer.)

- o Video Networking

  All of the proponents are coming to realize that digital HDTV transmission is actually a network protocol and telecommunications problem. Of course, networking and interactivity is one of our strengths. Note however, that we have not done much with realtime delivery guarantees.

  At a recent gigabit networking conference, it was agreed that a primary use of gigabit networks would be video. However, they also acknowledged that they didn't know very much about it and that a lot of work needs to be done to address video needs in computer/ communications networks. (CCITT is beginning inquiries into networking/telecomm requirements for video.)

- o Big Computer Company Backing and Influence

  The merger of computing, communications, and television gives us influence on the technical direction of HDTV. It can become something that is easy or difficult for us to incorporate. Apple's public position that they are pursuing consumer information services equipment (i.e., televisions as personal computers, or vis a versa) has given them already some influence to direct toward their interests.

- o Merger of the proponents

  The preferred outcome of the FCC trials is still a merger of the proponent systems with added new technology. Though the FCC process is moving forward, people are torn between the charter to select one versus the desire to take the real advantage that digital communications provides. We have valuable experience in creating and working in consortia that is missing in the television industry. Can Digital provide the impetus to get the proponents together?

There is a broad and a narrow question to consider: Broadly, how is Digital going to participate in the coming development of HDTV, media technology, and computing/information access. Narrowly, how does Digital better prepare itself for the shift in how computing is delivered to the end user.

Table of Attributes, Characteristics, and Processes
of the Digital HDTV Terrestrial Broadcasting Systems

	GI ATVA-I	AT&T Zenith	Sarnoff ADTV	MIT ATVA-P	
Picture:					
Lines/Frame	1050	787/788	1050	787/788	
Frames/Sec	29.97	59.94	29.97	59.94	Hz
Interlace	2:1	1:1	2:1	1:1	
Horiz Deflection	31.469	47.203	31.469	47.203	KHz
Aspect Ratio	16:9	16:9	16:9	16:9	
Active Pixels lumi	1408:960	1280:720	1440:960	1280:720	h:v
chroma	350:480	640:360	720:480		h:v
Pixel Aspect	33:40	1:1	27:32	1:1	v:h
Bandwidth lumi	22.	34.	27.	34.	MHz
chroma	5.5	17.		34.	MHz
Colorimetry	240M	240M	240M	240M	SMPTE
Video Compression	mc DCT	mc DCT/VQ	mc DCT	mc subband	
Block Size	8:8	8:8	8:8	8:8	pixels
Sample Frequency	51.8	75.3	54.	75.3	MHz
Audio:					
Bandwidth	20.	20.	20.	20.	KHz
Sample Freq	48.	47.203	48.	48.	KHz
Dynamic Range	85.	96.	96.		db
Channels	4.	4.	4.	4.	
Date Rate:					
Video	13.83	17.2	14.98	15.636	Mb/s
Audio	1760.	500.	512.	500.	Kb/s
Control Data	126.	40.	40.	126.	Kb/s
Auxiliary	126.	600.	512.	126.	Kb/s
Sync	n/a	580.	n/a	n/a	Kb/s
Total Data	19.43	21.52	21.00	19.43	Mb/s
Error Correction	3.59	2.5	4.96	3.042	Mb/s
Terrestrial:					
RF Modulation	16 QAM	4 VSB	QAM	16 QAM	
3 db Bandwidth	4.86	5.38	5.2	4.86	MHz
C/N Threshold	19.	18.	20.	19.	db
Channel Equalization	2-32	-2-20	16-40	2-32	us
Satellite:					
RF Modulation	QPSK	MSK	QPSK		
3 db Bandwidth	24 /2	20 /1	36 /3		MHz
C/N Threshold	8.	8.	8.		db

Addendum -- An Abbreviated History

The idea of an enhanced television with improved picture and sound began 25 years ago. The simple intent was to provide 35mm film quality pictures and high fidelity stereo sound. (Film and audio have improved since then. What we have now in HDTV is the quality of 25 year old film and audio.) The expectation was that this new television would be in the same mold as existing color television (NTSC), i.e., analog.

1968 -- NHK (Japanese Broadcasting Co.) began research program

1972 -- NHK defined the basic parameters of their HDTV proposal (5:3 aspect ratio, 1125 lines, 60 Hz interlaced refresh)

1981 -- NHK with Sony demonstrated prototypes for cameras, video tape recorders, satellite transmission, and displays

1982 -- FCC forms Advanced Television Advisory Committee (ATSC); their underlying agenda is to standardize on the NHK system, now called MUSE (MUltiple Sub-nyquist Encoding)

Though all along, some research occurred in the U.S. and Europe, Japan's growing strength in consumer electronics motivated them to greater levels of investment. It appeared that MUSE would be adopted as a worldwide HDTV standard. However:

1986 -- European consumer electronics companies blocked adoption (for economic reasons) of the MUSE system parameters at the plenary meeting in Dubrovnik of the CCIR (~Consultive Committee for International Radio)

In the meantime, there was rapid development of digital signal processing, digital signal transmission, high performance computing, and computer networks. This led a few people (mostly researchers at the Massachusetts Institute of Technology (MIT)) to realize the feasibility, advantages, and implications of digital rather than analog HDTV. Results of their early messages were:

1988 -- FCC creates Advisory Committee on Advanced Television Service (ACATS) to guide a competitive trial of HDTV proposals

1988 -- FCC mandates that HDTV fit within the same 6MHz spectrum allocations as existing television -- a constraint that favored digital compression techniques

1988 -- DARPA recognizes national interests in display technology and derivative video and signal processor technologies

There was a growing realization of the broader industrial derivatives of HDTV, represented by news media coverage and American Electronics Association's (AEA) call for addressing the "technology food chain". Then, the full implications of merged computing, communications, and television technology was raised:

1990 -- Committee on Open High Resolution Systems (COHRS) was initiated through MIT as an ad hoc multi-industry committee (including computer interests, e.g., Digital Equipment Corp.); COHRS promotes "architectural goodness" criteria of open systems, extensibility, scalability, interoperability, etc. to the FCC, Department of Commerce, State Department, U.S. CCIR committee, etc.

1990 -- (June) General Instruments proposes the first "all digital" HDTV system; MIT's system long was an analog/digital hybrid

1991 -- (January) Four of six HDTV proposals to the FCC adopt all digital systems

1991 -- (summer) COHRS "architectural goodness" criteria adopted as part of the FCC testing process to select a U.S. HDTV system

1991 -- (August) CableLabs issues RFP for digital compression methods and equipment for cable TV systems

The FCC testing process is now beginning. Initial testing results will be reported in June 1992. Additional terrestrial broadcast and cable testing will occur in late 1992. Final reports will appear in early 1993. And, the final FCC ruling on a U.S. HDTV system will appear in mid 1993.

HDTV

Printed by Sam Fuller

I N T E R O F F I C E M E M O R A N D U M

Doc. No: 009385
Date: 20-Dec-1991 04:39pm EST
From: CABRINETY
CABRINETY@ROYALT@MRGATE@REGINA

@DSG

Dept:
Tel No:

TO: SAM FULLER@MLO
TO: DICK FISHBURN@MLO

Subject: HDTV...

VMSmail To information: SACMAN::JOHNSON
VMSmail CC information: @HDTV.DIS,CABRINETY
Sender's personal name: LARRY CABRINETY DTN 235-8209 MS: DSG2-2/J5 20-Dec-1991 1625

+---------------------------+ TM
| d | i | g | i | t | a | l |
+---------------------------+

INTEROFFICE MEMORANDUM

TO: BILL JOHNSON

CC: GRANT SAVIERS
DICK FISHBURN
BILL STRECKER
DOM LACAVA
HENRY CROUSE
SAM FULLER
JAC SIMENSEN
MIKE THURK

DATE: 20 DEC 91
FROM: LARRY CABRINETY
DEPT: VIDEO, IMAGE & PRINT SYSTEMS GROUP (VIPS)
PHONE: 235-8209
MAIL: DSG2-2/J5
ENET: ROYALT::CABRINETY

SUBJECT: HDTV

BJ,

We, Digital, are reasonably well positioned to provide monitor/TV capability to meet future HDTV worldwide requirements. For example, we know that the optimum resolution is 1600 x 1200 and we have positioned ourselves to be able to provide leadership FTM technology from Zenith from a CRT viewpoint and within 5 years we would expect that flat panel technology in either EL or LCD would provide sufficient resolution capacity in large screens to meet the optimum requirements. From a Digital perspective, I believe our

major stumbling block is receivers and transmitters. Is this being addressed by your former telecommunications group? If so, who should we work with?

Larry
LPC/jhs

Printed by Sam Fuller

DIGITAL INTERNAL USE ONLY Document

I N T E R O F F I C E M E M O R A N D U M

Doc. No: 009384
Date: 20-Dec-1991 04:14pm EST
From: Bill Johnson
JOHNSON.BILL
Dept: Corporate Marketing Planning
Tel No: 223-3982

TO: See Below

Subject: UPDATE: SUPPORTING DIGITAL ROADSHOW IN N. AMERICA

Digital's Open Advantage in Action World Tour is on its way to the fifth of 32 North American cities to be visited between now and April 24, 1992. Approximately 10,000 customers are expected to attend the roadshow, offering Digital -- for the seventh year -- a unique opportunity to bring its software, networking, services and systems solutions directly to the customer. This year's show will highlight Digital's Open Advantage through examples of our open technology, open services and open business practices.

I would personally like to invite you to host one or more of these shows by presenting the opening remarks of the day and meeting one-on-one with customers. Your participation in last year's events illustrated Digital's commitment -- at the highest levels -- to customer satisfaction.

Attached are the dates and locations of this year's shows and the current commitments. Please review the list and let us know which of the remaining shows you will be able to host.

Responses can be sent to Sue Skonetski (FROSTY::SKONETSKI or SUE SKONETSKI @MKO), if you have any questions concerning the roadshow please call Sue at DTN 264-3022.

Regards,

B.J.

/km

DIGITAL WORLD TOUR SCHEDULE
DECEMBER 19, 1991

Date	Day	City	Executive
12/05	THU	ROCHESTER	
12/10	TUE	HARTFORD	
12/17	TUE	BOSTON	Rose Ann Giordano
		XMAS BREAK	
01/07	TUE	ALBANY	
01/09	THU	WILMINGTON DEL.	John Sims
01/14	TUE	LOUISVILLE	
01/16	THU	CLEVELAND	
01/21	TUE	COLUMBUS	
01/23	THU	ATLANTA	
01/30	THU	CHARLOTTE	Jim Cudmore
02/04	TUE	ORLANDO	Jack Smith
02/11	TUE	HOUSTON	
02/13	THU	AUSTIN	
02/18	TUE	DETROIT	
02/25	TUE	ANAHEIM	
02/27	THU	SANTA CLARA	
03/03	TUE	ST LOUIS	Jim Cudmore
03/05	THU	KANSAS CITY	
03/10	TUE	CHICAGO (POSSIBILITY)	
		BORDER CROSSING	
03/19	THU	HALIFAX	
03/24	TUE	QUEBEC CITY	Graeme Woodley*
03/26	THU	MONTREAL	Graeme Woodley*
03/31	TUE	OTTAWA	
04/02	THU	TORONTO	Dick Poulsen
04/06	MON	WINNIPEG	
04/09	THU	REGINA	
04/14	TUE	EDMONTON	
04/16	THU	CALGARY	Dick Poulsen
04/22	WED	VANCOUVER	
04/27	MON	VICTORIA	Jack Smith

*The Sales team has requested that the introduction be done in French

Distribution:

TO: John Alexanderson (ALEXANDERSON.JOHN)

From: JRDVOA::SIMENSEN 10-DEC-1991 01:45:56.64
To: MILPND::STRECKER,ASABET::CROUSE,MRGATE::"MLO::Dick Fishburn",CRA::FULLER
,SSVAX::SAVIERS,MRGATE::"TKO::Reilly",ROYALT::CABRINETY
CC: SIMENSEN
Subj: FYI.....More Japanese FPD Data

10-DEC-1991
T.Hayashi

FPD (LCD) STATUS in Japan

1. LCD Technology Comparison

Item	Simple Matrix		Active Matrix	
	STN	FLC	TFT	MIM
Contrast Ratio	10-20 : 1	40 : 1	100-150 : 1	50-100 : 1
Viewing angle X	60 deg	50 deg	120 deg	100 deg
Y	30 deg	40 deg	60 deg	45 deg
Reponse Time	100-300ms	70us/line	50ms	50ms
Grey Scale	16 (FRC)	16 (FRC)	16 (AM)	16 (PWM)
Cell Gap	4-7 um	1.5-2 um	10-15 um	10-15 um
Flicker	large	large	small	small
X-talk	large	large	small	midium
Total Display Quality	Low (Limited use)	Midium	Excellent	Good
Issue for product	Speed up	Productivity	Yield (Price)	Yield (Price)

2. Recent LCD Vendors Status

2-1 Vendor Category

o Objects of High Resolution LCD Vendor

Sharp, Hitachi, NEC, Toshiba, HOSHIDEN,
Matsushita, Seiko EPSON, Canon

o Category

GROUP A : Hitachi, NEC, Toshiba
- PC & WS system vendor
- Large internal needs for High Resolusion LCD

--> Priority on internal customer

GROUP B : Sharp, Seiko EPSON, Matsushita, Canon

- PC system vendor
- Small internal needs for High Resolution LCD

--> Priority on selling outside

GROUP C : HOSHIDEN

- LCD component vendor

2-2 Vendor Status

1) Sharp
   - STN, TFT
   - Largest LCD vendor in the world
   - Business goal : 50% of LCD market (1995)
   - Concentrating on yield improvement of VGA class TFT color LCD
   - High Resolution TFT schedule
     - o Sample : '93/Q1-Q2
     - o FVS : '93/Q4

2) Hitachi
   - STN, TFT
   - Priority on internal customer
   - High Resolution TFT schedule
     - o Sample : '92/Q4
     - o FVS : '93/Q1-

3) NEC
   - TFT color only
   - Concentrating on yield improvement of VGA class TFT color LCD
   - Priority on internal customer
   - High Resolution TFT schedule
     - o Sample : ?
     - o FVS : '93/Q1-

4) Toshiba (DTI)
   - STN, TFT
   - Joint TFT business with IBM
   - Concentrating on yield improvement of VGA class TFT color LCD

5) Matsushita
   - STN, TFT
   - Investigating mass-productivity of High Resolusion TFT till 1992
   - High Resolution TFT schedule
     - o Sample : ?
     - o FVS : '93 or'94

6) Seiko EPSON
   - STN, MIM
   - Improving display quality of MIM for High Resolution panel
   - High Resolution MIM schedule
     - o Sample : '92/Q2
     - o FVS : '93/Q1-Q2

7) HOSHIDEN
   - TFT only
   - Concentrating on High Resolution TFT development
   - Needs joint-development contract for High Resolution TFT panel

8) Canon
   - FLCD only
   - Attractive technology for large scale & High Resolution panel

- They had already contracted with HP.
  No chance for DEC ?
- High Resolution MIM schedule
  - o Sample : '92/Q1
  - o FVS : '93/Q3-Q4

3. Conclusion

- o Possible High Resolution LCD vendor for DEC would be GROUP B or C.
- o DEC should more closely contact to GROUP B or GROUP C vendors for High Resolution TFT/MIM color LCD with financial commitment.

[Major LCD vendor's Investment & Volume Plan]

		1989	1990	1991	1992	1993	1994	1995
Sharp	Vol.	$350M	$520M	$880M	$1270M	$2130M	$2990M	$3850M
	Invest.	$110M	<-------	$770M	-------->	<------	$770M	--------->
Hitachi	Vol.	$170M	$230M	$310M	$380M	$560M	$740M	$920M
	Invest.	$80M						
NEC	Vol.	--	--	$140M	$220M	$300M	$380M	$460M
	Invest.	$15M	$60M	$60M	<----------	$460M	----------	>
Toshiba	Vol.	$150M	$200M	$280M	$400M	$520M	$650M	$770M
	Invest.		$250M	<-------	$370M	-------->		
HOSHIDEN	Vol.	$80M	$120M	$120M	$190M	$310M	$430M	$540M
	Invest.	<-------	$150M	-------->	<----------	$230M	----------	>
Matsushita	Vol.	$100M	$150M	$150M		$380M		$770M
	Invest.		<---	$310M	--->			
Seiko EPSON	Vol.	$350M	$460M	$580M	$770M	$850M	$930M	$1000M
	Invest.	$80M	$80M	$80M	$80M			
SANYO	Vol.	$170M	$200M	$250M				$770M
	Invest.	$40M	$10M	<----------	$350M	----------	>	
Optorex	Vol.	$220M	$280M	$320M				
	Invest.	$20M	$80M	$40M				
Seiko Densi	Vol.	$80M		$100M		$150M		$310M
	Invest.	$15M	$15M	$15M	$15M	$50M		$120M
CITIZEN	Vol.	$50M	$100M	$120M	$190M			$310M
	Invest.			$80M				
Stanley	Vol.	$90M	$90M	$110M	$130M	$160M	$190M	$230M
	Invest.	$40M	$4M	$40M	$4M	$50M		
Canon	Vol.							$2300M
	Invest			<----------	$770M	----------	>	

From: JRDVOA::FUJII "AKIKO FUJII JRD/HQ 045-336-5506 06-Dec-1991 1009" 5-DEC-1991 20:12:35.08
To: MILPND::STRECKER
CC: ASABET::CROUSE,CORE::FISHBURN,CRA::FULLER,TKOVOA::NAGAMINE,MTS$"TKO::ED REILLY",SSVAX::SAVIERS,SIMENSEN,FUJII
Subj: Flat Panel Display Technology

digital

To: Bill Strecker

From: Jac Simensen

cc: Henry Crouse
Dick Fishburn
Sam Fuller
Toshio Nagamine
Ed Reilly
Grant Saviers

Subj: Flat Panel Display Technology

Bill,

No doubt you are aware of the major advances in Flat Panel Display Technology that have occurred in Japan own the last two years. The demo that Steve Severson gave you last week of the Japan R&D developed VLC portable workstation included a proto type of a Matsushita monochrome LCD which will be in volume production in about 7-8 months.

I think that most of the cost, performance and resolution issues with FPD's are quickly being resolved. There seems little doubt that FPD's will soon replace CRT's in most new PC's and workstations, both monochrome and color. During 1992 and 1993, Hitachi, Toshiba and other Japanese companies will be bringing PC's and Workstations to market which will include color and monochrome FPD's with response times less than 50 ms and contrast of 50:1 to 30:1.
(See attachment 1.)

The purpose of this memo is to highlight the strategic threat FPD's present to Digital and to propose several actions to address this threat.

The growing opinion in Japan is that over the next three to five years, demand for competitive, high performance, high resolution FPD's is likely to exceed supply. Digital needs to act immediately to assure ourselves of access to competitive FPD's in quantities sufficient for our needs. Systems suppliers like Hitachi, Toshiba and NEC are unlikely (or will perhaps be unwilling) to produce competitive FPD's in quantity for competitors. Other FPD' makers like Seiko Denshi, Optorex, possively Matsushita are already involved in alliances where their partners will have first call on their FPD output.
(See attachment 2.)

Given what we've been able to discover in Japan, it looks like only a few suppliers of competitive LCD FPD's remain as reliable potential sources for Digital over the next three to five years; these seem to be Sharp, Seiko Epson and possibly Cannon. From a short to medium term perspective, Sharp seems to be the best bet.

Recommendations
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To address the issues raised in this memo, I suggest you consider four actions:

1. Investigate the likelihood of a near term FPD shortage and the degree of risk to Digital of a three to five year shortage in supply.

2. Establish a one or two person FPD Technology Center in Japan to track FPD technology progress and FPD company status and alignment. This would include trucking the progress of Japanese projects to integrate systems electronics into the display module, possibly onto the same substrate.

3. Consider an FPD alliance with Sharp, Seiko Epson, Cannon or another.

4. If the FPD lockout is considered serious enough or opportunities great enough, consider alliance with a Japanese company to produce competitive
~~~~~~~~~~~~~~~

FPD's in the USA. (Obviously a major investment.)

Please let me know if Japan R&D can provide further information or assistance.

CJS/af

(Attachment 1)
18-Nov-1991
T.Hayashi

1024 x 768 class MONOCHROME

No	Vendor	Tech.	S P E C.					Delivery	Price (yen)
			Res.	Size	Pitch	C/G	Speed		
1	Matsushita	STN /MONO	1024 x768	12.6"	0.25	2grey	200ms	92/Feb	77K
2	SHARP	TSTN /MONO	1024 x768	9.6"	0.19	2grey	Tr:600ms Tf:250ms	Now	TBD
3	Hitachi	STN /MONO	1024 x768	11.4"	0.23	2grey	700ms	Now	70K
4	Seiko EPSON	DSTN /MONO	1024 x768	13"	0.25	2grey	700ms	Now	115K
5	SANYO	STN /MONO	1120 x780	10.1"	0.19	2grey	500ms	Now	69K

2. 1024 x 768 class COLOR

No	Vendor	Tech.	S P E C.					Delivery	Price (yen)
			Res.	Size	Pitch	C/G	Speed		
1	SHARP	TFT /Color	1024 x768	11.8"	0.234	512 Color	Tr:<50ms Tf:<50ms	TBD	TBD
2	Seiko EPSON	MIM /Color	1280 x800	13"	0.219	4096 Color		--	--
3	Seiko EPSON	MIM /Color	1024 x768	(13")	(0.25)	4096 Color		92/2Q	TBD
4	Hitachi	TFT /Color	1120 x780	11"	0.204	512 Color	Tr:<50ms Tf:<50ms	92/4Q	TBD
5	Matsushita	TFT /Color	1152 x900	15"	0.261	Full Color	Tr:<50ms Tf:<50ms	TBD	TBD
6	HOSIDEN	TFT /Color	1280 x800	15"	0.252	4096 Color	Tr:<50ms Tf:<50ms		
7	TOSHIBA	TFT /Color	1152 x900	13.8"	0.24	4096 Color	Tr:<60ms Tf:<60ms	--	--

1280 x 1024 calss MONOCHROME

No	Vendor	Tech.	S P E C.					Delivery	Price (yen)
			Res.	Size	Pitch	C/G	Speed		
1	CANON	FLCD /MONO	1280 x1024	15"	0.22	4grey	70us /line	92/1Q	TBD
2	SHARP	TSTN /MONO	1280 x1024	15.1"	0.23	2grey	370ms	TBD	TBD
3	SANYO	TFT /MONO	1280 x1024	12.9"	0.20	4grey		92/Aug	TBD
4	HOSIDEN	TFT /MONO	1280 x1024	15.4"	0.238	?	Tr:20ms Tf:30ms	92/1Q ¡Á2Q	<200K
5	SHARP	EL /MONO	1280 x1024	12.9"	0.20	4grey		91/4Q	140K ¡Á200K
6	Mitsubishi	PDP /MONO	1280 x1024	16.8"	0.26	2grey		92/Feb	
7	Fujitsu	PDP /MONO	1280 x1024	16.1"	0.25	2grey		Now	150K

1280 x 1024 class COLOR

No	Vendor	Tech.	S P E C.					Delivery	Price (yen)
			Res.	Size	Pitch	C/G	Speed		
1	CANON	FLCD /Color	1280 x1024	15"	0.217	16 Color	70us /line	TBD	TBD
2	Mitsubishi	PDP /Color	1280 x1024	20"	0.30 ¡Á0.32	4096 Color		93/2Q	TBD

(Attachment 2)

Major Alliances on FPD's

Hitachi	-	AEG(germany)	alliance
Toshiba		IBM	Joint Venture
SeikoDenshi	-	Olivetti	Joint Venture
SeikoEpson	-	Rockwell	alliance
Optorex	-	Hyundai(Korea)	alliance
Canon	-	HP	contract ?
Hoshiden	-	Apple	contract ?

Major investimant by Japanese company

	Investment		Volume (1991)
Sharp	$ 700 M	(1990 - 92)	$ 880 M
Hitachi	300	(1990 - 91)	230
NEC	540	(1990 - 95)	
Toshiba (incl DTI)	600	(1990 - 93)	280
Hoshiden	380	(1989 - 95)	120
Sanyo	360	(1990 - 94)	250
Mitsubish	150	(1991)	
Matsushita	300	(1990 - 91)	150
Casio	400	(1990 - 93)	230
SeikoEpson	300	(1989 - 92)	570
Optorex	130	(1989 - 91)	320
SeikoDensi	100	(1989 - 93)	100
Citizen	80	(1991)	100
Alps			100
Stanley	130	(1989 - 93)	110
Fujitsu	80	(1990 - 91)	
Canon	770	(1991 - 95)	
Kyocera			
Sony			

From: RDVAX::MACHEFSKY "EXTERNAL RESEARCH PROGRAM, WEST COAST 415-723-4339 06-Dec-1991 0251" 6-DEC-199
1 02:55:01.44
To: @SUN
CC:
Subj: New DECstations snare 2,037 first day orders

[Thanks to Dom Ricchetti for this note.]

From monahan@wrksys.enet Thu Dec 5 08:14:05 1991
Received: by busboy.pa.dec.com; id AA01147; Thu, 5 Dec 91 08:14:03 -0800
Received: by fenris.pa.dec.com; id AA20802; Thu, 5 Dec 91 08:14:00 -0800
Date: Thu, 5 Dec 91 08:13:59 -0800
Message-Id: <9112051614.AA20802@fenris.pa.dec.com>
From: monahan@wrksys.enet (JIM, WORKSTATIONS FINANCE, 223-6436 05-Dec-1991 1113)
To: @competitive
Cc: MONAHAN
Subject: fyi..2,037 first day orders on new Decstation 5000s.

source:
Computer Industry News from MISG for 12/4/91
Courtesy of Micro Tech Research, Inc.

DIGITAL's FOUR NEW LOW END WORKSTATIONS RECEIVED A WARM ANALYST RECEPTION.

WorkGroup Technologies analyst John Dunkle sees Digital as having a competitive low end workstation lineup for the first time in a long while. Digital said it has 2,037 first day orders for the new DECstation 5000 models. Dunkle believes that giving existing Digital DECstation 5000 users the ability to trade up to the new RISC engine will help to boost the firm's 15.2% market share. Aberdeen analyst Thomas Wilmott noted that Digital is trying to recoup market share lost to Sun over the last four or five years. Wilmott expects competitive responses from IBM, HP and Sun shortly. He sees IBM and HP dominating the high end, while Digital and Sun dominate the low end workstation market at present. (BG,12/4/91,p70)