Introduction and Summary

SUMMARY

During 1989, High Definition Television (HDTV) moved from obscurity to center stage in the ongoing debate over the role of the Federal Government in U.S. industrial competitiveness. HDTV and related High-Resolution System (HRS) technologies in the computer and communications sectors may significantly impact U.S. electronics manufacturing, accelerate fundamental restructuring of the U.S. communications infrastructure, and provide a host of valuable services.

Manufacturing

HDTVS must process huge quantities of information at speeds approaching those of today's supercomputers in order to display a real-time, full-color, high-definition video signal. HDTVS are able to do this at relatively low cost through the use of circuitry dedicated to specialized tasks. In contrast, supercomputers are software programmable and do a much broader range of information handling and computation.

HDTV is driving the state-of-the-art in a number of technologies that will be important to future generations of computer and communications equipment. These include certain aspects of digital signal processing for real-time video signals; high-performance displays; fast, high-density magnetic and optical data storage; technologies for packaging and interconnecting these electronics; and, as with all high-volume consumer electronics, processes for manufacturing these sophisticated products at affordable costs.

Consumer electronics has long been the principal driver of important aspects of these and other technologies. For example, television has long pushed display technology. VCRs, compact disks, and digital audio tape have driven important data storage technologies. Products such as calculators, watches, and LCD TVs have been important in the development of packaging/interconnect technologies such as tape automated bonding and surface mount. Light-emitting diodes (LEDs) in watches, calculators, and indicators; and diode lasers in CD-players are examples of important optoelectronic technologies driven by the consumer market. Finally, important manufacturing technologies, such as automatic insertion equipment to place components on printed circuit boards, were developed for the high-volume consumer electronics industry.

Video entertainment markets will be worth billions of dollars, whatever form they take in the future. The economies of scale realized in producing for markets this large combined with the technological linkages noted before may aid manufacturers in penetrating other markets using similar products and technologies, particularly the computer and communications sectors.

Consumer electronics is characterized by fierce competition, large volume production, and low profit margins. Because of this, consumer electronics may be the equivalent of the "coal miner's canary" for manufacturers of electronics—providing a sensitive indicator of their managerial and technical performance in design, production, and quality; of the health of the environment they operate in (macroeconomic, regulatory, and structural); and of the effectiveness of government policy towards foreign trade practices. Consumer electronics manufacturing is nearly dead in the United States. Much of what remains is domestic ''screwdriver assembly' of components and subassemblies produced abroad.

Congress might question the wisdom of any further government involvement in HDTV if they view the technology in a narrow sense—as nothing more than a near-term improvement over today's TV. However, if it is viewed

broadly—as a possible first step back into consumer electronics manufacturing; as a principal driver of HRS technologies for future computer and communications equipment; or as a component of a national fiber information network with HDTV or related products serving as the home terminal-then Congress may find that HDTV and related HRS technologies could contribute to several national goals.

HDTV may also bean instructive case study of the difficulties facing the United States in reversing the erosion of U.S. leadership in many electronic technologies and in global and domestic electronics markets (figure l-l). The United States is seriously lagging technically and/or in market share in semiconductor materials; ceramic packaging; DRAMs, gate arrays, CMOS and ECL devices generally; LCD displays; optoelectronics; and floppy disk and helical scanning drives (VCRS); to name only a few. The United States will not long remain a world leader in electronics technologies if its technological foundation continues to crumble in this manner.

HDTV and related HRS will not by themselves determine the fate of the entire U.S. electronics industry. They will only have a direct impact on technologies and products for handling visual information, and these impacts will not begin to be felt for several years. In the near- to mid-term, the U.S. electronics industry faces substantial challenges. Many technologies must be developed—including materials, x-ray lithography, large-area lithography, optoelectronics, packaging/interconnect, and others—and much greater effort must be devoted to manufacturing with quality at low cost.

The responses to these challenges should not be viewed as independent efforts. The electronics industry is a complex and highly interdependent whole. For example, the design of leading-edge microprocessors requires access to high performance computers which, in turn, depend on leading-edge materials, semiconductor manufacturing equipment, packaging/interconnect, and other leading-edge technologies. Manufacturing these microprocessors will become increasingly difficult if vertically integrated foreign competitors control the basic materials and semiconductor manufacturing equipment. Selling them will be similarly difficult if these foreign competitors control most other components (memory and other chips, optical and magnetic storage, displays); have superior packaging/interconnect and assembly technologies (e.g., chip on glass); and prefer to use their own microprocessors instead of purchasing them from U.S. manufacturers. Although the fragmented entrepreneurial U.S. electronics industry is remarkably innovative, giant foreign corporations can easily invest more heavily in critical technologies or simply buy out the U.S. entrepreneur.

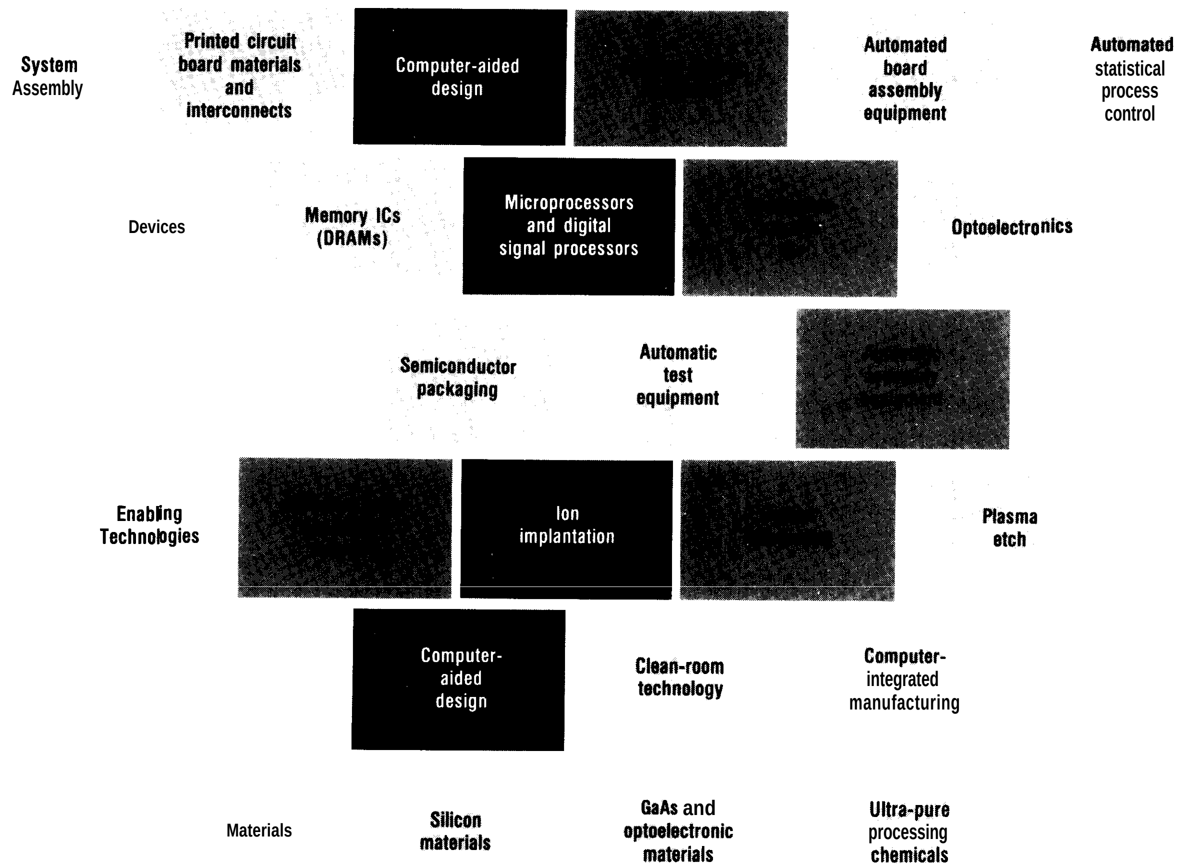
HDTV and HRS should thus be viewed as only part of a larger and more comprehensive effort to understand and resolve the problems facing the U.S. electronics industry. These include: the high cost of capital; lack of vertical and/or horizontal integration; inattention to manufacturing process and quality, poor design for manufacturability, and the separation of R&D from manufacturing; poor or adversarial relationships with suppliers; weakness in the U.S. educational system; industrial and trade policies in other nations that have aided competitors; inadequate foreign protection of U.S. intellectual property; and foreign trade violations and closed foreign markets. These issues are discussed in greater detail in a recent OTA report.[1]

Communications Infrastructure

The communications industry is currently undergoing dramatic, technology-driven change through the increasing use of digital electronics and fiber optics. In the midterm, the continued incorporation of advanced electronics and photonics into the existing public telephone net-

[1] U.S. Congress, Office of Technology Assessment, *Making ?'/zings Better: Competing in Manufacturing*, OTA-ITE-443 (Washington, DC: US. Government Printing Office, February 1990).

Figure I-l—Erosion of U.S. Leadership in Semiconductor and Related Technologies



Technologies in which the United States is lagging Japan are shown in light tones; those in which the United States and Japan are roughly equal are shown in medium tones; those in which the United States is leading Japan are shown in dark tones.

SOURCES: Adapted from the Report of the Federal Interagency Staff Working Group, "The Semiconductor Industry," National Academy of Sciences, 1987; National Research Council, *Advanced Processing of Electronic Materials in the United States and Japan* (Washington, DC: National Academy Press, 1988); W.C. Holton, J. Dussault, D.A. Hodges, C.L. Liu, J.D. Plummer, D.E. Thomas, and B.F. Wu, "Computer Integrated Manufacturing (CIM) and Computer Assisted Design (CAD) for the Semiconductor Industry in Japan," JTECH Panel Report, Department of Commerce, Science Applications International Corp., December 1988; Manufacturing Studies Board, The *Future of Electronics Assembly: Report of the Panel on Strategic Electronics Manufacturing Technologies* (Washington, DC: National Academy Press, 1988).

work will make many new and improved interactive information services available. Radio frequency communications are also rapidly changing due to such innovations as cellular telephones and other products.

HDTV could accelerate these changes in the communications infrastructure. The greater infermation content of HDTVS broadcast signal has raised the most significant issues for radio frequency spectrum allocation in decades. HDTV bandwidth requirements present problems for making the transition to terrestrial HDTV broadcasting, but digital technologies offer the prospect of more efficient use of the limited available spectrum than is possible with today's TV system—which is based on 40-year-old analog electronics technologies. Some of the broadcast spectrum might thus eventually be freed for other uses. For example, it has been suggested that if sufficient spectrum became available, cellular telephones could become more broadly competitive with today's phone system for voice communications.

HDTV might also speed the extension of fiber to the home by stimulating market demand for high-quality video entertainment. In the mid-term, a mixed cable TV and telephone company network might provide a modest level of interactive video services. Whether or not such a system can evolve into a national two-way broadband fiber network is unclear. This is an important consideration in establishing a financial and regulatory framework for the communications industry.[2]

Services

HDTV and related HRS technologies may offer a host of important services to individuals as well as to business and industry. Interactive video, medical imaging, desktop publishing, and computer graphics are examples of services already in advanced stages of development or on the market for high-end commercial users (box l-l). Other services may not be developed for many years, and many more remain to be invented. Video information technologies will become increasingly important in computer and communications systems in order to make best use of the most important human sense—vision.

The United States has the opportunity to establish a more powerful and flexible HDTV system than those currently being developed and introduced in Japan and Europe. America has many strengths in HDTV and HRS-related component technologies, as well as in highly innovative HDTV transmission standards and receiver designs now under development in a number of U.S.-based facilities.

The window of opportunity for U.S. firms to enter or to strengthen their position in these markets could close quickly, however, if the strategies of foreign competitors are successful. Many U.S. firms seriously lag in manufacturing practices—both managerial and technological—and there is little consumer electronics manufacturing remaining in the United States on which to build. These deficiencies could be overcome—the Japanese surmounted far greater obstacles in developing their domestic computer industry (app. E)—but doing so would require considerable effort and discipline on the part of both U.S. industry and government.

INTRODUCTION

HDTV is one of several possible forms for the next generation of home video entertainment; following Black and White (B&W) TV in the 1940s, color TV in the 1950s, and VCRs in the 1970s. It promises to deliver pictures to the home as clear as those seen in movie theaters, with sound comparable to compact disk players.

But HDTV is far more than just a pretty picture. It is part of an ongoing evolution in home electronics toward computer-like digital technologies. This evolution began with such things as automatic electronic tuners on stereos and TVs, compact disk players, and electronic controls on microwave ovens and many other household appliances. It continues today with the introduction of Improved Definition TV (IDTV) that uses computer memories and other digital techniques to provide a much better picture even with today's broadcasts. The evolution will continue in the future with HDTV or other advanced video entertainment products.

HDTV is also at the leading edge of a much broader, though less well publicized, transition in computers and communications equipment to technologies that can create, manipulate, transmit, and display high-quality visual information, including full-motion video as seen on television receivers. In many respects, Advanced TV (ATV), interactive video, computers, and communications are all gradually merging technologically. Known generically as High Resolution Systems (F-I'M), these systems will allow the user to interact with that being displayed, and will have profound implications for education, entertainment, and work in the future.

[2]See, U.S. Congress, Office of Technology Assessment, *Critical Connections: Communication for the Future,* OTA-CIT-407 (Washington, DC: U.S. Government Printing Office, January 1990).

Box 1-1—Digital Video Information and Telecommunications Services

Digital video information and telecommunications technologies (DIVITECH) may potentially offer a variety of services beyond entertainment. Some of these are listed below.

Telemedicine—Because of its high resolution and true rendition of color, advanced video communications technologies could be used to transmit medical images such as x-rays, CAT scans, or color pictures of tissue to leading experts in distant cities for instant diagnosis. A distant expert might even observe and provide advice during a critical operation. People in rural areas with little access to world class medical facilities could particularly benefit.

Education—Recent advances in manipulating digital video data allow the viewer to interact directly with real-world images. For example, the viewer can "stroll' through ancient Athens at will, the computer selecting and displaying the appropriate audio and video signals (prerecorded on location) in response to the viewer's direction. The viewer could similarly examine the effect of different strategies on the outcome of a battle; take apart and rebuild an auto engine; or dissect a frog, with detailed information available on demand on how each part works individually and with other parts. This ability to interact with what is being displayed will make these technologies far more important to education than today's TVs. Advanced video technologies could thus be used widely in education, from pre-school through medical school.

Simulation—Engineering simulation, including computer aided design of structures, electronic components and equipment, aircraft, and a host of others is already a vital market. As for interactive video, recent advances in computer-generated images could extend simulations to such things as building design-where a prospective client might take a realistic "walk" through a proposed design.

Photography—Pictures taken by electronic still cameras could be displayed on a screen or sent over a network for immediate printing at a distant film developer. With computer assistance, photographic-quality images and digital audio might one-day be edited almost as easily as words are today.

Telecommunications-A host of new services, ranging from videophones and teleconferencing to telemarketing new goods could become available to the consumer. One might even design a personal telenewspaper by using a computer program to search the news services, TV news, PBS educational programs, and others for written or video information of particular interest that could be stored and later displayed-for example, at breakfast time.

Publishing-Desk-top publishing using personal computers has already revolutionized the business. Advanced video technologies will accelerate this by allowing the transmission and display of high-quality visual material. NYNEX is now experimenting with the transmission of advertising copy between agencies and clients over a fiber-optics network in New York City.

Defense—HRS technologies could enhance many of today's defense technologies. Examples might include: using electronic cameras for reconnaissance to eliminate the delays and logistics in processing film; providing high resolution maps for targeting and/or very close-in air support of ground troops; or improving cockpit displays for pilots—overlaying information about incoming missiles, ground fire, or aircraft with fuel availability and weapons' status on a display of the upcoming target.

SOURCES: Paul Kemezis, "HDTV Slowly Moves Into Medical Applications," New *Technology Week*, Aug. 15, 1988; Arch C. Luther, "You Are There. . . And In Control,"*IEEE Spectrum*, September 1988; William Booth, ''BendingReality's Borders,'*Washington Post*, Oct. 23, 1989, p. A3; "What's Ahead in Phones and High-Resolution TV," *Science Focus, vol.* 3, No. 2, Fall 1988, New York Academy of Sciences; U.S. General Accounting Office, ''High-Definition Television: Applications for This New Technology," December 1989.

Early generations of these technologies are already affecting our professional lives in important ways. High-performance graphics-based workstations and personal computers, laser printers, copiers, fax machines, and other technologies are revolutionizing the office. Interactive video systems are becoming available that allow an architect to "stroll" through a building being designed, or a student to call up video material in an electronic encyclopedia. At home or in the office, this fusion of computer, communications, and imaging technologies will make widely accessible a host of new services (box 1-1).

Similarly, many government activities could benefit from HRS technologies. For example, the Federal Aviation Administration (FAA) has already contracted with Sony (Japan) for high-resolution displays to monitor air traffic. The military could use these technologies for training simulators, command and control centers, teleconferencing, and aerial reconnaissance—eliminating the delays and difficulties inherent in processing film. NASA could use HRS technologies for deep space exploration, remote sensing of the Earth, and for monitoring launches. For example, higher resolution pictures would have aided the analysis of the Space Shuttle Challenger tragedy. In March 1989, NASA conducted its first test of HDTV by videotaping the launch of the Discovery shuttle and transmitting the pictures within the Space Center and as far away as Orlando, Florida, by fiber-optic links.[3]

The role of HDTV as a consumer product in the future information society remains unclear. Skeptics portray HDTV as simply providing better entertainment for ''couch potatoes,'' and claim that there will not be a sufficient consumer market to support a more complex or capable technology. Advocates portray HDTV as the basic technology platform on which tomorrow's home and perhaps even office information services will be built—a veritable keystone for the video information archway of the future.

Although such scenarios suggest that HDTV might eventually become the home information center—providing entertainment, computer, and telecommunications services-it is perhaps more likely that these different services will instead continue to be primarily provided by separate, specialized pieces of equipment. People simply work that way. While the teenager is on the videophone, one parent could watch video on a big screen in the family room, while the other parent could use the computer in the study to balance the monthly finances.

HDTV might thus be one of three platforms for home information services, the others being the computer and the videophone. (In homes that would not otherwise purchase a computer, the HDTV might serve as an affordable means of providing some computing power and would then open a wide range of services.) All three types of equipment will probably evolve common basic designs that allow easy exchange of information among them and could significantly overlap in the services they provide. Overtime, it may become increasingly difficult and moot to distinguish these different types of digital equipment from each other. The large, high-quality screen of the HDTV might be the most notable difference.

These video information services will neither replace today's media quickly, nor will they until they provide significantly greater functionality at an affordable price. For example, simply reprinting a newspaper story on a bulky, hard-to-read ATV or computer display will not induce people to give up the convenience of newspapers, which can be carried around and read anywhere. But video information services that deliver more in-depth information on a news program upon request; can send a movie clip to a friend; or provide electronic yellow pages that include video clips of restaurants that viewers might want to try could attract a great many newspaper readers (a possibility of obviously great concern to the newspaper industry[4]).

Despite the potential impacts of HDTV and related HRS technologies on U.S. electronics manufacturing and on the U.S. communications infrastructure, and, despite the opportunities that new video information services may offer, the United States significantly lags Japan and Europe in developing and manufacturing many of these products.

This report focuses primarily on consumer HDTV for several reasons: HDTV raises thorny policy issues; HDTV is driving a number of technologies and manufacturing processes for HRS more generally; and HDTV may significantly impact our communications infrastruc-

[3]Richard Doherty, 6'HDTV Cameras Capture Shuttle Launch,'' *Electronic Engineering Times*, Mar. 20, 1989, p. 19.

[4]''Should the U.S. Free the Baby Bells?'' *Business Week*, Mar. 12, 1990, p. 124.

ture through possible radio frequency spectrum reallocation and perhaps by accelerating the deployment of fiber-optic systems.[5]

Less attention is paid to intermediate forms of Advanced TV such as Improved Definition or Extended Definition TV (IDTV, EDTV): IDTV has little impact on the communications infrastructure; EDTV'S impact on communications is modest and EDTV may be bypassed if simulcast systems are chosen; and neither IDTV nor EDTV are driving technologies as hard as HDTV is today.

Less attention is also given to alternative forms of video entertainment and information systems such as interactive video: it has little impact on the communications infrastructure; it may become an element of the discussion of HDTV if flexible designs for HDTV receivers are chosen as the U.S. standard; and it faces many of the same questions about consumer appeal as HDTV.

There is similarly little discussion of video program production: it provides the United States a net $2.5 billion trade surplus—compared to a $5 billion[6] trade deficit for consumer video equipment—and it has little impact on either U.S. manufacturing performance or the U.S. communications infrastructure.

Finally, the market for video production equipment is smaller than that for household video equipment. There is less emphasis on the much larger generic category of High Resolution Systems—which represent much of future computer and communications systems—than for HDTV. These areas will be referred to briefly throughout this study, and will be discussed in more detail in future OTA reports.

The Historical Development of HDTV (Ch. 2)

The Japanese have been selling HDTV studio production equipment since 1984 and are now gearing up large-scale commercial production of HDTV receivers. The Europeans began a crash program in June 1986 and now lag the Japanese by just 2 to 3 years. In contrast, the United States will not even begin testing to establish HDTV transmission standards until mid- 1990 and U.S.-manufactured HDTVS could not likely be commercially available until 1993 or 1994.

The Japanese effort is particularly noteworthy. Japan considers HDTV to be an important step into the future information society. It foresees numerous technological linkages between HDTV, High Resolution Systems, and other parts of its highly successful electronics industries. As in other countries, the Japanese face the "chicken-and-egg" problem of who invests first: consumers will not buy HDTVS until the price comes down and there are enough HDTV programs to watch, but manufacturers cannot reduce the unit price until sales volumes are large, and movie producers and broadcasters will not provide HDTV programs until there is a sufficient audience. The Japanese believe that the best way to overcome this problem is by sharing the costs and risks between the government and the private sector. The Japanese Government has therefore spun a complex web of direct and indirect R&D, financial, and market promotion efforts to stimulate the development of the HDTV market.

In contrast, all U.S.-owned firms, except Zenith, have abandoned the TV receiver manufacturing business. Many factors contributed to this exodus of U.S. firms, including: the relatively poor manufacturing performance by some U.S. firms (see app. A); and the failure of the U.S. Government to protect U.S. industry from foreign trade violations (see app. B). As a result of the loss of the U.S. TV market, the little work done on HDTV in the United States has largely been by or for foreign-owned consumer electronics firms or by small, underfunded university programs and entrepreneurs. The Defense Advanced Research Projects Agency's (DARPA) planned R&D program is the most significant

[5] The term HDTV is, on occasion, used loosely to include Advanced TV systems generally.

[6] Sarah Hall, International Trade Administration, Us. @~@ of Commerce, personal communication, Nov. 16, 1989.

recent step to reverse this, but there are serious questions about the Administration's commitment to this effort.

Communications Technologies (Ch. 3)

Historical, economic, and technological factors have combined to provide the United States five major electronic communication media: terrestrial and satellite communications using the radio frequency spectrum; coaxial cables for TV; twisted copper pairs of wires in the telephone network; and, recently, optical fiber for the high traffic "backbones" of both the telephone and cable TV networks.

The greater information content of HDTV'S broadcast signal will require changes in the allocation and use of the existing TV broadcast channels and could potentially free spectrum for use in mobile communications and other services. HDTV could spur the use of Direct Broadcast Satellites (DBS) and might also speed broader use of fiber optics in cable and possibly telephone networks by stimulating market demand for high-quality video entertainment.

Television Technology (Ch. 4)

Video entertainment systems may take a variety of forms in the future, including (in order of increasing picture quality) Intermediate Definition TV, Extended Definition TV, and High Definition TV; or perhaps various forms of interactive video either in conjunction with these Advanced TVs or as separate systems. Of all ATVS currently under advanced development, HDTV may have particular consumer appeal because of its greater potential for providing viewers the feeling of 'being there' that one sometimes gets in watching a high-quality motion picture up-close and, for example, having the sense of moving with a stunt plane when it makes a fast turn.

Television systems have three general functions—production, transmission, and reception of TV programming—all of which will require substantial changes from today in order to make the transition to HDTV.

Production

International efforts are currently focused on developing common production formats that will allow easy conversion between different regional standards. Earlier attempts to establish a single global production standard foundered on the lack of compatibility between existing systems and the cost of converting from one to another. Earl y recognition by European interests of the potential competitive threat to their domestic electronics manufacturing posed by having a single common standard based on the Japanese system was also a factor in stopping the establishment of a single global production standard.

Transmission

It is difficult to squeeze the greater information content of an HDTV signal into the charnel bandwidths allocated to terrestrial broadcasting, especially given the inefficiencies of conventional color TV signals. The Japanese and Europeans have therefore opted to instead develop HDTV services through Direct Broadcast Satellite (DBS) systems operating at higher frequencies not currently heavily used. In the United States, the greater importance of the existing broadcasting system, issues of localism and programming diversity, and other factors make the development of a terrestrial HDTV broadcasting capability for HDTV more important than it is in Japan or Europe.

Terrestrial transmission systems proposed for Advanced TV services in the United States are based on augmentation of the existing NTSC transmissions with an additional 3- or 6-MHz signal; or on simulcasting (simultaneously broadcasting) in the charnels now left vacant to prevent interference between stations (taboo channels). Although the NTSC system was a remarkable triumph when it was developed—given the electronics technologies of the 1950s—more efficient use of the broadcast spectrum is now possible with today's electronics technologies. Augmentation systems will continue to use, in part, the NTSC system and may thus tend to lock into place less efficient use of the broadcast spectrum. In contrast, simulcast systems might eventually allow a large amount of radio frequency spectrum now reserved for NTSC broadcasts to be vacated and used for such services as mobile communications.

Receivers

Advanced TV receivers of greatest interest in the near-term are the Multiport Receiver and the Open Architecture Receiver (OAR). Multiport receivers would be adaptable to a limited range of predetermined broadcast standards and would provide limited access for adding voice/data/video communications.[7] OARS follow the path pioneered by the personal computer industry and would be adaptable to a much broader set of broadcast standards, personal communications, computer functions, or other services that might be of interest to consumers. This could open a host of new markets for entrepreneurs.

Advanced TV systems are evolving naturally from today's conventional, largely analog systems through the increasing use of computer-like digital electronics. This evolution of TV technology to digital electronics is inexorable, even if its speed is uncertain. Similarly, computer and communications systems are evolving towards greater use of still and video images as now seen primarily on TV. Advanced TV, computer and telecommunications systems are expected to continue to evolve towards reasonably common forms—HRSs. The impact of HDTVS and HRSs if connected to a national fiber communications network could revolutionize information services.

Technological Linkages (Ch. 5)

HDTV is driving the state-of-the-artin certain digital signal processing, data storage, display, packaging/interconnect, and other technologies, as described above. As with consumer electronics generally, HDTV will also push the limits of cost-effective manufacturing. This could be one of the most important impacts of HDTV for the United States.

The expectation of a large market is forcing potential HDTV manufacturers to push the state-of-the-art in several areas of HDTV-related technologies. These technological linkages could assist HDTV producers in other HRS markets. Simply developing technologies does little good, however, without markets to sell in.

In the past, the United States has tended to assume that if technologies were developed, markets would follow. Faced with large, often vertically integrated and aggressive foreign competitors, market shares may be as important as technology development. These foreign firms are much more likely to use their own internally developed semiconductors and other components than to buy them from a U.S. firm (as might a vertically integrated U.S. firm). Some foreign firms are also more likely to buy components they don't make internally from local suppliers with whom they have long-term preferential relationships. These relationships can be very difficult to crack, regardless of the price or performance of the technology offered by the outsider.

Controlling the market, however, is not enough. Even with a strong technology base and 70 percent of the world's personal computer market, the United States still lost the (merchant) DRAM industry to Japan. This was due to a variety of factors, including: relatively less efficient manufacturing by some U.S. firms (app. C); foreign trade violations and closed foreign markets (app. D); and industry and trade policies in Japan that encouraged heavy investment in and rapid development of their domestic industry.

Advanced Television Markets (Ch. 6)

Forecasts based on analogies with past *successful* products, project U.S. sales of HDTVs at 10 to 15 million sets annually within 15 years. Some expect a large business/industry market for HDTV equipment to develop much sooner. Yet others suggest that the HDTV market will

[7] Arpad G. Toth and Joseph Donahue, "An Multiport Receiver: Preliminary Analysis," *First Report of the EIA ATV Multiport Receiver Committee*, Sept. 11, 1989.

not develop and that consumer needs can be met by intermediate products such as Improved Definition TV or Extended Definition TV, or instead byproducts such as interactive video. In fact, there will probably be markets for all of these products. The large uncertainties in how video entertainment markets will develop in the future should not obscure the underlying trend in consumer video towards digital electronics, high-performance fiat panel displays, high-density optical and magnetic recording, and other key technologies.

The HDTV market projected by these forecasts varies between $5 billion and $12 billion (1988 dollars) by 2003. VCRs, movie production, and broadcasting equipment increase these potential values. The overall U.S. consumer electronics market was worth $30 billion in factory sales in 1987 and is growing rapidly.[8] The High Resolution System market will be larger yet, encompassing a broad array of imaging and image processing markets in the computer, consumer electronics, and telecommunications sectors.

The relative importance of the future HDTV market has also been compared with that of the computer sector. Such comparisons are not very useful; there are simply too many uncertainties. Regardless of the precise form consumer video products take in coming years, the consumer electronics sector will continue to be a large and important market, and video entertainment will continue to be its most important component. Computers and communications equipment will also make greater use of still and video images, but they will probably lag consumer video in driving some of the key technologies such as digital signal processing, high-performance displays, optical and magnetic storage, and certain manufacturing processes.

U.S. Manufacturing of HDTV

Proponents argue that government support for HDTV and related HRS R&D might serve several national goals.

HDTV might serve as a stepping stone for U.S. firms to reenter consumer electronics manufacturing. Consumer electronics is a large market; it also supports many upstream industries. For example, roughly one-fourth of Japanese semiconductor output is currently used in consumer products, and TVs and VCRs are a major portion of this.[9] Similarly, 70 percent of the $8 billion (1988) world display industry is for consumer products. There will continue to be a large demand for video entertainment and other consumer electronics equipment, regardless of the specific form these technologies take. As noted above, consumer electronics is also an important driver of manufacturing processes.

HDTV might serve as a principal driver of many High Resolution System (HRS) technologies due to the exceptional demands it places on display, video processor, storage, and other technologies. At one time, U.S. firms could ignore the consumer electronics market at less risk because analog electronics were used. With the shift of consumer equipment to digital electronics, the linkages to the computer and telecommunication industries are becoming much more important. U.S. firms can no longer ignore the consumer market with impunity.

HRS technologies will be very important to the computer and communication industries in coming years. As a forerunner to video, manufacturers sold roughly 9 billion dollars' worth of hardware and software in the United States in 1988 for commercial graphics applications, with sales expected to rise to over $25 billion by 1993.[10] There are similarly large markets for display technologies; for imaging equipment such as facsimile machines; and for telecommu-

[8] Electronic Industries Association *Consumer Electronics Annual Review, 1988 cd.,* Washington, DC.

[9] "Japan Electronics Almanac," Dempa Publications, various years; Kenneth Flamm, Brookings Institution personal communication VCRs alone account for 12 percent of total Japanese IC production: "TV's High-Stakes, High-Tech Battle," *Fortune,* Oct. 24, 1988.

[10] "The Graphics Revolution," *Business Week,* Nov. 28, 1988.

nications equipment, including that using wide-band switching and fiber optics. American firms are increasingly lagging foreign competitors in many of these technologies; more R&D is needed, together with greater attention to manufacturing with quality at affordable prices.

Finally, HDTV or related HRS might serve as the home terminal on a national fiber information network. In the midterm, the Integrated Services Digital Network (ISDN) will make possible a host of information services short of high-quality real-time video. In the longer term, a national two-way fiber network would make possible many desirable video information services. If a national fiber network is made a national goal, then policies to aid its implementation should be put into place in the near-term. These might include a framework to encourage additional effort in developing and manufacturing video information systems.

Skeptics insist that if HDTV is important, industry will invest in it independently and will do so more wisely than the government could; that there is no need for government support.

Skeptics argue that HDTV is likely to be a relatively small market (at most $30 billion in 20 years) compared to the entire world electronics market (which is already $450 billion or more) and can therefore be ignored. The same argument could be made about almost any segment of a market and ignores the relative importance of specific products in driving the state-of-the-art in important technologies. For example, the total U.S. supercomputer market was just $1.4 billion in 1988, but supercomputers are very important in driving a number of leading-edge technologies. DRAMs were just a $2.5 billion market in 1987—5 percent of the total world semiconductor market-but DRAMs drive many important semiconductor manufacturing technologies. HDTV and related HRS are similarly driving many important technologies (ch. 5).

In contrast to American firms, many foreign competitors seem much more cautious about abandoning markets. This may be due to: the significant financial and technical skills needed to reenter high-technology manufacturing; the potential linkages with other existing markets; or the new opportunities that being in a market may create. Being in many parallel markets can also provide economies of scale in R&D and production of the underlying components, and tends to insulate a firm from downturns in any particular market segment.

Some skeptics argue that trying to outguess the market by backing a specific product is foolish: instead of HDTVS, consumers may prefer lower-cost systems with somewhat less resolution, or systems that provide much more interactivity. This point may prove to be true. Consumer markets will likely develop around each of these as well as other applications. Neither industry nor government can guess the precise form that these markets will take; nor is it necessary to do so. There is a clear trend towards video information systems, which involve many of the underlying technologies now being most strongly driven by HDTV.

Other skeptics suggest that it doesn't matter if HDTV and related electronics products are manufactured abroad. They even speculate that it helps the American consumer if these products are dumped in U.S. markets-that this effectively gives us something for nothing. Viewed narrowly, consumers agree. Consumers want the best possible HDTV programs and pictures at the lowest possible price, and without having to pay any subsidies—either through taxes to support R&D, or added fees to cable companies or other distributors.

This argument is based on a questionable definition of consumer interest. If U.S. consumers are to buy these goods and maintain a high standard of living, they must have high-paying jobs in a strong economy. The United States will lose potential jobs-especially the skilled jobs needed to ensure a high standard of living in the United States-if the electronics or the displays for HDTVS and related HRSS are produced offshore. Consumers in other countries have often paid taxes and price subsidies in order to maintain their jobs and develop their manufacturing sector.

Finally, some skeptics insist that if HDTV is potentially such a large market and so important a driver of technology, then industry would enter it. The implication is that U.S. industry's hesitation to enter indicates that HDTV is likely to be a turkey. This might prove true, yet Japanese and European industry have embraced HDTV. This difference in attitude may, in part, be due to: the history of the U.S. consumer electronics industry; the supports Japanese and European industry receive from their governments; and the barriers now facing prospective U.S. entrants.

U.S. industry has largely abandoned consumer electronics manufacturing. In today's color TV industry, for example, the only significant American-owned firm remaining is Zenith, which has just 14 percent of the U.S. (2.8 percent of the world) color TV market. In order to remain in the TV business, Zenith recently sold its highly profitable computer division to Groupe Bull, a 90 percent French Government-owned firm.[11] In contrast, there are currently 10 Japanese firms, 3 European firms, 2 Korean firms, and 1 Taiwanese firm producing TVs and components at some 32 locations in the United States.[12] A significant portion of this work is screwdriver assembly of electronic components and subassemblies manufactured elsewhere.

The history of the U.S. consumer electronics industry is long and tortured. Numerous factors contributed to its decline. Appendixes A and B focus on two of these many factors for the color TV industry: less-competitive manufacturing by some U.S. firms than their foreign competitors; and trade violations by foreign firms coupled with a failure of the U.S. Government to adequately protect U.S. industry. Given this history, U.S. industry has good reason to be cautious about reentering consumer electronics.

American manufacturers face significant barriers if they are to reenter the consumer electronics industry and manufacture Advanced TVs:

- *Low Market* Share—Foreign-owned firms control the U.S. domestic TV market. Foreign competitors can and do use this base to hone their manufacturing skills, build their production and distribution infrastructure, and generate revenues for development of ATVS. This might also enable foreign firms to quickly initiate large-scale production of any innovation developed for the U.S. market-perhaps more quickly than the U.S. innovator.
- *Low Profits*—The U.S. TV market today provides little or no profit. Zenith, for example, has not made a full-year's profit on its television business since 1984.[13] Few U.S. firms could justify entering such a business to their stockholders.
- *Large Capital* investments—Manufacturers must risk large upfront investments and withstand years of losses in order to create an ATV market. These investments are large and are increasing rapidly as manufacturing processes grow more complex. For example, capital equipment for a minimum-efficient-scale, state-of-the-art DRAM fabrication facility now costs perhaps $300-$400 million.
- *Manufacturing* Skills—Many U.S. firms lag behind foreign competitors in a number of manufacturing technologies important to the production of HDTV (ch. 5).
- *Inequities in Foreign Trade*—U.S. manufacturers may not trust the government to adequately protect them from foreign dumping; they may also have little faith that they will be able to enter or export to the

[11] Evelyn Richards, "French to Purchase Zenith Computer Unit," *Washington Post,* Oct. 3, 1989, p. Cl.

[12] Electronic Industries Association, HDTV Info Packet, and Suzanne Heaton, Electronic Industries Association, personal communication, Dec. 27, 1988.

[13] Jerry K. Pearlman, testimony at hearings before the House Subcommittee on Telecommunications and Finance, Committee on Energy and Commerce, Sept. 7, 1988.

Japanese or to export to the European ATV markets. Without being able to penetrate those markets, U.S. manufacturers may be unable to realize the same economies of scale as their foreign competitors, who can compete in the United States. Foreign producers with protected home markets can expand production with much greater confidence that it will pay off than U.S. producers who have no such assured markets for their sales.

POLICY ISSUES

U.S. industry thus faces significant barriers to entering HDTV manufacturing. Japanese firms struggled under somewhat different, but in many respects even greater, disadvantages while developing their computer industry in the 1960s and 1970s. Yet through a variety of mechanisms (app. E), they have developed world-class capabilities across the spectrum of computer technologies and products.

Developing competitive Advanced TV, consumer electronics, or HRS manufacturing industries in the United States carries many potential benefits, especially in strengthening manufacturing abilities in electronics and in developing technologies that have important spillover applications in other branches of the electronics industries. To succeed in consumer electronics, firms must meet demanding tests of manufacturing excellence: the ability to turn out reliable, well-designed goods at high volume, while keeping costs competitive. What firms learn in meeting these tests for consumer electronics can then be applied to other products, such as computers and telecommunications equipment.

Technological linkages between HDTV/HRS and other industries are equally significant. The knowledge gained in developing core technologies for these systems may sometimes provide a critical edge in competition for other markets in this fast-paced industry. U.S. firms might also find it difficult to get access on equal terms to such technologies if they are developed by foreign competitors. For example, if a small group of like-minded foreign companies were to gain control of an important component, such as flat panel displays, U.S. firms might be vulnerable to overpricing or outright denial of sales. This is not an unheard of practice. Fujitsu, which produces both semiconductors and supercomputers, is reported to have delayed for many months in supplying critical semiconductors to the U.S. supercomputer company Cray Research, Inc.; and Nikon reportedly withheld its latest and best lithographic stepper from U.S. semiconductor manufacturers.

For the reasons outlined in the previous section, the prospects look poor for U.S.-owned firms to reenter manufacturing in the consumer electronics field. A few foreign-owned firms based in the United States are pursuing HRS research here. Possibly, with some form of government encouragement, either in developing technologies or in rebuilding manufacturing capability, or both, U.S. firms might become more interested in risking their own capital and efforts in the field as well. That possibility immediately raises the question of what exactly constitutes a U.S. firm? This question is explored below. But U.S. efforts to support ATV or HRS technologies have been fragmented and abortive so far, in part because such support raises policy issues that have not yet been resolved in public debate. This report does not attempt to resolve them either, but the following issues should be addressed if Congress wishes to pursue options to support a domestic HDTV/HRS industry.

The existence of growing international competition—and the clear decline of U.S. manufacturing competitiveness—has raised the general possibility of increased government support for industry. This makes the question of corporate nationality central. Government support should go to serve the interests of American citizens in this new global environment, but, in Robert Reich's words, "Who Is Us?"[14]

[14] Robert Reich, "Who Is Us?" *Harvard Business Review*, January-February 1990, pp. 53-62.

This question has become increasingly pressing because there have been two fundamental changes in the American economy. First, many large American firms have become global: they do an increasing proportion of their business elsewhere, and U.S.-owned firms are doing more sales, manufacturing, and even design and R&D off-shore, in markets like Japan or the EC, or in low-cost platforms like Malaysia and Thailand. Second, foreign-owned firms have diversified into the United States, and many now have substantial manufacturing efforts in the United States. Foreign-owned R&D and design facilities are also opening in the United States, and some foreign firms have acquired U.S. high-tech businesses in electronics and other industries, and support their R&D as well.

Corporate nationality is an exceedingly complex issue, and only a brief overview is possible here.[15] Ownership has traditionally been the sole criterion of nationality. The fact that American firms were owned by Americans, tended to site their production in the United States, and made almost all their sales in the United States allowed the ownership criterion to represent all the other attributes of nationality. In addition, there was the unspoken assumption that American firms would in some sense act to maintain American national interests. But the shift toward off-shore production, technology development, and contracting by U.S. manufacturing firms has undercut this assumption. And ownership itself is not an unambiguous concept, as ownership does not always mean control: a minority share ownership can exercise control in some cases while a majority ownership may not be sufficient to take key decisions in others. There is little sign that U.S. firms are in fact putting the national interest before their own—partly because that would be a breach of their fiduciary duty to their shareholders.[16]

Thus an alternative view of corporate nationality is now emerging, where the key criterion is the contribution of the firm to the national economy, or national competitiveness. Ownership is only one part of that contribution; not one that is easily quantified. While profits are a relatively small part of a firm's overall direct contribution to the economy in which it operates, they can be a critically important source of funding for R&D, and growth and wealth. Thus, even though their share of value is small, profits may be disproportionately important. Nor is the flow of profits clear: they can in part be recaptured by foreign firms plowing back profits into R&D or capital investments in the United States or by Americans who are fast increasing their holdings of foreign securities. The same is true for foreigners, whose increasing holdings of U.S. securities cause profits to be repatriated elsewhere.

Aside from ownership, most value created by a firm comes from research, development, manufacturing, related services, and sales. Each of these elements can be located in the United States or elsewhere, with differing contributions to the national economy. Recent testimony before Congress has stressed the importance of performance-oriented criteria for determining whether a firm qualifies as American-the extent to which the firm provides jobs, tax receipts, R&D, technology transfer, and other benefits to the United States, or contributes positively to the U.S. trade account.[17]

An extension of this view is offered by Reich, who argues that the critical contribution of a firm to the economy lies in its support for a world-class work force. The kind of business

[15] A complete analysis will be developed in the forthcoming OTA report on trade and industrial policy. This will be the third and final report of the assessment on Technology, Innovation and U.S. Trade, the first two of which were: U.S. Congress, Office of Technology Assessment, *Paying the Bill: Manufacturing and America's Trade Deficit*, OTA-ITE-390 (Washington, DC: U.S. Government Printing Office, June 1988); and U.S. Congress, Office of Technology Assessment, *Making Things Better: Competing in Manufacturing*, op. cit., footnote 1.

[16] Reich, op. cit., footnote 14.

[17] John Kline, testimony at hearings before the House Subcommittee on Science, Research and Technology, Committee on Science, Space, and Technology, and the House Subcommittee on International Scientific Cooperation Committee on Science, Space, and Technology, Nov. 1, 1989.

being conducted in the United States will have implications for the kind of work force being produced, and hence for the attractiveness of the United States as a site for high-technology, high value-added manufacturing.[18]

Some witnesses and some Representatives at the hearing[19] also underlined the importance of reciprocity between the treatment of foreign-owned firms in the United States and the treatment of U.S.-owned firms in the corresponding foreign country. These comments reflected views similar to those embedded in S. 1191, the FY 1990 appropriations bill for NIST.

Corporate nationality becomes an extremely complex issue once the simple but perhaps outmoded criterion of ownership is abandoned. First, the various activities of business—production, R&D, support activities, sales, trade—must be weighed against each other. Is R&D intrinsically more valuable to the United States than an equivalent amount of value added in sales? How should quantitative criteria (e.g., a certain percentage of value added) be balanced against qualitative criteria (e.g., a commitment to doing R&D in the United States)?

These problems can be solved in principle, but practical application could be difficult. The Europeans have already found difficulties even in determining the percentage of locally produced content in some goods, and recently lost a key anti-dumping case before a GATT tribunal, partly over this issue.[20] Qualitative judgments are even more difficult. The combination could threaten the viability of the GATT in the future..

Finally, the complexity is compounded by the different definitional contexts. Definitions that may be appropriate for controlling foreign direct investment may not be useful when qualifying firms for direct government support, or R&D contracts.

Despite the difficulties, nations have found ways in which to discriminate on the basis of corporate nationality. The EC is funding a number of R&D consortia. It appears that a two-tier system of discrimination maybe evolving: firms which are foreign-owned but which act as good corporate citizens (developing a fully integrated manufacturing complex with the EC, even exporting back to their country of ownership) appear to have better access to government support than foreign-owned firms which are not such good citizens. The best government support may be reserved for firms which are not foreign-owned-even though the explicit authority for such discrimination is sometimes hard to find. So far, decisions have been made case-by-case.

Advanced TV is clearly a case where the United States must play catch-up if it is to be in the game. All but one U.S.-owned company have left the business of making televisions, and the remaining company is not financially strong. The questions are whether and how to support an industry that is practically nonexistent, and where foreign producers are clearly ahead. In the past, countries that have succeeded in doing this have relied heavily on protection from foreign competitors—in the case of Japan, protection of domestic markets not just against imports, but in many cases from foreign direct investment as well. In Europe, which is also playing catch-up with the United States and Japan in a number of industries, the inclination against foreign firms' participation is less pervasive, especially in some countries. American and Japanese firms have been permitted to participate in some

[18] In Reich's article, Todd Hixon and Ranch Kimball distinguish between importers, simple screw-driver assembly (like the plants that make most consumer electronics products in the United States), plant complexes (which produce and even modify existing designs, but do not provide a full line of R&D in support of new ones), and fully integrated business operations; the latter is a relatively undefined concept which stresses tight integration of basic research, development design, and production. Reich, op.cit., footnote 14.

[19] Hearings before the House Subcommittee on Science, Research and Technology, Committee on Science, Space, and Technology, and the House Subcommittee in International Scientific Cooperation Committee on Science, Space, and Technology,"What is a U.S. Company?" Nov. 1, 1989.

[20] William Dullforce, "JapanScores Victory overEC onDuties," *Financial Times, Mar. 29,* 1990; Peter Montagnon and Lucy Kellaway, "ECRefuses To Adopt GATT Report on Dumping, " *Financial Times,* Apr. 41990.

EC-funded R&D programs, and foreign investment is now encouraged, especially in industries like electronics and motor vehicles. Nonetheless, domestically owned firms still seem to be favored for access to government-and EC-funded programs aimed at hastening technical development.

The European and American governments face different problems in HDTV; Europe still has a domestic, European-owned consumer electronics manufacturing industry. There are companies that produce televisions, many of them with production and even research facilities in the United States. Most are foreign-owned. Sony, Philips N. A., and Thomson are involved in ATV, and would probably be willing and able to take advantage of any govemment-supported program to foster HRS technology development. Once again, that raises the question of what criteria the U.S. Government would establish to determine the participation of companies.

The interests of firms and the interests of nations are not always the same. American firms, like European and Japanese firms, are increasingly likely to be involved in a variety of international cooperative agreements with other fins. Multinational firms have many choices of where they will perform R&D and manufacturing. Right now, the United States is not an attractive location for developing and manufacturing televisions and other consumer electronics products, except for foreign-owned firms with external sources of capital and other advantages stemming from foreign bases of operation. To generate interest among domestic firms in reentering the business of developing and making televisions, the government probably will need to change the rules for operating here, including altering the capital and investment market for manufacturing in the United States.

In the long run, the most promising way of assuring that domestic efforts to support any new technology will result in domestic value added, is to make the United States a more attractive location for manufacturing. The United States now has disadvantages in cost compared with many developing nations, and disadvantages in its financial environment and quality of human resources compared with many advanced nations, including Japan and much of the EC. In addition, the EC and Japan, among others, have substantial government programs to support new technology development and diffusion of manufacturing technology. The United States compares poorly here, too. Improvements in these areas will help to ensure that any government support of new technologies or infant industries are more likely to lead to domestic development and manufacturing.

NATIONAL SECURITY

High Resolution Systems (HRS) and related technologies are likely to play an important role in future military systems—analyzing the battlefield, targetting the enemy, or parrying the enemy's attack could all benefit from high-quality, real-time video information (see box l-l). HRS technologies will, however, probably be driven primarily by the needs of the commercial sector.

The defense strategy of the United States has long relied on technologically superior weapons to overcome numerically superior foes. Electronic technologies are a critical element in this strategy. The broad loss of U.S. leadership in semiconductor and other electronics technologies, particularly in their manufacture, raises significant concerns for U.S. defense capabilities in the future.[21]

Dependence on foreign-sourced technologies generates risks to the U.S. defense posture: supply lines might be disrupted during a crisis;

[21] Office of the Under Secretary of Defense for Acquisition "Report of Defense Science Board Task Force on Defense Semiconductor Dependency, February 1987; U.S. Congress, Office of Technology Assessment, *The Defense Technology Base: Introduction and Overview,* OTA-ISC-374 (Washington, DC: U.S. Government PrintingOffice, March 1988); U.S. Congress, Office of Technology Assessment *Holding the Edge: Maintaining the Defense Technology Base,* OTA-ISC-420 (Washington, DC: U.S. Government Printing Office, April 1989).

a supplier might withhold critical components due to pressure from adversaries; or an adversary might gain access to critical technologies more easily if they are foreign- rather than U. S.-sourced. For example, the Soviet Union was able to purchase a sophisticated milling machine from Toshiba (Japan) and Kongsberg (Norway) in 1987. This technology enabled the Soviets to construct much quieter propellers for their submarines and has thus greatly reduced their detectability.

Foreign suppliers might also judge their commercial interests as more important than U.S. security interests. For example, they might withhold state-of-the-art technologies that the United States needs for defense applications in order to gain a commercial edge. Such withholding may already occur in the commercial sector for semiconductor manufacturing equipment and certain computer chips, among others.

On the other hand, the performance attainable by U.S. weapon systems maybe reduced in the absence of the best available technology, some of which is commercially available from our allies. It may also be more expensive to procure systems solely from domestic sources rather than from lower cost foreign sources.

The defense market is no longer large enough to drive the development of many electronics technologies. In 1987, the Defense Science Board Task Force on Semiconductor Dependency found that, in contrast to the 1950s and 1960s, DoD procurement of semiconductors was too small compared to civilian markets to be of much importance to the overall semiconductor industry: It concluded, however, that a healthy semiconductor industry was critical to national defense. Defense applications may also lag far behind the state-of-the-art due to the long procurement times. The same point could be made about many other electronics technologies, from components to computers, and is likely to be the case for HRS technologies as well.

The Defense Advanced Research Projects Agency (DARPA) is supporting generic R&D in HRS displays and display electronics (ch. 2), but it will not be able to leverage more than a small fraction of the R&D that would be conducted by a viable civilian HDTV/HRS industry. Further, DoD and DARPA do not have the legislative authority to directly promote a civilian HDTV/HRS industry.

A strong civilian HRS technology base is necessary if many HRS technologies are to be available for defense needs at all. The low costs realized for HRS technologies in the commercial sector, however, will not be automatically translated into low-cost HRS for defense applications. The complexity and specialized nature of defense systems results in long product cycles, high R&D and engineering costs, and stringent performance and reliability criteria that may have little relationship to commercial needs—such as for electronics that can withstand high levels of radiation. Further engineering development of commercially ‘available components is often necessary; and even when commercial components can be used, they are often just a small fraction of the total system cost. Byzantine procurement practices also keep costs high.[22]

THE COMMUNICATIONS INFRASTRUCTURE

HDTV could involve much of the U.S. communications infrastructure-terrestrial, cable, and satellite broadcasting; mobile communications; and potentially even the telephone companies. The current terrestrial broadcast spectrum allocation and transmission standards have been in place for nearly 40 years. Accommodating the larger information content of an HDTV-quality picture could force changes in the frequency allocation and more efficient use of the spectrum. These changes would also have conversion costs and create competitive tensions among the media. HDTV opens new opportuni-

[22] "Special Issue: The Price for Might," *IEEE Spectrum,* November 1988; U.S. Congress, Office of Technology Assessment, *Holding the Edge: Maintaining the Defense Technology Base,* op. cit., footnote 21.

ties to develop standards and systems that allow for an easy and flexible transition to future communications systems such as interactive high-resolution video on optical fiber.

Recorded Media

HDTV might be first introduced into the U.S. market through recorded media such as HD-VCR tapes, which are not subject to FCC regulation. The sale of HDTV-quality videotapes and associated consumer electronics equipment might create a market that would then define a de facto standard for all U.S. media, whether optimal or not.

HD-VCRs may not require data compression to the extent needed for terrestrial broadcasting. This would allow HD-VCR producers to set higher quality standards than might be practical for terrestrial broadcasters or cable operators. In the longer term, wider bandwidths might continue to provide HD-VCRs or other recorded media a competitive advantage over broadcast media+ able, terrestrial, satellite—for certain types of programming.

Terrestrial Broadcasters

HDTV could dramatically impact terrestrial broadcasting. A 1988 FCC study found that with the current geographical limits and channel separation requirements,[23] increasing the TV channel width 50 percent (several of the HDTV proposals would require greater bandwidth than this) might force a quarter of today's TV stations off the air.[24]

Policymakers could use the introduction of HDTV as an opportunity to reexamine the entire question of spectrum allocation for the first time since the current system was defined in 1952.[25] The standards and frequency allocations made in the early days of TV broadcasting were intended to keep the cost of receivers within reach of the mass market by using then current technology. There was little need then to conserve the spectrum.

Technological advances since 1952 allow more efficient use of the spectrum at little additional cost, permitting more channels of higher quality to be packed into less space. The spectrum saved can be used for other services, such as mobile communications.[26]

The FCC could choose an *augmentation* policy that would minimize the impact HDTV technologies have on spectrum use. Existing broadcasters would be granted a 3- or 6-MHz chunk of spectrum—most likely one of the ''taboo channels' (one left vacant by regulation to reduce interference between local stations)—in addition to their existing 6-MHz NTSC channel in order to transmit the added information that HDTV needs to create a high-quality picture. If a taboo channel was unavailable, then a noncontiguous charnel would be used. The wider the frequency separation between the main NTSC channel and the augmentation channel, the more likely they would suffer different types and amounts of distortion—making it difficult to meld the two signals seamlessly into one picture.

Systems that augment NTSC broadcasts would tend to lock in the same inefficiencies of the NTSC technology that currently hamper the industry (ch. 4). This might prevent the development of additional broadcast TV channels or prevent other uses of this spectrum.

---

[23] Geographic limits require roughly 50 mile separation if the stations are transmitting over adjacent channels, 150 to 200 miles separation if transmitting over the same channel. UHF charnel separation is typically one blank channel between active stations in the same geographiarea; and five blank channels between active stations in the same geographic area for VHF. Channel separation requirements are given in more detail in 47 CFR 73.609; 47 CFR 73.610.

[24] "A High-Tech, High Stakes HDTV Gamble," *Editorial Research Reports,* vol. 1, No. 7, 1989.

[25] Sixth Report and Order, Television Allocations, 41 FCC 167 (1952). The NTIA has begun a major project to reassess the allocation Of radio frequency spectrum. Kathleen Killette, "New NTIA Chief Tackles Agenda,'' *Multichannel News,* Aug. 28, 1989, p. 34.

[26] Dale N. Hatfield and Gene G. Ax, ''The Opportunity Costs of Spectrum Allocated to Hi@ Definition Television,'' paper presented at the 16th annual Arlie House Telecommunications Policy Research Conference, Arlie, VA, Oct. 30, 1988.

A *simulcast* policy would have a much greater long-term impact than augmentation, depending on how it was implemented. The simulcast signals would not have to be compatible with existing NTSC standards and would require few if any taboo channels; a new set of standards could be adopted for them that would permit closer spacing of the new stations' channel assignments. As the penetration of HDTV sets increased, the NTSC stations might be phased out and the freed spectrum used for: 1) a next generation of even higher quality video broadcasting technology; 2) additional new TV stations; or 3) mobile communications or other services.

Cable Television

The possibly wider bandwidth of HDTV broadcasts might require cable operators to use more fiber-optic technology or perhaps lease portions of the telephone companies' fiber-optic networks. Cable operators may also consider using DBS to supplement cable systems.

A system using a cable company's coaxial cable and a telephone company's twisted copper pairs might be able to provide a reasonable level of interactive video services in the midterm (ch. 3). Existing coaxial systems can provide HDTV-quality programming, particularly when strengthened with a fiber optic backbone. Existing twisted copper pairs of the telephone network will be able to provide a data rate sufficient for most information services-but not moderate-to high-definition real-time video-within the planned upgrades to the N-ISDN level of service.

Direct Broadcast Satellites

Direct Broadcast Satellites use frequencies too high to be of practical use to earthbound broadcasters; there is a relatively broad range of frequencies available; and satellite broadcasters have not yet developed strong vested interests in a particular allocation of these radio frequency bands although competition for geosynchronous orbital space is keen. It is therefore easier to adjust the satellite transmission system to meet the demands of HDTV. A partnership was recently formed in the United States to establish a DBS system by as early as 1993.[27] Some analysts believe that a DBS system could ''cherry-pick' the most lucrative HDTV opportunities and poses a formidable threat to cable-based or other delivery systems.[28]

Mobile Communications

The potential benefits of using additional spectrum for HDTV broadcasting must be balanced against the benefits of using portions of the TV spectrum for other purposes such as mobile communications. Due to the physics of radio wave propagation in the atmosphere, the most desirable frequencies for mobile communications are the same as those now used for TV. When the current TV broadcasting system was put into place and the channels allocated in the 1940s and early 1950s, there was no competition for these frequencies from alternative uses; nor did alternative distribution systems for TV—such as cable or satellite—exist. Today, there are many alternate means for distributing TV; the choices for mobile communications are more limited.

HDTV could have an enormous impact on mobile communications such as cellular telephone, paging services, and related systems. More spectrum might be made available for these services during the transition to HDTV if simulcast standards are used and charnels are repacked. In the longer term, additional spectrum might also become available if terrestrial broadcasters were unable to provide as high-quality pictures as competitors-which could cause their viewing audience to shift to alternative services and allow these frequencies to be reallocated to other uses.

Additional spectrum for land mobile services could help reduce future congestion on mobile

[27] John Burgess, "Satellite Partnership Plans Pay-TV System,'' *Washington Post*, Feb. 22, 1990, p. El.

[28] David Rosen, "The Market for Broadband Services via Fiber to the Home," *Telematics*, *vol.* 6, No. 5, May 1989.

frequencies, particularly during rush hours in cities like Los Angeles, New York, and Washington, D.C. Spectrum and digital radio technologies might allow economical and portable personal communications to be made available to most individuals. With sufficient spectrum, cellular systems might someday compete effectively with local telephone companies wire-line systems.[29] Rates for telephone services might then be left to the competitive market the way that cellular rates are now.

To develop awidely available personal communications network, however, will require more spectrum than is currently available. Although the United States is still a leader in mobile communications technologies, it could falter unless the industry can gain similar access to spectrum and, correspondingly, achieve similar market scales as its competitors in foreign markets.

Telephone Companies

Twisted copper-pair will continue to be the predominant medium in the local loop for the next 10 to 20 years. With the transition to N-ISDN (ch. 3), the existing copper-pair network will be able to handle most information needs, including voice, data, and even some low- to moderate-quality video. Over the mid-term, mixed telephone/copper pair and cable TV/coaxial cable networks might provide a medium level of interactive information services: cable could provide a high flow of information (hundreds of Mbps), including high-quality video, from a central location to the home; and copper pairs could transmit data at a rate of 1.5 Mbps (two pair) from the home to any other point desired through the switched network of the public phone system.

Fiber is likely to be the medium of choice throughout the cable and telephone networks in the longer term. Inserting fiber in the cable backbone as a first step significantly improves cable capacity and performance for a relatively small investment. In contrast, although telephone companies can replace their backbones for roughly the same cost as cable companies, the copper pairs in the local telephone loop to the home do not have sufficient capacity to deliver a high-definition signal.

Cable systems cannot easily be adapted to provide high-capacity switched two-way communications such as the public phone system does. Regulatory and financial structures may hamper a move to such a system.[30] An important question confronting policymakers is whether a mixed cable/telephone network is an important intermediate step toward a national two-way broadband network or an evolutionary dead-end. If the former, changes in the regulatory environment to aid this transition would be necessary; if the latter, means of encouraging a direct transition to a national broadband network must be considered.

Market Share

Terrestrial broadcasters (as do all spectrum users) have limited spectrum available to them; in turn, this limits the quality of the pictures they are able to deliver to viewers. If terrestrial broadcasters cannot deliver pictures of as high quality as cable or DBS broadcasters, they may lose market share. Because of this, many U.S. terrestrial broadcasters want a single uniform transmission standard applied to all broadcast media—terrestrial, cable, DBS, VCRs—to limit all media to the same technical capability as terrestrial broadcasters.

Conversely, many of the competing media look to HDTV as an opportunity for them to capture market share from terrestrial broadcasters by use of their greater technical potential and flexibility to transmit high-quality HDTV to the consumer. Terrestrial broadcasters have little to gain and a lot to lose in such a contest: they currently have between 54 and 59 percent of the

[29] Hatfield and AX, op. cit., footnote 26.

[30] Bruce L. Egan and Douglas A. Conn, "Capital Budgeting Alternatives For Residential Broadband Networks," Center for Telecommunications and Information Studies, Columbia University, 1989.

television audience, and TV households watch programs more than 7 hours/day .31

There is more at stake in the contest for market share among the various media than simply profits: it could overturn the traditional roles that these media have played in serving the public. Broadcast TV is a central cultural focus in American life, providing a shared experience and information for all. Over-the-air broadcasters are the only ones to be required by a statutory obligation to serve local audiences—providing news, local election coverage, public announcements, and community affairs. Similarly, public broadcasting stations are major providers of educational programming. Because of these roles and the lack of similar regulatory demands on alternative media, there is concern that if broadcasters are unable to provide the same quality service as alternative media, these services could be lost. While market forces will ensure the provision of acceptable TV programming, Congress may need to take steps to ensure comparable services—news, community affairs, etc.—will be fully and equitably provided to the public by each medium.

costs

The costs of upgrading to HDTV for program producers, broadcasters, and consumers could be substantial, depending on the standard chosen. Program producers will need to convert existing studio equipment to video HDTV production equipment, but this may reduce production costs by eliminating delays in processing film and by facilitating editing and incorporation of special effects in the production process.

Estimates of the cost of upgrading terrestrial broadcaster's NTSC equipment to HDTV capability range from $7.4 million to $40 million.[32] A simulcast system might cost less than one using augmentation channels, because much of the existing transmission equipment could be used (except for the digital coding, and it would not necessarily require new wide-band equipment) and the transmission power requirements would be much less.[33]

Costs for cable companies may be less. The FCC Advisory Committee has estimated that the extra cost of introducing 12 channels of HDTV programming on a sample cable system serving 100,000 subscribers would be about $1.9 million.[34]

Consumers, too, may find HDTV receivers more expensive than the set they use now. By upgrading to HDTV at the time they would normally replace their old set, these costs could be blunted somewhat.

Finally, if the HDTV system is more spectrum efficient, these costs must be weighed against the benefits of freeing valuable spectrum for other uses. Consumers cannot make this trade-off, however; policymakers must.

The chicken-and-egg problem of who invests first might only be resolved by all acting in concert. Color TV was successfully introduced only through the patience and enormous investment—some $3 billion in 1988 dollars-of RCA.[35] A similar risk will have to be borne to launch HDTV. On the other hand, UHF broadcasting was made possible by government action through the "All Channel Receiver Law" which requires all TV sets sold in the

[31] A.C. Nielson Co., personal communication October 1989.

[32] FCC ATV Advisory Committee, Systems Subcommittee, Working Party 3, *Terrestrial* Specialist Group 1, "Interim Report," table 1, Apr. 10,1989. The Boston Consulting Group, "Development of a U.S. Based ATV Industry,' Preliminary Report prepared for the American Electronics Association 1989, p. 22.

[33] Howard Miller, "The Simulcast Strategy for HDTV," *PBS*, 1989.

[34] FCC ATV Advisory Committee, op. cit., footnote 32, attachment E, table 2; and Boston Consulting Group, op. cit., footnote 32.

[35] U.S. Congress, House Subcommittee on Telecommunications and Finance, Committee on Energy and Commerce, *Consortia and the Development of High Definition Systems*, testimony presented by Barry Whalen, Sept. 13, 1988.

United States to have both VHF and UHF tuners.[36] This prevented manufacturers from cutting costs by eliminating the UHF tuner—thus raising costs to' consumers slightly-but over time allowed the development of a sufficient market so that UHF broadcasting could be successfully launched.

THE STANDARDS-SETTING PROCESS

Standards can reduce or prevent confusion in the marketplace. Standards allow manufacturers to increase production efficiency by producing in large volumes for a uniform market; they can stimulate competition; and they reassure consumers that whichever brand of HDTV they buy or wherever they use it in the United States, it will be able to receive and display the local broadcasts.

These lessons have been hard learned. After unsuccessful attempts to set AM stereo radio standards, for example, the FCC left the decision to the ''marketplace' in 1982.[37] Several incompatible systems then began to be adopted; this increased consumer, broadcaster, and manufacturer confusion. As a result, AM stereo broadcasting is growing very slowly, and AM radio generally is losing market share to FM radio.

Standards sometimes have drawbacks as well. When a technology is rapidly changing, standards can lock in an obsolete technology; standards can limit choice; and if poorly designed yet widely used, standards can slow innovation.[38] A good example might be the QWERTY typewriter. Designed in the late 1800s, the QWERTY layout was intended to limit typing speeds; the mechanical systems then available could not otherwise keep up with a fast typist and tended to jam. Since then, however, this keyboard has proven impossible to dislodge despite its widely acknowledged shortcomings.

Standards have also been used to promote national political and/or commercial interests. Rather than using the U.S. NTSC system, France developed and adopted its own color TV standard, SECAM, in the early 1960s in order to protect its color TV industry during the developmental stages. By 1976, the French TV industry accounted for roughly 0.5 percent of the French GNP.[39] Similarly, patents on the German color TV system, PAL, were used to help exclude non-European manufacturers from the European market.[40]

In the United States, technical standards for domestic communication technologies are currently handled almost exclusively by the FCC. Not only has Congress granted the agency virtually sole jurisdiction over broadcasting standards,[41] but the courts have also recognized that its legislative authority permits the agency to preempt conflicting State or local regulations of technical standards in telephone[42] or cable television.[43] Where the courts have found that national uniformity is important to foster interstate commerce, they have prevented States from establishing differing standards.

[36] 47 CFR Section 15.65.

[37] Stanley M. Besen and Leland L. Johnson, *Compatibility Standards, Competition, and Innovation in the Broadcasting Industry* (SW@ Monica, CA: Rand Corp., November 1986). Note that the FCC faced several difficulties in setting this standard, including incomplete information on the performance of different systems, conflicting test data or data that was gathered under differing conditions, and fierce opposition from the firms that would have lost had the tentative FCC findings been formalized.

[38] David Hack, Library of Congress, Congressional Research Service, "Telecommunications and Information Systems Standardization-Is America Ready," 87-458 SPR, May 21, 1987.

[39] Rhonda J. Crane, *The Politics of International Standards: France and the Color TV War* (Norwood, NJ: Ablex Publishing Corp., 1979).

[40] Trade policy may have played a more important role in keeping imports out.

[41] *See, e.g., Gagliardo* v. *United States,* 366 F.2d 720, 723 (9th Cir. 1966).

[42] *North Carolina Utilities Commission v. FCC*, 537 F.2d 787 (4th Cir. 1976) upholding the FCC's standards for customer premises equipment (CPE).

[43] *City of New York v. FCC*, 108 S.Ct. 1637 (1988).

The manner in which the FCC administers this power can have a significant impact on many areas of telecommunications; thus the nature of the ATV standards-setting process could strongly influence who benefits and who loses from those decisions. Four aspects of the process appear to have particularly important impacts within the United States itself: 1) how much discretion is delegated to the marketplace; 2) how fast the process is pushed; 3) whether all serious proposals are fully considered; and 4) whether the process permits the selection of a standard that combines aspects of different proposals. An important related issue is U.S. participation in international standards fora; this complex issue will be discussed elsewhere.

Standards Setting and Marketplace Participants

Ideally, the participants in a market would reach a consensus on the best standards to adopt for a particular product, that maximizes their profits at the same time that they maximize the attractiveness of the product to the public. Private sector firms have the technical expertise and the best knowledge of the markets; and they are financially accountable for their errors. The marketplace, however, provides many incentives for firms to establish standards unrelated to social benefit.

The FCC Advisory Committee on Advanced Television Services provides a mechanism for the direct input of private firm expertise. This advisory committee is voluntary and open to all who wish to participate. Most of those who currently participate represent manufacturing or media interests—they can't afford not to participate. In contrast, representatives of labor and consumer interests face difficulties in participating.

Private sector firms directly influence the standards-setting process by providing regular and extensive technical staff participation to the committee; by conducting independent and/or supporting studies; and by widely distributing technical documentation. These are potentially valuable inputs and are incorporated in FCC decisionmaking. Yet there is also the potential for abuse. Large firms may be able to fund more staff participation and technical inputs than those with limited resources. This can bias the process.

Foreign TV manufacturers, for example, may be able to channel much greater resources into the standards-setting process than U.S. TV manufacturers, since they now dominate the U.S. television market. The standards promoted by foreign manufacturers will not necessarily represent U.S. national interests in developing domestic communications infrastructure; these standards almost certainly do not represent U.S. national interests in encouraging additional U.S. firms to reenter ATV manufacturing. Foreign governments often do not allow reciprocal access by U.S. firms to their standards-setting processes for similar reasons.

U.S. broadcasters might oppose standards that would make it easier for the FCC to reallocate portions of terrestrial broadcasting spectrum to other purposes in the future, regardless of the long-term interests of the public in mobile communications or other services.

Finally, if market participants are unable to reach a consensus on a single choice, there is danger that multiple and incompatible standards could result. This could raise uncertainty among manufacturers and consumers and hinder the introduction of ATV.

The Timetable for Establishing Standards

In responding to the array of issues raised by HDTV there are two conflicting time pressures: 1) taking the necessary time to establish a flexible standard that can support the rapidly changing technologies and needs for the next several decades; and 2) setting standards quickly enough that the U.S. market can grow in parallel with those in Europe and Japan, thus providing U.S. producers similar opportunities for realizing economies of scale and learning in production.

If the United States acts precipitously and establishes standards prematurely, the ATV

30-368 - 90 - 2 : QL 3

equipment produced under those standards might quickly become obsolete, the Nation might have to endure with inferior technology, or have excessive difficulties in making the transition to future generations of equipment.

Alternatively, if potential U.S. entrants wait for a national fiber system, for example, before entering the ATV market, they could wait 20 years or more. During that time, foreign competitors would have the opportunity to further strengthen their manufacturing capabilities and distribution systems, and would receive enormous revenues for conducting R&D into new technologies. If additional U.S.-owned or U.S.-based firms are to enter these markets, there is no substitute for getting in quickly and gaining intense day-to-day manufacturing experience.

Providing Full Opportunities for All Serious Proponents

Without some minimum threshold for those seeking to establish ATV standards, the FCC could be subject to numerous quack proposals submitted in the misguided hope of winning a standards ''lottery. '' Indeed, at least one of the proposals submitted on paper was believed to ''challenge the known laws of information theory. '[44] The FCC Advisory Committee currently requires standards proponents to submit a fully developed set of broadcasting and reception hardware to the Advanced TV Test Center (ATTC) for testing;[45] and the ATTC in turn requires the proponent to post a $200,000 bond to hold a time slot for testing their system (this bond can be waived). On its face, this makes sense. The FCC should not spend government money to develop and test a private group's system, particularly if all the royalties go to that private group.

On the other hand, designing and building a complete set of hardware can cost several million dollars; buying test equipment to debug the hardware before presenting it to the ATTC can cost millions more. Even fairly large firms, such as Zenith, are straining to find the manpower and financial resources to meet these demands. It is not surprising, then, that other U.S. proponents, who are generally small, entrepreneurial or university-based efforts, are having even greater problems. Of the more than 20 standards proposals submitted to the FCC, only 5 or 6 appear likely to be developed into hardware at this time due in part to the lack of financial resources. Several of these are of EDTV-rather than of HDTV-quality and all but one or two are sponsored by foreign-based manufacturers. Even the FCC Advisory Committee has obliquely noted this problem.[46]

It is not entirely clear why the U.S. capital markets have failed to provide the necessary financing, but they have not. If financial support is not forthcoming there is the risk that a foreign-owned standard will be selected and potentially hundreds of millions of dollars in license royalties will flow to that entity, despite the possibility of a superior U.S.-owned system that could not be considered for lack of a few million dollars in timely funding.

This early focus on hardware may also be counterproductive for other reasons. Today, complex systems are always simulated on a computer before they are produced. For HDTV this is particularly important because many of the improvements in hardware that can be expected in coming years should be assessed, but the technologies themselves are not and will not be available for years. For example, it may be useful to develop a broader set of standards that allows for the gradual upgrading of ATV to

[44]FCC Advisory Committee on ATV, Systems Subcommittee, ''Interim Report, '' Apr. 10, 1989, SS/WPI Interim Progress Report, Feb. 12, 1989.

[45]Richard E. Wiley, ''Second Interim Report of the FCC Advisory Committee on Advanced Television Service,'' Apr. 26, 1989.

@'FCC Advisory Committee on Advanced Television Service,' Systems Subcommittee,"InterimRepO%" Apr. 10, 1989; "AnAssessment of the ATV Systems and Technologies Presented at the Nov. 14-18 Meeting of SS/WPI,'' p. 3.''MIT has provided outstanding technical information ranging from technical papers on psychophysical aspects of television to ATV system proposals. At the "marathon" meeting MIT presented very interesting results from computer simulation studies onATV transmission in low quality analog channels . . . [but] MIT. . . . has declined to submit hardware for testing."

a fiber system, or that can handle the differing requirements of commercial or industrial users.

The standards process is already falling behind schedule. This is due, in part, to the rapid evolution of the technology and the difficulty of developing a broadcast standard for HDTV—which many groups are beginning to more fully appreciate. Ultimately, of course, any proposed standard must be proven in full-scale tests with real hardware before it can be formally adopted. Full-scale manufacturing and marketing will require a firm with enormous financial resources and skilled manpower.

Hybrid Standards

The current requirement that proponents provide their own hardware combined with the FCC's limited technical and financial resources for designing and testing ATV systems may hinder the synthesis of a standard from the best features of several proposals. Proponents of particular standards might also object to such a synthesis, gambling instead for their proposal to be chosen exclusively.

In Europe and Japan the governments have maintained extensive staff experience through their national telecommunications services and broadcasting organizations. Raising the level of technical manpower and financial resources within the FCC and possibly utilizing the expertise within universities and National Laboratories, including the U.S. Department of Commerce's National Institute of Science and Technology (NIST), might enable the government to play a greater role in protecting U.S. national interests and reduce U.S. reliance on foreign industry groups with potentially conflicting agendas.

Alternatively, a small elite group of industry and university technical experts might be formed and funded to work together, or in parallel, to synthesize the best possible standard from the numerous competing proposals. A corresponding patent pool might be formed with appropriate safeguards for the interests of the individuals and companies involved and to pay back the government its investment from royalties. Some portion of these patent pool royalties might also be used to fund R&D in video entertainment technologies, ranging from camera to broadcasting to receiver display technologies.

Royalties to RCA similarly supported a significant fraction of the R&D in consumer electronics done in the United States. RCA was established by GE, Westinghouse, and AT&Tin 1919 at the request of high U.S. Government officials (including the Acting Secretary of the Navy, Franklin D. Roosevelt) who wished to prevent foreign domination of the growing transatlantic communications services.[47]

[47] Undersea cables were already under foreign (if friendly) control. In contrast, the 'wireless" stations of British owned American Marconi Company had been held by the U.S. Government during WWI for wartime purposes. Rather than return these stations to foreign control, RCA was formed and these stations were transferred to it in 1920. RCA Corp. "RCA: Unhistorical Perspective," 1978. For a discussion of the development and fate of RCA, See: "The U.S. Television Set Market, Prewar to 1970"; Donald Christiansen, "A Stirring Giant,'' *IEEE Spectrum,* February 1986; Nhora Cortes-Comerer, "A Venerable Giant Sharpens its Claws," *IEEE Spectrum,* February 1986; Herb Brody, "Picking Up The Pieces of RCA," *High Technology Business, May 1988.*