

The Consumer-Electronics Industry in the United States: Its Decline and Future Revival

High-definition television may be the vehicle by which to reverse the decline of U.S. participation in consumer-electronics markets, but a new set of government policies and business strategies is vital to successful reentry into that market.

In an analysis of the consumer-electronics industry, three major questions arise. Why did U.S.-based manufacturing in consumer electronics decline so rapidly in the 1960s and 1970s? Has the rapid decline of U.S. consumer electronics hurt the competitiveness of other branches of the electronics industry? Will there be opportunities for reentry into consumer-electronics markets by U.S. manufacturers in the future? The first question can be answered in terms of U.S. responses to international competition in two important high-volume consumer-electronics markets: color televisions and video cassette recorders (VCRs).¹ The answer to the second question derives from the impact of competitive decline in consumer electronics on electronic components industries, particularly the manufacture of semiconductors and displays. The third question requires consideration of emerging markets for high-definition television (HDTV).

The Rapid Decline of the U.S. Television Industry

The U.S. television industry, which led the world into the television age, is now only a remnant of its former self. At the beginning of the 1950s, there were 140 firms in the industry, only fifty remained by 1956, twenty-seven by 1960, and five by 1980.² The number of workers in the industry declined from a high of 100,000 in 1966 to 33,000 in 1984.³ As of 1986, only two U.S.-owned firms, Zenith and RCA, manufactured TVs in the United States. In 1987, RCA's TV manufacturing facilities were acquired by General Electric (GE) and then sold in January 1988 to Thomson, a French firm. In the late 1980s, Zenith operated its TV manufacturing at a loss; low prices rendered making money on TVs impossible. Thomson suffered financial losses in the U.S. market for the same reason.

Some of the relative decline of the U.S. television industry, particularly in lower-priced TVs, can be attributed to increased production in low-wage developing countries. But the world leader in consumer-electronics production, including televisions, is now Japan. Of the top ten firms producing color TVs in the early 1980s, five were Japanese.⁴ Japan's share of global consumer-electronics production in 1988 was 36 percent; the United States' share was only 6.7 percent.⁵

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Japanese Production and Marketing Strategies

The success of Japanese TVs in world markets is the result of intelligent technological and marketing strategies on the part of Japanese firms, along with predatory pricing (documented in a series of successful but unenforced antidumping petitions).⁶ Of primary importance was the early replacement of tubes with semiconductors in Japanese products. Sony Corporation sold the first all-transistor monochrome TV in 1959, and soon after all the larger Japanese electronics firms (Matsushita, Mitsubishi, Hitachi, Toshiba, and Sanyo) introduced transistorized monochrome receivers. A U.S. manufacturer, Motorola, developed the first prototype solid-state color television in 1966, but Hitachi was the first to produce a commercial solid-state color TV in 1969. By 1970, 90 percent of all color TVs produced in Japan were solid-state.⁷

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Japanese firms began to market TVs in the United States in the early 1960s but confined themselves mainly to smaller units (less than 19-inch screens), which they sold through department stores or large electronics retailers rather than through licensed distributors. At first these sets sold because they were simply cheaper than their U.S.-made counterparts. They used tubes, and the circuit designs were inferior to those of U.S. products. But the Japanese were quick to replace tubes, first with transistors, then with integrated circuits, while they continuously improved circuit designs. As large-scale, integrated (LSI) circuit technology allowed semiconductor manufacturers to put more transistors on a single device, Japanese TV producers were able to reduce the parts counts in TV sets substantially.

Not only did Japanese TV producers reduce the parts counts faster than U.S. firms due to the rapid introduction of semiconductors, but also they were faster in automating assembly of circuit boards. Tube technology, because of the fragility of the components and the importance of hand-wiring to assure quality control, required considerable labor-intensive work. Semiconductor technology was more amenable to automation of assembly, but the key to automation was to develop devices for automatically aligning and inserting semiconductor components on circuit boards.

Automated insertion equipment was pioneered by Japanese firms in the late 1960s. The first generation of such manually controlled equipment was operating by 1968, and a second generation of faster, manually controlled equip-

ment was produced in 1972. Finally, a third generation, about ten times faster than the first generation, allowed for limited numerical or computer control of the insertion process.⁸ This gradual and incremental improvement of insertion equipment provides a parallel with the incremental improvement of semiconductor manufacturing equipment by Japanese firms later in the 1970s.

Because they used semiconductors rather than tubes, Japanese TVs became more reliable and required less maintenance and servicing. During the mid-1970s, for example, U.S.-made color TVs were failing at five times the Japanese rate.⁹ By 1977, the number of faults discovered in production were 1.4 to 2.0 per set in the United States and only .01 to .03 in Japan.¹⁰ The greater reliability and durability of Japanese sets made it possible to sell them widely without building an extensive service network. Thus service networks of U.S. manufacturers were converted from a barrier to entry for foreign firms to a financial liability.

The third key to Japanese competitiveness was their more rapid reduction of the number of circuit boards in TVs. For example, only in the mid-1980s was General Electric able to put the circuitry for its color TVs on a single board, which Japanese firms had been doing since 1976.¹¹ The switch to single-board chassis further reduced the labor time required for assembly.¹²

U.S. Firms Locate New Production Facilities Offshore

In the late 1960s, the main U.S. television manufacturers began to take advantage of the 806.30 and 807.00 provisions of the tariff code to locate production to low-wage countries in Asia and Latin America (mainly in Mexico). All production of monochrome receivers was soon relocated offshore, while production of color receivers remained, for the most part, in the United States. The offshore products were converted more quickly to semiconductor components than the domestic products, and that created expertise in manufacturing transistorized TVs in the wrong places. U.S. firms were overly cautious in incorporating semiconductor technology in color TVs—they doubted that they could obtain the same level of performance with semiconductors that they had already achieved with tubes. But the Japanese firms proved them wrong, and U.S. firms paid a high price for their mistake.

One of the reasons for the slow introduction of automated insertion equipment and the single-board chassis in U.S. manufacturing was the heavy reliance on offshore "board stuffing" operations to keep assembly costs down. The offshore board stuffers, mainly in Mexico and Southeast Asia, were not considered sufficiently reliable for single-board chassis assembly. In addition, the engineers of U.S. firms believed that integrated circuits would not be as reliable as tubes and wished to avoid the high maintenance costs that would be associated with the repair

of a single-board chassis, so they were perhaps overly cautious about reducing the number of circuit boards in sets.

Furthermore, U.S. firms spent more than enough effort in maintaining the distributor networks in the belief that their main customers would continue to demand larger sets with higher quality pictures, which would necessarily require more servicing than their Japanese or Southeast Asian competitors were offering. They believed that consumers did not care about semiconductor componentry as much as they cared about the size and quality of the picture, and they did not believe that semiconductors would be as reliable as tubes.

... U.S. manufacturing declined in consumer electronics [because ...] U.S. management lacked vision, ... focused too much on labor costs and not enough on the incorporation of new technologies. ... failed to see the importance of new components technologies in television, ... failed to see the market potential for VCRs.

U.S. firms, therefore, kept color TV production onshore after they had moved black-and-white TV production offshore. They were slow to introduce semiconductor components and to reduce the number of circuit boards. They were not sufficiently worried about Japanese competition, underestimating the ability of Japanese firms to produce TVs with semiconductor components and to move up from simple black-and-white sets to small color sets and finally to larger color sets. In this respect, U.S. firms resembled their colleagues in the automobile industry who were willing to concede the market for low-priced subcompact vehicles to Japanese competitors in the belief that they would maintain production-cost and distribution advantages in high-priced vehicles. However, Japanese firms quickly applied the lessons they learned in competing in the low-end markets to higher-end products, while U.S. firms were cutting themselves off from this important source of learning.

The Stillbirth of the U.S. Video Recorder Industry

Sales of televisions and VCRs account for more than half of total sales of consumer-electronics equipment in the United States and other large industrialized nations. In 1987, sales of color televisions in the United States were \$6.3 billion; VCRs were \$5.1 billion. Only 230,000 of the 13.3 million VCRs sold in the United States in 1987 were manufactured there. Net imports were valued at over \$3

billion.¹³

Had a few U.S. firms been able to shift their activities from television to VCR production in the 1970s, the consumer-electronics industry might have been able to subsist despite the mistakes made in TV production. The story of the video recorder industry in the United States is sad.¹⁴ One company, Ampex Corporation, owned all of the patents required for producing video recorders and used those patents to dominate the markets for professional video recording equipment (sold mainly to TV broadcasting stations). But it was unable to turn that technological advantage into a commercial one in the vast consumer market for video cassette recorders (VCRs) that arose in the 1980s. The result was that no U.S. firm produced VCRs in the 1980s; instead they marketed products made in Japan. Only RCA continued to design VCRs, but even RCA was unable to manufacture them. The failure of U.S. firms to match Japanese technology in VCRs made it virtually impossible for them to take advantage of the growing video camera and camcorder markets as well.

In 1968, a Vice President of Ampex, Richard J. Elkus, Jr., produced an internal report calling for a strategic shift toward producing a video recorder for the consumer market. He recommended scrapping the development of a new machine, the VR-7700, in favor of a machine he called the "Instacorder" which used 1/2-inch tape, and was compact, easy-to-use, and self-loading. In other words, Elkus proposed that Ampex should build something like a video cassette recorder. The Instavideo project was given the go-ahead by top management, and while the engineers in California and Illinois attempted to create a prototype, Elkus proceeded with a number of business plans for financing and marketing the product.

However, Ampex had difficulties obtaining a Japanese patent for its professional video recorders. Like many U.S. firms in similar circumstances, Ampex was tempted to circumvent its patent and marketing problems in Japan by forming a joint venture with a Japanese firm. The first joint venture, with Sony signed in July 1960, called for Sony to produce a portable version of the Ampex professional recorder in exchange for Japanese production of Ampex recorders for non-broadcast customers. This venture had enjoyed only limited success, especially after Sony introduced a transistorized recorder, the SV-201, in 1961. CEO William Roberts was concerned that Sony was capable of stealing Ampex's technology, so he let the agreement lapse.

In 1964, Ampex and Toshiba formed a joint venture called Toamco. This venture manufactured Ampex-designed professional tape recorders and computer tape units, which were sold by Toshiba in Japan and by Ampex elsewhere. Because Toamco was not doing well financially in the late 1960s, CEO Roberts gave it the task of producing the Instavideo. This decision was governed by concerns over cash and engineering personnel shortages in Ampex,

by the desire to avoid a deal with a U.S. firm that could become a domestic competitor, and by the need to produce a machine compatible with the emerging standard for video recording tape, a 1/2-inch format called the EIAJ-Type 1, which had been pioneered by the Japanese.¹⁵

The first Instavideo machine was demonstrated at the Americana Hotel in New York on September 2, 1970. The machine used an automatic-loading cartridge system—rather than a cassette—with a tape capacity of 60-minutes extended play, compatible with the EIAJ-Type 1 standard, weighed less than 16 pounds and included a monochrome TV camera. The unit with camera was priced at \$1,500, without at \$1,000. The demonstration was a smashing success. Ampex stock increased in value by 45 percent, and the firm was able to use the enthusiasm about its new product announcement to ward off financial difficulties for a few more months.¹⁶

By exiting consumer markets, U.S. electronics firms missed an important opportunity to learn how to implement new production methods for high-volume production of electronic systems.

By the beginning of 1971, however, Toamco was having difficulties producing the Instavideo, while Ampex was experiencing severe financial difficulties. In addition, Matsushita had marketed a cheaper video recorder at about that time, taking some of the luster off the Ampex Instavideo announcement. By the end of 1971, Ampex reported a loss of \$12 million. Its sales of magnetic tape and consumer audio equipment plummeted as cheaper imports came onto the market, and it became overly dependent on debt capital to finance some of its acquisitions. CEO Roberts resigned at the request of the board of managers and was succeeded by Richard Elkus, Sr., who cut back Ampex's expenditures and investments in order to restore the firm to fiscal soundness. Such austerity clearly was necessary; the firm reported a loss of \$90 million in 1972. Unfortunately, one of the projects that was cut was the Instavideo project, and the death of Instavideo ended the probability for any U.S.-owned firm to participate in the breathtaking growth of the home video recorder market.

The inability of Ampex to commercialize its lead in video recorder technology, therefore, was primarily a function of its financial weakness, a result, in turn, of poor management. Ampex made a particularly unfortunate joint venture arrangement with Toshiba which hastened the diffusion of VCR technology to Japan. Apparently, Ampex was approached by Magnavox prior to deciding to go with

the joint venture with Toshiba, but it decided in favor of the Toshiba deal because it thought that the Japanese firm was less likely to become a serious competitor.¹⁷

Larger U.S. firms, such as RCA, GE, or Zenith, did not seem to have the vision to see the future of VCR markets and did not attempt to acquire Ampex or to salvage the Instavideo project by purchasing the VCR technology. (Ampex itself was partly to blame in favoring a Japanese partnership over a U.S. partnership out of fear of being overwhelmed by a U.S. partner.) The subsequent failed efforts of RCA to produce a videodisc system suggest that even by the late 1970s it had not developed a proper understanding of the nature of consumer demand for home videotape systems, and GE did not perceive a great future for its consumer-electronics operations. Thus, Japan's earlier successes in cameras and optical equipment together with its growing strength in VCRs paved the way for success in video cameras and projection TVs in the 1980s.

The Explanation of Decline: A Summary

The answers to why U.S. manufacturing declined in consumer electronics are now clear. U.S. management lacked vision, and their analysis of the Japanese threat in consumer electronics focused too much on labor costs and not enough on the incorporation of new technologies. They failed to see the importance of new components technologies in television, and they failed to see the market potential for VCRs. U.S. television firms tried to circumvent their higher labor costs by manufacturing in low-wage countries. While defensible in the short run, it put the firms on a technological trajectory which was disastrous in the long run.

From the early days of their entry, Japanese firms were engaged in some degree of dumping in U.S. markets. Simultaneously, Japanese markets were closed by high-tariff and non-tariff barriers to U.S. products during this period; no U.S.-owned TV firm was permitted to establish a manufacturing presence in Japan. Even though Japanese trade/investment barriers and weak enforcement of trade laws by the U.S. government speeded the decline of the U.S. industry, greater reliability and lower production costs were the basis for Japanese global competitiveness in consumer electronics. U.S. firms lacked the vision to match Japanese innovations in component and assembly technologies, and the result was that U.S.-owned firms controlled less than 7 percent of world consumer-electronics markets by the late 1980s.

The Importance of the Decline of Consumer Electronics

As noted, the decline of the U.S.-owned television industry hurt the ability of U.S. firms to compete in follow-

on products like VCRs and video cameras. In addition, the loss of the consumer-electronics industry eventually handicapped the U.S. semiconductor industry in its efforts to compete with Japanese firms. Semiconductor producers in the United States were not able to keep up with the state of the art in high-volume composite metal oxide on silicon CMOS process technology, nor were they able to match the developments in optoelectronics (particularly CCDs or charge-coupled devices), liquid crystal displays (LCDs), and consumer-oriented analog circuitry.¹⁸

One important result of the failure of U.S. consumer electronics was the reduction of the proportional importance of consumer demand to total demand for semiconductors. Whereas consumer end-use accounted for more than 40 percent of total consumption of semiconductors in Japan in 1988, it accounted for only 7 percent in the United States.¹⁹ To the extent that the structure of consumption of semiconductors in Japan differs radically from that of the United States, it remains difficult for U.S. firms—which have specialized in products for the computer, telecommunications, industrial and automotive markets—to penetrate Japanese markets. The Japanese firms have used this fact to explain why U.S. penetration of the Japanese market has remained less than 10 percent, despite a 30-40 percent share of the European market.

Current consumer-oriented semiconductors are quite different from semiconductors used in computers, telecommunications, or other end-uses. They tend to involve analog rather than digital circuitry. Digital techniques are increasingly important in consumer electronics, however, so the gap between consumer and non-consumer componentry is rapidly decreasing. Portable consumer-electronics products use integrated circuits which dissipate less electrical power, such as CMOS devices. CMOS-based consumer products, which can be battery-operated, are compact. The Japanese dominance of consumer markets, therefore, has contributed to Japanese dominance of markets for CMOS semiconductors and downstream products, such as laptop computers, which depend heavily on CMOS technology.²⁰

Another example of this technology was the recent growth in demand for hand-held LCD TVs. In 1984, only 32,000 LCD TVs were sold in the United States. By 1986, 771,000 LCD TVs were sold in the United States, all of them imported from Japan. In 1986, Japanese firms produced over 1.7 million LCD TVs. They had been able to lower their learning curves for production of LCDs so quickly that it was difficult for their foreign competitors to enter that market. Because LCDs are used in laptop computers also, it was difficult for many U.S. firms to enter laptop markets successfully—because they would have had to purchase the LCDs from Japanese competitors.²¹

Weakness in consumer production has had other repercussions besides reducing the volume of domestic demand for electronic components like CMOS integrated

circuits and LCDs, however. By exiting consumer markets, U.S. electronics firms missed an important opportunity to learn how to implement new production methods for high-volume production of electronic systems. High-volume consumer-electronics production in Japan has driven innovations not only in automated insertion for assembly of printed circuit boards (as mentioned above) but also in successor technologies like surface-mount technology (SMT), tape-automated bonding (TAB), amorphous and polysilicon processing, and chip-on-glass (COG) technology.²²

Reentry into Consumer-Electronics Markets

Whether U.S. firms should reenter markets for the next generation of consumer products is a major consideration. The case for reentry lies largely with the potential benefits of participation in high-volume electronics markets for next-generation products like high-definition television (HDTV). HDTV will differ from the current generation of TV by combining a sharper picture with a wider screen (16:9 instead of the current 4:3) and compact-disk (CD) quality sound.

Although substantial costs were connected with the exit of U.S. electronics firms from consumer markets, the benefits of participating in consumer markets in the 1950s and 1960s were substantial in terms of economic growth, employment, and technological advancement. These benefits shifted to Japan in the 1970s and 1980s. There is a growing recognition in the United States of the need to reenter high-volume consumer markets. Is HDTV, however, the right vehicle? Since HDTV requires important advances in integrated circuit-and-display technologies and since HDTV signal delivery could help to justify the building of a national broadband fiber network, politically important actors in the United States have tended to say yes.²³

U.S. reentry via HDTV in the context of Japanese domination of global markets is not likely to be easy: the U.S. market is open, whereas the markets of Europe and Asia are not; only one major U.S. firm is in high-volume consumer markets; U.S. consumer circuitry production is weak; and U.S. electronics firms are less vertically integrated than those of Europe and Asia. Two of these main reasons are elaborated below.

The U.S. Market is Open, So Profits Are Low

Prices, and therefore profit margins, in the United States since the 1970s have been notoriously low for all major producers in consumer electronics. Clearly more competition exists in U.S. markets than in either Europe and Japan. Thus U.S. electronics firms exited consumer electronics to concentrate their efforts on computers, telecommunications equipment, and automotive electronics. As a

result, reentry into consumer markets will be difficult. U.S. firms are likely to demand certain guarantees about enforcement of antidumping laws and government support for market-opening initiatives abroad—given their experiences with poor trade law enforcement in the 1970s and 1980s—before they invest their capital in new consumer activities. Major uncertainties connected with new technologies and technological standards will also discourage investment in this area. Thus, the focus of both business strategy and public policy has to be in reducing risk and uncertainty for high-volume production of advanced consumer products in the United States.

Only One Major U.S. Firm Exists

The three largest high-volume consumer-electronics producers in the United States, Thomson, Zenith, and Philips control about 50 percent of the American market for TVs. Thomson is French, Philips is Dutch, Zenith is American. Zenith has been losing money in consumer-electronics markets for a number of years. In order to stay in the television business the company had to sell its more profitable computer business (Zenith Data Systems) to Groupe Bull of France in 1990. More recently, it solicited new investments from a Korean firm, Lucky Goldstar, to ward off a hostile buyout by a New Jersey-based air-conditioner company. It has entered an alliance with AT&T to develop a viable HDTV system for America. If Zenith's HDTV efforts fail to result in renewed profitability in the next 3 to 4 years, the firm will probably be sold or liquidated.

Thomson has many advantages in its competition with Japanese firms: a relatively sheltered home market in Europe; the considerable technological resources of its acquisitions in the United States (the old RCA and GE consumer divisions); and its status as a highly diversified, global corporation with the backing of the French government. The main strength of Philips is its excellent record of innovation in both products and processes. Like Thomson, it has a sheltered home market in Europe and has been intelligent in its overseas acquisitions and international joint ventures. But both Philips and Thomson have been losing money in the last two years and have suffered from heavy competition from Asian firms even in their home markets.

Japanese firms are substantially ahead of both U.S. and European firms in developing HDTV products. Besides Japanese dominance of current consumer-electronics markets, the Japanese government and electronics firms have been working together to develop HDTV technologies and standards. The Japanese HDTV standard, called MUSE or Hi-Vision, has been in place since 1984. Moreover, Japanese firms have developed a broad range of HDTV products, some of which are currently on the market. Neither U.S. nor European firms are as far along in the development or commercialization of HDTV products. Thus, there is

some logic in a joint U.S.-European effort to catch up with Japan. This logic is confounded, to some extent, by the debate over global and regional HDTV standards.

HDTV Standards Debates

HDTV standards will set the framework for competition in the next generation of consumer video products. HDTV standards have been set already in Japan and Europe. The Japanese standard, MUSE or Hi-Vision, is incompatible with the European standard, HD-MAC, but both rely primarily on direct broadcast satellites (DBS) for delivery of HDTV signals. Alternative HDTV standards have been proposed to the Federal Communications Commission (FCC) for the United States, which will begin testing proposed systems in the summer of 1991; its standards process should be completed sometime in 1993. The lateness of standard-setting in the United States is not necessarily a disadvantage, as the United States may select a standard based on more advanced HDTV technologies than those incorporated in Japanese and European HDTV systems. In any case, there is a great likelihood that each major industrial region will become increasingly committed to mutually incompatible HDTV standards.

Definition in television refers to the sharpness or resolution of the picture transmitted and received. One way of measuring resolution is by counting the number of horizontal lines scanned on the video screen. Another is by measuring the vertical and horizontal resolution directly using a test pattern. The latter is, on the whole, a better measure of the sharpness of the actual picture, especially as one moves from analog to digital TV.

The two main standards families in contemporary TV today, NTSC (the American standard) and PAL/SECAM (the European standard), have 525 and 625 scanning lines respectively. The other main difference between the two systems is the number of fields transmitted per second: NTSC-60, PAL/SECAM-50. The maximum theoretical resolution of an NTSC image is 360 by 360 pixels; PAL/SECAM resolution theoretically can be higher because of the greater number of scanning lines. The greater frequency of fields per second of NTSC cuts down on various artifacts, such as flicker and moire effects. HDTV will have more than 1,000 scanning lines and resolution of at least 700 by 700.

Production, Transmission, and Reception Standards

In the discussion of HDTV standards, a variety of standards is involved in the chain from production to transmission to reception. Global production standards for HDTV were proposed in the 1980s because of widespread dissatisfaction among programmers and broadcasters about the costs of converting from film to video tape and from the PAL/SECAM to NTSC standards. Video production standards involve sharper images than video transmission stan-

dards because picture information is always lost in transmission and reception. Nippon Hoso Kyokai (NHK) first proposed a studio- production standard called Hi-Vision in the early 1980s, after more than ten years of research in NHK Laboratories. The NHK production standard called for 1,125 scanning lines per frame, 60 fields per second, 2:1 interlaced scanning, and a 16:9 aspect ratio. The bandwidth of the signal required to provide the necessary data for this production standard was 30 megahertz.

The European Reaction to the NHK Proposal for a Global Production Standard

During the 1980s the European governments and firms became progressively more committed to multiplexed analog component (MAC) transmission and reception standards. MAC was developed initially to improve and rationalize transmissions to PAL/SECAM receivers. Britain's Independent Broadcast Authority and the BBC Engineering Department engineered MAC to take advantage of the emerging CCIR 601 standard for digital TV production. Because the MAC signal was designed for DBS transmission and was, therefore, limited to 8.1 megahertz in bandwidth, only the sound portion of the transmission was transmitted in digital form, while the video image remained in analog. MAC separated the information concerning luminance (brightness) from chrominance (color) in the signal to get a better picture, but consumers had to buy a small converter to decode the MAC signal for their non-MAC TV sets. The idea behind MAC was to reduce transmission costs for the national broadcasters by replacing terrestrial with satellite transmission. It was hoped that the system would evolve toward complete digitization of both video and sound. In the meantime, consumers would appreciate the better sound and slightly sharper picture they would get with MAC.²⁴

After MAC was developed, considerable squabbling arose among the Europeans about how to implement it. The European Broadcasting Union (EBU) provided two alternative versions of MAC: D-MAC and C-MAC. D-MAC was suitable for transmission by cable, while C-MAC was suitable for transmission by satellite only. The British supported C-MAC initially, despite opposition from the French and the Germans on the basis of high costs of producing the receivers that could take advantage of the additional data channels available in the C-MAC signal, because they had a national strategy for combining TV with videotext. Later, after the French and Germans developed D2-MAC, which could be broadcast either by cable or by satellite, the British supported D-MAC for the same reason.

The root of the problem, therefore, was that the Europeans were still thinking of national TV standards as a way of insulating domestic markets from international competition. MAC had never been promoted outside of

Europe, and it became clear that only standards at the European level would do the job. In addition, after the CCIR meeting in Dubrovnik, many Europeans realized that the various versions of MAC had not addressed the real competitive threats from Japan: i.e., higher picture resolution and wider screens. The European governments, therefore, turned away from their petty infighting over versions of MAC to develop collectively a high-definition version of MAC that would be uniform across Europe.²⁵

Whether U.S. firms should reenter markets for the next generation of consumer products [depends on] ... the potential benefits of participation in high-volume electronics markets for next-generation products like high-definition television (HDTV).

In July 1986, the European Community initiated a 200 million ECU (\$180 million) research project coordinated under the Eureka Project to develop a 50Hz advanced television system.²⁶ The main European TV firms (Thomson, Philips, Bosch and Thorn-EMI) favored a system which used a MAC signal because they had already invested considerable in MAC technology. Nevertheless, MAC had some desirable qualities in comparison with the NHK competition: e.g., easier convertibility to NTSC than MUSE (because it used progressive instead of interlaced scanning). As in the case of MUSE, however, true MAC systems involved broader bandwidth than NTSC systems (i.e., more than one 6-megahertz channel) and, therefore, were best suited to satellite or cable transmission.

In September 1988, in Brighton, England, the Eureka-95 HDTV Project demonstrated prototype versions of HD-MAC systems, from production to reception. This demonstration showed that the Eureka project had been a technical success. It remained to be demonstrated, however, that HD-MAC products would be commercial successes. Philips initially pushed for the adoption of an HD-MAC-like solution to the HDTV standards debate in the United States through its North American subsidiary but abandoned these efforts as soon as it became evident that they would not be well received. Thomson, in contrast, did not try to impose its European MAC efforts on its U.S. operations but left it up to Thomson USA in collaboration with the Sarnoff Lab to devise a North American answer. Eventually Thomson and Philips collaborated to present a "European" alternative to NHK's "Japanese" solution (see below).

The U.S. Government Reconsiders the Standards Issue

Partly as a result of the embarrassing conflict with the Europeans at the Dubrovnik meeting, U.S. officials began to question the wisdom of adopting Japanese production standards for HDTV. The vocal European concerns over the continued viability of their electronics manufacturers in the face of Japanese dominance of HDTV markets made U.S. electronics manufacturers (previously not major participants in U.S. HDTV standards debates) consider the possibility that adoption of Japanese standards would foreclose prospects for their future reentry into high-volume consumer markets.

U.S. terrestrial broadcasters began to realize that adoption of the Japanese production standard might result in acceptance of the Japanese transmission standard (with its 8.1-megahertz channels) which would lead inevitably to a reallocation of TV channels by the FCC. The terrestrial broadcasters feared, in addition, that the cable operators might have an advantage in delivering 8.1-megahertz signals during the period in which the FCC was reallocating spectrum. They pushed, accordingly, for a transmission standard that did not disturb the existing allocation based on 6-megahertz TV channels. Thus was born the "simulcast" approach adopted by the FCC for the U.S. HDTV standards.²⁷

A number of companies and laboratories proposed HDTV systems for the United States, the most important of which are ACTV and ADTV systems proposed by a consortium made up of the North American Philips Corporation, Thomson Consumer Electronics, NBC, and the David Saroff Research Center in Princeton, New Jersey; the Spectrum Compatible system proposed by Zenith and AT&T; the Narrow MUSE system proposed by NHK; and the all-digital system proposed by the American Television Alliance (MIT and General Instruments).²⁸

As time has come closer to testing of proposed systems, more and more interest has been evidenced in all-

digital systems. Since both the Japanese and European standards are analog systems, the American system will necessarily be quite different. It is not clear yet that the digital approach will work, but the head of the FCC, Alfred Sikes, has leaned strongly in this direction, hoping that an all-digital HDTV will be something the United States can do better than the Japanese and the Europeans. It seems clear, however, that Japanese and European firms will be major suppliers of HDTV systems for the American market, no matter what standard is selected.

Summary

There is now solid agreement that it would be desirable for U.S. firms to participate to a greater degree than they have in the last two decades in high-volume, consumer-electronics markets. There is also increasing consensus that the reentry vehicle for greater participation is HDTV. The American HDTV standard is likely to be distinctive from those in Japan and Europe in stressing digital technologies over analog ones. Whether this turns out to be a boon for U.S. firms remains to be seen. A precondition for the successful reentry in high-volume consumer markets via HDTV is a set of government policies and business strategies that compensate for the current weaknesses of U.S. firms in consumer components and high-volume manufacturing of systems. Compensation can take many forms, but it has to combine the building of domestic capabilities with the fostering of new international alliances.

A formerly technologically dominant nation like the United States needs to rethink its economic strategies in a world where technological competence is more widely dispersed. There is no such thing as a successful and purely "national" strategy in today's consumer-electronics markets. Perhaps there is no such thing as a successful national strategy in any industry anymore.

Notes

1. World markets for radios had been captured by Japanese firms by the 1960s—and many of the factors that will be used below to explain the decline of the TV and VCR industries apply also to the radio industry.
2. James H. Wooster, *Industrial Policy and International Competitiveness: A Case Study of U.S.-Japanese Competition in the Television Industry*, Ph.D. dissertation, University of Massachusetts, February 1986, p. 35; Ira C. Magaziner and Robert B. Reich, *Minding America's Business: The Decline and Rise of the American Economy* (New York: Vintage, 1982), p. 171.
3. David H. Staelin, "The Decline of U.S. Consumer Electronics Manufacturing: History, Hypotheses and Remedies," Consumer Electronics Working Group, Commission on Industrial Productivity, MIT, Cambridge, MA, April 1988, p. 18.
4. The five largest Japanese color TV producers in 1982 were Matsushita, Sony, Toshiba, Hitachi, and Sanyo. See BIS-Mackintosh data cited in Jacques Pelkmans and Rita Beuter, "Standardization and Competitiveness: Private and Public Strategies in the EC Colour TV Industry," paper prepared for an INSEAD Symposium, "Product Standardization as a Tool of Competitive Strategy, June 9-10, 1986, p. 26.
5. Dataquest.
6. See David Yoffie, *Zenith and the Color Television Fight*, Harvard Business School, Boston, MA, Case No. 9-383-070, May 1984 revision.
7. James E. Millstein, "Decline in an Expanding Industry: Japanese Competition in Color Television," in John Zysman and Laura Tyson, eds., *American Industry in International Competition* (Ithaca, NY: Cornell University Press, 1983), pp. 117-118.

8. Wooster, pp. 162-163.
9. Wooster, p. 146.
10. Staelin, p. 17.
11. Wooster, p. 140.
12. Wooster, p. 161. Wooster breaks this down as follows: of the total drop in assembly labor time between 1974 and 1978, 55 percent was accounted for by reduction in component counts, 33 percent by automation of assembly, and 14 percent by reduction in the number of circuit boards.
13. These data are found in the *1987 Electronic Market Data Book* (Washington, D.C.: Electronic Industries Association, 1987).
14. The rest of this section relies heavily on two sources: Richard S. Rosenbloom and Karen J. Freese, "Ampex Corporation and Video Innovation," *Research on Technological Innovation, Management and Policy*, vol. 2, 1985; James Lardner, *Fast Forward: Hollywood, the Japanese and the VCR Wars* (New York: Norton, 1987).
15. U.S. equipment and tape producers did not think that 1/2-inch tape would be able to match the high-quality standards they expected and did not attempt to create a standard format. The Japanese firms, in contrast, knew that they needed a narrower tape if they were going to market a video recorder for home use and decided they did not need to build such equipment to studio- or industrial-level standards.
16. Richard Elkus, Presentation at a meeting on HDTV at the American Electronics Association, Santa Clara, California, June 6, 1988.
17. Richard Elkus, Presentation at a conference on "Seizing Opportunities of Change—Strategic Electronic Markets for Semiconductors," sponsored by Dataquest and the Semiconductor Industry Association, Santa Clara, California, September 29, 1988.
18. See Adam Watson-Brown, "Towards the Triumph of the Matt Black Box," *Intermedia*, vol. 16, January 1988, p. 24.
19. Data provided to the author by the Semiconductor Industry Association.
20. This argument is made most convincingly in Michael Borrus, *Competing for Control* (Cambridge, MA: Ballinger, 1988).
21. U.S. International Trade Commission, *Liquid Crystal Display Television Receivers from Japan*, USITC Publication 2042, Washington, DC, December 1987.
22. See Michael Borrus and Jeffrey A. Hart, "Display's the Thing," unpublished manuscript, Department of Political Science, Indiana University, May 1991.
23. For elaboration of these points, see Jeffrey A. Hart, *Strategic Impacts of High Definition Television for U.S. Manufacturing* (Ann Arbor, MI: National Center for Manufacturing Sciences, September 1989), p. 42.
24. Telephone interviews with Adam Watson-Brown.
25. Watson-Brown, "Towards the Triumph . . ."; Watson-Brown, "The Campaign . . ."; How Soon the Super Telly," *The Economist*, January 30, 1988, p. 70.
26. Lee McKnight and Suzanne Neil, "The HDTV War: The Politics of HDTV Standardization," Research Program on Communications Technology, MIT, Cambridge, MA, October 1987, p. 7.
27. The simulcast approach means that all broadcasters would be allocated two 6-megahertz channels, one to continue broadcasting NTSC signals and the second for HDTV. People with NTSC receivers do not have to scrap their sets or buy downconverters, while people buying new TVs have an incentive to buy an HDTV set.
28. See William Sweet, "Future of Electronics Companies at Stake in Development of New TV Systems," *Physics Today*, vol. 44, March 1991, p. 57.