Developing the Electronics Industry

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Consumer Electronics

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The consumer electronics industry is a large member of the family of electronics industries. Consumer electronics products are diverse, ranging from the simplest electronic calculators and watches to the almost professional-quality equipment purchased by audiophiles and videophiles. The Consumer Electronics Show held each year in Las Vegas by the U.S. Electronic Industries Association (EIA) has thousands of exhibitors from dozens of countries. Each year several new product categories are introduced as some entrepreneur finds yet another way to apply microelectronics technology to meet (or create) consumer demand. Table 5.1 is a classification of consumer electronics equipment used by the EIA.

The two main groups of products in the consumer electronics industry are audio and video equipment. In recent years, however, there has been rapid growth in home information systems. An increasing share of consumer electronics sales is in video games and home computers. Further miniaturization of circuitry and displays is making possible a new set of consumer electronics products called personal electronics—such as notebook and palmtop computers—which are relatively inexpensive and highly portable, and bring to the individual consumer capabilities previously available only to larger business customers. Coupled with the development of cellular telephone networks and other wireless communication systems, this is likely to make the market for advanced portable electronics more important at home, at work, and at play. Some of the boundaries between consumer and industrial products are breaking down thanks to the increasing use in both of digital circuitry and their connection to telecommunications networks. It will eventually become necessary to think of the market in terms of the portability of products rather than in terms of the location (e.g., home, factory, office) of their end users.

Audio and video equipment are important sources of high-volume demand for electronics components that are also used in computers and telecommunications equipment. Displays—particularly cathode ray tubes (CRTs) and liquid crystal displays (LCDs)—are necessary components in both televisions and computers, but they are increasingly found in telephones, telecommunications equipment, medical equipment, and military electronic systems. Similarly, many types of semiconductor components are common to all kinds of electronic systems. Although consumer electronics equipment has not always required the same kinds of transistors and integrated circuits that are used in computers and telecommunications equipment, in recent years the types of chips used in both categories of products have begun to converge. For example, one is much more likely to find microprocessors and memory devices (and other forms of digital circuitry) in the current generation of consumer products than in the past.

Market for Consumer Electronics Equipment

The consumer electronics market has been characterized by sustained rapid growth and major shifts of market share among producer regions. The consumer electronics industry in the United States went from a position of global dominance after World War II to extreme weakness. The consumer electronics industry in Europe experienced strong competitive pressures from Asian producers in the 1970s and responded with a combination of highly concentrated ownership, government subsidies for R&D, and barriers to trade and inward investment (including the use of incompatible European stan-

dards). The next round of competition in consumer electronics products is likely to involve a new set of video technologies connected with high-definition television (HDTV). HDTV receivers will differ from the current generation of televisions by improved picture quality achieved through doubling the horizontal and vertical resolution of video images, widening the screen, and high-fidelity digital stereo sound. The market for HDTV products is projected to develop first in Japan, but it will eventually spread to all other regions. The technologies underlying HDTV products will be more closely linked to those necessary for competitiveness in computers and telecommunications equipment than were the technologies underlying the current generation of video equipment. For this reason, the United States and Europe are interested in enhancing their HDTV capabilities and are trying to compensate for their late starts.

Table 5.1 Classification of Consumer Electronics Products

I. Video equipment
   - A. Color television receivers
   - B. Monochrome television receivers
   - C. Projection television
   - D. LCD or hand-held television
   - E. Video cassette recorders (VCRs)
   - F. Color cameras
   - G. Video disc players
   - H. Blank video cassettes

II. Audio equipment
   - A. Audio systems
   - B. Audio components
   - C. Home radio
   - D. Portable audio equipment
   - E. Car audio
   - F. Blank audio cassettes

III. Home computers
IV. Video and electronic games
V. Telephones
VI. Calculators and watches

Source: U.S. Electronic Industries Association.

The United States and Europe are the world's two largest markets for consumer electronic equipment. Sales of consumer electronics in the United States increased from about $8 billion in 1977 to around $33 billion in 1990 (see Table 5.2). Sales of televisions, VCRs, and camcorders—the main video products—made up around 29 percent of the total market for consumer electronics in the United States in 1990. The largest segment of this market was color televisions, of which about 21 million units worth $6.4 billion were sold. The market for video cassette recorders (VCRs) at $2.4 billion in 1990 was the third largest segment, after car audio

Table 5.2 Factory Sales of Consumer Electronics Products in the United States, Including Imports, 1977–90 (US$ millions)

Year	Mono. TVs	Color TVs	Projection TVs	VCRs	Video disc players	Audio systems	Audio components	Home radio	Portable audio	Car audio	Audio cassettes	Video cassettes	Other [a]	Total
1977	530	3,289	0	180	0	606	1,275	523	1,208	534	0	0	0	8,145
1978	549	3,674	0	326	0	748	1,143	436	1,649	582	0	0	0	9,107
1979	561	3,685	0	389	0	748	1,178	436	1,739	623	0	0	0	9,359
1980	588	4,210	0	621	0	809	1,424	468	1,403	1,368	0	0	7	10,891
1981	505	4,349	287	1,127	55	720	1,363	501	1,157	2,000	227	0	191	12,291
1982	507	4,253	236	1,303	54	573	1,181	530	971	2,100	202	357	1,810	14,077
1983	465	5,002	268	2,162	81	630	1,268	565	1,102	1,900	234	580	3,065	17,322
1984	419	5,538	385	3,585	45	976	913	661	1,191	2,500	256	770	3,780	21,019
1985	328	5,565	488	4,738	23	1,372	1,132	379	1,140	2,761	270	1,055	5,822	25,073
1986	373	6,040	529	3,978	26	1,370	1,358	408	1,389	3,135	300	1,235	6,058	27,479
1987	341	6,303	527	3,442	26	1,048	1,715	409	1,469	3,523	375	1,006	6,446	29,023
1988	236	6,277	529	2,848	34	1,225	1,854	377	1,547	3,937	367	936	7,261	30,247
1989	156	6,530	478	2,625	50	1,217	1,871	379	1,595	4,125	384	923	8,497	31,666
1990	132	6,376	626	2,439	72	1,270	1,935	360	1,645	4,292	376	948	9,354	32,937

a. This category includes personal computers and some other items that may be used for business purposes rather than for personal entertainment. The Electronic Industries Association began to count personal computers only in 1982, which helps account for the rapid growth in this area.

Source: 1987 Electronic Market Data Book, Washington, D.C., Electronic Industries Association, 1987, p. 6; *1988 Electronic Market Data Book*, Washington, D.C., Electronic Industries Association, 1988, p. 6; *The U.S. Consumer Electronics Industry in Review: 1991 Edition*, Washington, D.C., Electronic Industries Association, 1991, p. 9.

systems. As in the United States, the European consumer electronics market comprises mainly video products. About 16 million color televisions, worth $9.5 billion, were sold in 1986. The United Kingdom, France, Germany, and Italy all had purchases of over 2 million units each in 1986. Together, these four countries accounted for 70 percent of the total European market for televisions. In Europe in 1986, 7.2 million VCRs were sold, the total value of which was $5.1 billion, of which the United Kingdom, France, Germany, and Italy accounted for around 70 percent.[1]

There are major imbalances between the geographical location of production and consumption of consumer electronics equipment. High consumption of televisions and VCRs in the United States and Europe, along with limited local production only of televisions, results in these two largest world markets' being net importers of consumer electronic equipment. The United States has a particularly large trade deficit in consumer electronics. In 1987, for example, the United States imported $13.6 billion more than it exported in consumer electronics, up from $7.9 billion in 1983.[2] Of the 10 million VCRs sold in the United States in 1990, over 90 percent were imported directly, mainly from Japan and the Republic of Korea. Less than 10 percent were assembled from imported parts. Since larger televisions are increasingly assembled or manufactured in the United States, the largest part of the U.S. trade deficit in consumer electronics is attributable to imports of VCRs.[3] The U.S. trade deficit in consumer electronics declined to around $10 billion in 1989 and 1990, thanks to increased local manufacturing of previously imported products, mainly televisions. Japan had an overall surplus in consumer electronics of about 2.5 trillion yen in 1990 (see Table 5.3). The United States is by far the most important single destination for Japanese exports.[4] However, Japanese exports of consumer electronics were hurt by the revaluation of the yen in 1985; they dropped from 3.5 trillion yen in 1985 around 2.2 trillion yen in 1988, but partly recovered to 2.6 trillion by 1990. Since imports were almost negligible in Japan, even with the recent growth of imports from Southeast Asia, the trade surplus also dropped between 1985 and 1988 by about 1.3 trillion yen (see Table 5.3).

Production of Consumer Electronics Equipment

World production of consumer electronics equipment totaled $63 billion in 1990. This represents around 11 percent of world production in electronics in general (see Tables 5.4 and 5.5).[5] Consumer electronics production grew at an average rate of 10.6 percent per year between 1985 and 1990, but slowed down in 1989-90. Japan had the largest share of global consumer electronics production—around 49 percent in 1990. Newly industrialized economies (NIEs) in Western Europe and Asia had roughly equal shares, around 20 percent each, in that year. The United States produced a little over 10 percent of the global total of consumer electronics equipment (see Table 5.5).

Of the world's 10 largest producers of color televisions in the early 1980s, 5 were Japanese (see Table 5.6). Philips was the world's largest single producer in 1982, but Matsushita was a very close second. Philips owns 25 percent of Grundig and since 1985 has controlled that firm. The purchase of GE/RCA by Thomson in 1988 made Thomson's total production approximately equal to that of the third ranked firm—Sony. Zenith was the only U.S. firm in the top 10 in 1982. With the closure of its U.S. assembly operations in the United States in 1992, Zenith became dependent on its Mexican operations and on an alliance with Lucky Goldstar of Korea to maintain its share of world markets.

Declining Production in the United States

The U.S. consumer electronics industry, which had led the world into the radio and television ages, is now only a shadow of its former self. This

Table 5.3 Balance of Trade in Consumer Electronics, Japan, 1987–90
(yen trillions)

Year	*Exports*	*Imports*	*Balance*
1978	1.352	0.021	1.331
1979	1.480	0.037	1.443
1980	2.047	0.038	2.009
1981	2.600	0.033	2.567
1982	2.620	0.026	2.594
1983	2.829	0.020	2.809
1984	3.495	0.023	3.472
1985	3.805	0.024	3.781
1986	2.940	0.032	2.908
1987	2.317	0.061	2.256
1988	2.208	0.098	2.118
1989	2.287	0.145	2.142
1990	2.618	0.113	2.505

Source: Facts and Figures '88, Tokyo Electronic Industries Association of Japan, 1988, pp. 36–45; *Facts and Figures '91*, Tokyo, Electronic Industries Association of Japan, 1991, pp. 42–43, and 46–47.

Table 5.4 Total Electronics Production by Selected Region, 1984–90
(US$ billions)

Region	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*
United States	169	166	175	190	201	205	211
Japan	71	75	108	129	166	165	165
Western Europe	79	87	116	140	150	151	155
Newly industrialized economies	16	21	27	38	49	57	60
Total	335	349	426	497	566	578	591

Source: Facts and Figures on the Japanese Electronics Industry, Tokyo, Electronic Industries Associaton of Japan, 1988, p. 17; *Facts and Figures '91*, Tokyo, Electronic Industries Association of Japan, 1991, p. 115.

Table 5.5 Consumer Electronics Production by Selected Region, 1984–90
(US$ billions)

Region	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*
United States	6.4	5.7	6.3	6.1	7.2	6.2	6.4
Japan	19.9	20.4	26.1	27.2	33.2	20.5	30.6
Western Europe	7.0	7.1	10.1	12.1	12.5	12.1	12.3
Newly industrialized economies	—	6.0	7.7	10.6	12.9	13.3	13.6
Total	—	39.2	50.2	56.0	65.8	62.1	62.9

— Not available.

Source: Same as Table 5.4.

Table 5.6 Top Ten Producers of Color TVs Worldwide, 1982

Firm	*Country*	*Production (thousands)*
Philips	Netherlands	4,600
Matsushita	Japan	4,500
Sony	Japan	3,400
Toshiba	Japan	2,800
Hitachi	Japan	2,500
RCA	United States	1,800
Zenith	United States	1,800
Thomson	France	1,700
Sanyo	Japan	1,600
Grundig	Germany	1,600

Source: BIS-Mackintosh as cited in Jacques Pelkmans and Rita Beuter, "Standardization and Competitiveness: Private and Public Strategies in the EC Colour TV Industry," paper prepared for the INSEAD symposium, Product Standardization as a Tool of Competitive Strategy, June 9–10, 1986, p. 26.

can be attributed largely to a failure in the managerial vision of U.S. firms. In particular, U.S. firms' analysis of the Japanese threat in consumer electronics focused too much on labor costs and not enough on the incorporation of new technologies. U.S. television firms tried to get around their high labor costs by manufacturing in low-wage countries. While this was rational in the short run, it put the firms on a technological trajectory that was disastrous in the long run. U.S. firms also failed to see the importance of new component technologies in television, and did not recognize in time the market potential of VCRs. Besides greater reliability and lower production costs that were at the root of the increased Japanese global competitiveness in consumer electronics, Japanese trade and investment barriers, along with weak enforcement of trade laws by the U.S. government speeded the decline of the U.S. industry. Japanese firms engaged to some degree in dumping consumer electronics products on U.S. markets from the early days of their entry. Japanese markets were closed to U.S. producers by high tariff and nontariff barriers during this period, and no U.S.-owned television firm was permitted to establish a manufacturing presence in Japan.

THE DEMISE OF U.S. TELEVISION MANUFACTURING. At the beginning of the 1950s, there were 140 firms in the U.S television manufacturing industry; only 50 remained by 1956, 27 by 1960, and 5 by 1980.[6] The number of workers in the industry declined from a

high of 100,000 in 1966 to 33,000 in 1984.[7] As of 1986, only three U.S.-owned firms—Zenith, RCA, and Curtis Mathes—manufactured televisions in the United States. In 1987, RCA's television manufacturing facilities were acquired by General Electric (GE) and then sold in January 1988 to Thomson, a French firm. By the late 1980s, the only remaining U.S.-owned television manufacturing was Zenith (see Table 5.7). In the late 1980s, Zenith operated its television manufacturing operations at a loss, because of low prices in the industry as a whole. Thomson suffered financial losses in the U.S. market for the same reason. Zenith sold its more profitable computer business (Zenith Data Systems) to Groupe Bull of France in 1990 in order to stay in the television business. It solicited new investments in 1991 from a Korean firm, Lucky Goldstar, to ward off a hostile buy-out by a New Jersey-based air conditioner company. In 1992, Zenith closed its U.S. plants and relied entirely on its factories in Mexico. It has entered an alliance with AT&T to develop a viable HDTV system for the United States. If Zenith's HDTV efforts fail to result in renewed profitability in the next three to four years, the firm will probably be sold or liquidated.

Some of the relative decline of the U.S. television industry can be attributed to a shift in production to low-wage developing countries. This is particularly true of lower-priced audio equipment and televisions. In the late 1960s, most of the major U.S. television manufacturers began to locate plants for final assembly in low-wage countries in Asia and Latin America (mainly in Mexico). Firms that established assembly plants overseas for production of exports to the United States did not have to pay export duties on parts sent to those plants and only paid U.S. import duties on the value added abroad. 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, creating expertise in manufacturing transistorized televisions in the wrong (from the U.S. viewpoint) places. Moreover, heavy reliance on offshore assembly led to slow introduction of automated insertion equipment and single-board chassis. The offshore operations, mainly in Mexico and East Asia, were at the time not considered sufficiently reliable for single-board chassis assembly.

Table 5.7 The Fifteen Top Television Brands in the U.S. Color TV Market, 1989

Firm	*Market share (percentage)*
RCA (Thomson)	16.3
Zenith	12.0
Magnavox (Philips)	6.4
Sony	6.4
General Electric (Thomson)	5.6
Sears, XLI	5.0
Sharp	4.8
Mitsubishi	3.6
Emerson	3.5
Toshiba	3.5
Sylvania (Philips)	3.3
Panasonic	3.2
Montgomery Ward	2.5
Hitachi	2.5
Goldstar	2.1

Note: Sears and Montgomery Ward purchase televisions mainly from Asia and European producers and then put their own brand names on them.

Source: Television Digest as cited in *The New York Times*, March 10, 1990, p. 17.

The largest single source of television exports to the United States in 1990 was Mexico. Most of these exports came from the *maquiladora* plants in Northern Mexico. Under Mexican law, firms that assemble products solely for export do not have to pay import duties. Under the U.S. tariff code, firms that establish plants overseas for production of exports to the United States do not have to pay export duties and pay only import duties on the value added abroad. Accordingly, all the major firms involved in supplying consumer electronics products to the United States have located assembly plants below the border with Mexico to take advantage of U.S. and Mexican laws. The main incentive for doing this is to reduce direct labor costs in the assembly phase of manufacturing. In 1987, there were about 1,250 *maquiladoras* employing 330,000 workers.[8] Only 30 of these were owned by Japanese firms, but about 19 percent of all *maquiladora* workers were employed by those firms.[9] Zenith has a large *maquiladora*, which produced around 60 percent of all the televisions it sold in the United States. After the closure of its assembly plants in the United States in 1992, Zenith's Mexican facility will be assembling all the televisions it sells in the United States. Both Philips and Thomson also have Mexican plants, but the domestic content of their products (domestic over total value added) is actually higher than Zenith's.[10] The *maquiladora* system not only allows the consumer electronics firms to reduce their as-

sembly costs, it is a useful way of reminding U.S. workers of the need to keep their productivity high in order to justify their higher wages.

These movements, however, have been to some extent offset by foreign companies setting up television plants and R&D in the United States. Although only a little more than 12 percent of the total television market is supplied by U.S.-owned firms, approximately 70 percent of the value of televisions sold on the U.S. market is estimated to be domestic in origin. The reason is that most foreign firms have set up plants in the United States to manufacture picture tubes and cabinets and to assemble televisions locally. The tube and the cabinet combined with the local labor costs are the main contributors to the domestic content of televisions sold in the United States. The circuitry in televisions contributes only about 5 to 7 percent of the manufacturing costs of an average television. Very little of this circuitry is produced in the United States. U.S. final assembly operations were established by the major Japanese producers in the following sequence: Sony in 1972, Matsushita in 1974, Sanyo in 1976, Mitsubishi in 1977, Toshiba in 1978, and Hitachi and Sharp in 1980. With the exception of Matsushita's purchase of Motorola's Quasar division in 1974, all the Japanese facilities are new ones. The Korean firm, Lucky Goldstar, built an assembly plant in California in 1981. Philips and Thomson established their presence in the United States mainly through acquisitions of U.S. firms. Philips purchased Magnavox in 1975 and Sylvania in 1981. Thomson bought RCA/GE consumer electronics from GE in 1988. Thus, every major supplier of consumer electronics to the United States has at least an assembly operation in the United States. Some—like Philips and Thomson—have a major research facility, as well as components manufacturing operations. Of the Japanese firms, only Sony has invested in a major R&D facility for consumer electronics in the United States.

The main challenge to the U.S. television industry, however, has not been from low-wage countries, rather mainly from Japan, whose share of consumer electronics production in 1990 was 49 percent (see Table 5.4). Of the top 10 firms producing color televisions in the early 1980s, 5 were Japanese (see Table 5.6).[11] Japan also leads in production of higher-priced televisions, VCRs, and camcorders.

The success of Japanese televisions in the U.S. (and other) markets is the result of technological and marketing strategies on the part of Japanese firms, along with some predatory pricing (documented in a series of successful but unenforced antidumping petitions).[12] Of primary importance was the early replacement of vacuum tubes with semiconductors. Sony Corporation sold the first all-transistor monochrome television in 1959. Soon after, all the larger Japanese electronics firms (Matsushita, Mitsubishi, Hitachi, Toshiba, Sharp, 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 television in 1969. By 1970, 90 percent of all color televisions produced in Japan were solid-state.[13] Semiconductor technology was more amenable than vacuum tubes to automation of assembly. Development of devices for automatically aligning and inserting semiconductor components on circuit boards was pioneered by Japanese firms in the late 1960s. The first generation of such equipment was operating by 1968, and it was manually rather than automatically controlled. A second generation was produced in 1972 that was much faster, but was still controlled manually. The third generation was about 10 times faster than the first generation and allowed for limited numerical or computer control of the insertion process.[14] In a related development, large-scale integrated (LSI) circuit technology allowed semiconductor manufacturers to put more transistors on a single device, and Japanese television producers were able to substantially reduce the number of parts and circuit boards per television set. For example, it was only in the mid-1980s that General Electric was able to put the circuitry for its color televisions on a single board, whereas Japanese firms had been doing so since 1976. The switch to single-board chassis further reduced the labor time required for assembly.[15]

Japanese firms began to market televisions in the United States in the early 1960s, but they mainly confined sales to smaller units (with screens smaller than 19 inches) 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. However, they used tubes and the circuit designs were inferior to U.S. products. Soon, however, tubes were replaced first with transistors and then with integrated circuits, circuit designs continuously improved, and televisions became more reliable and required less maintenance and servicing. During the mid-1970s, for example, U.S.-made color televisions were failing at five times the Japanese rate.[16] 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.[17]

The greater reliability and durability of Japanese sets made it possible to sell them widely without building an extensive service network. The service networks of the U.S. manufacturers were thus converted from a barrier to entry for foreign firms to a financial liability. U.S. firms spent a considerable effort 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 East Asian competitors were offering, that consumers did not care about semiconductor componentry as much as they cared about the size and quality of the picture, and that semiconductors would not be as reliable as tubes. U.S. firms, therefore, kept color television production in the United States after they moved black-and-white television production offshore, and they were slow to introduce semiconductor components and to reduce the number of circuit boards, and they underestimated the ability of Japanese firms to produce televisions 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, they 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 continue to have production-cost and distribution advantages in high-priced vehicles. But in actuality, 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. Despite the mistakes made in television production, the U.S. consumer electronics industry might still have been able to hang on, had a few U.S. firms been able to shift their activities from television to VCR production in the 1970s. The story of Ampex Corporation illustrates how this did not happen.[18] Ampex 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 television broadcasting stations, but it was unable to turn that technological advantage into a commercial one in the vast consumer market for VCRs that arose in the 1980s.

Like many other U.S. firms, Ampex attempted to get around patent and marketing problems in Japan by forming a joint venture in 1960 with a Japanese firm, Sony. Sony would produce a portable version of the Ampex professional recorder in exchange for Japanese production of Ampex recorders for nonbroadcasting customers. This venture was of only limited success, especially after Sony introduced a transistorized recorder of its own in 1961. In 1968, Ampex management decided to make a strategic shift toward producing a video recorder for the consumer market, scrapping the development of a new professional video recorder, the VR-7700, in favor of a consumer-oriented machine called the "Instacorder" which used half-inch tape, and was compact, easy-to-use, and self-loading. While the engineers in California and Illinois developed a prototype, a number of business arrangements for financing and marketing the product were attempted. Toamco, a joint venture between Ampex and Toshiba, was formed in 1964 to manufacture Ampex-designed professional tape recorders and computer tape units that were sold by Toshiba in Japan and by Ampex elsewhere. Toamco was not doing well financially in the late 1960s and was given 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 that was compatible with the emerging standard for video recording tape, a half-inch format called the EIAJ-Type 1, which had been pioneered by the Japanese.[19]

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. It weighed less than 16 pounds, and included a monochrome television camera. The tape was compatible with the EIAJ-Type 1 standard. 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 after its new product announcement to ward off financial difficulties for a few more months.[20]

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. Also, sales of Ampex magnetic tape and consumer audio equipment plummeted as cheaper imports had come onto the market. Ampex became overly dependent on debt capital to finance some of its acquisitions, and by the end of 1971 it reported a loss of $12 million, which rose to $90 million in 1972. In order to restore the firm

to fiscal soundness, management cut back Ampex's expenditures and investments. One of the projects that was cut was the Instavideo project, which ended the chances 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 poor management leading to financial weakness. The joint venture with Toshiba hastened the diffusion of U.S. VCR technology to Japan. Reportedly, Ampex was approached by Magnavox before it decided 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 be a serious competitor in the future.[21] Larger U.S. firms, such as RCA, GE, or Zenith, apparently did not 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. The subsequent failed efforts of RCA to market a video disc system suggest that even by the late 1970s the large U.S. consumer electronics firms had not developed a proper understanding of the nature of consumer demand for home videotape systems. GE apparently did not perceive a great future for its consumer electronics operations. 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 televisions in the 1980s.

IMPACT OF THE DECLINE OF THE U.S. CONSUMER ELECTRONICS INDUSTRY ON U.S. COMPETITIVENESS IN ELECTRONICS. The decline of the U.S. 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 U.S. 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 (and particularly CCDs or charge-coupled devices), liquid crystal displays (LCDs), and consumer-oriented analog circuitry.[22]

One important result of the failure of U.S. consumer electronics was to reduce the proportional importance of consumer demand in total demand for semiconductors. Whereas consumer end use accounted for more than 40 percent of total consumption of semiconductors in Japan in 1988, the same figure for the United States was around 7 percent.[23] 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. Japanese firms have used this fact to explain why U.S. penetration of the Japanese semiconductor market has remained lower than 15 percent, despite a 30 to 40 percent share of the European market.[24]

The current generation of consumer-oriented semiconductors are quite different from the 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 nonconsumer componentry is rapidly decreasing. Portable consumer electronics products use integrated circuits that dissipate less electrical power, such as CMOS devices. CMOS-based consumer products can be battery-operated and very compact. The Japanese dominance of consumer markets, therefore, has contributed to their dominance of markets for CMOS semiconductors and downstream products like laptop computers, which depend heavily on CMOS technology.[25]

Another example was the growth in demand for hand-held LCD televisions. In 1984, only 32,000 LCD televisions were sold in the United States. By 1986, 771,000 LCD televisions were sold in the United States, all of them imported from Japan. In 1986, Japanese firms produced over 1.7 million LCD televisions. They had been able to descend their learning curves for production of LCDs so quickly that it was difficult for their foreign competitors to enter the market for LCD televisions. LCDs are used also in laptop computers, so it was harder for many U.S. computer firms to enter laptop markets successfully because they had to purchase LCDs from Japanese competitors (or at least from potential competitors).[26]

Weakness in U.S. consumer electronics production has had other repercussions besides reducing the volume of domestic demand for electronic components like CMOS integrated circuits and LCDs. 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, but also in successor technologies like sur-

face-mount technology (SMT), tape-automated bonding (TAB), amorphous and polysilicon processing, and chip-on-glass (COG) technology.[27]

Emergence of Japan as a Major Producer

Driven by technological innovation and successful market strategies discussed above, Japanese production of consumer electronic equipment rose dramatically between 1967 and 1990 (see Table 5.8). In 1967, Japan produced 1.3 million color televisions. Production of color televisions peaked in 1985 at 17.9 million units, but fell back to around 14 million in the next two years.[28] Because Japanese firms were able to dominate VCR and audio equipment markets in the 1980s, they were able to increase overall production of consumer electronics even though the production for televisions stabilized. VCR production in terms of value first exceeded production of televisions in 1981. By 1987, VCR production was almost twice the value of television production. VCR production began to drop off in value in the mid-1980s, despite the fact that volume continued to increase. The average selling price of VCRs declined substantially in the mid- to late 1980s, thanks partly to increased competition from the Asian NIEs. Overall production of consumer electronics continued to increase slowly in the 1985-87 period, but exports declined and imports rose after 1986. New video equipment (camcorders, projection televisions, and other items) partially compensated for the decline in volume of sales of audio equipment, televisions, and VCRs.

Table 5.8 Production of Consumer Electronics Equipment in Japan, 1967–90
(yen billions)

Year	*TVs*	*VCRs*	*Total*
1967	133.2	0	133.2
1968	278.6	0	278.6
1969	503.7	0	503.7
1970	681.3	0	681.3
1971	608.2	0	608.2
1972	715.0	0	715.0
1973	686.2	0	686.2
1974	615.1	0	615.1
1975	584.5	0	584.5
1976	768.1	0	768.1
1977	700.8	0	700.8
1978	617.3	204.1	821.4
1979	640.8	296.2	937.0
1980	711.9	562.8	1,274.7
1981	739.0	1,086.8	1,825.8
1982	683.1	1,285.0	1,968.1
1983	684.6	1,514.0	2,198.6
1984	755.8	2,090.0	2,845.8
1985	897.1	1,889.2	2,786.3
1986	723.8	1,659.4	2,383.2
1987	765.1	1,241.5	2,006.6
1988	814.1	1,212.0	2.026.1
1989	819.3	1,134.6	1,953.9
1990	874.6	1,078.5	1,953.1

Source: Facts and Figures, Tokyo, Electronic Industries Association of Japan, 1988 and 1991.

The largest producers of consumer electronic equipment in Japan are Matsushita, Sony, Toshiba, Sanyo, Sharp, Mitsubishi, NEC, and Hitachi. All these firms, with the possible exception of Sony, are vertically integrated electronics companies with ties to larger units called *keiretsu*, groups of firms clustered around a leading bank. They all produce a significant proportion of the semiconductor components used in their own consumer products. Japanese strength in semiconductors has been an important reason for the continued growth of their consumer electronics business. All the major firms, again with the exception of Sony, are quite diversified.

European Production

Despite similar patterns of overall production and consumption, a major difference between Europe and the United States is that the major European consumer electronics firms were able to survive in the presence of Asian competition. Only 14 percent of the European market for color televisions was supplied by Japanese firms in 1976. Tables 5.9 and 5.10 list the main European producers of color televisions and VCRs.

The European consumer electronics industry survived primarily on the basis of extensive government assistance in various forms, including R&D subsidies, the promotion of mergers and acquisitions, the granting of exclusive patent rights for European standards, and a variety of trade and investment barriers to keep out Asian competitors.[29] The two most important European firms—Philips and Thomson—produced a substantial number of televisions and VCRs in Europe and in North America. Their strategy included a strong commitment to local production in North America as part of a global defense against Asian competition. Philips purchased two large U.S. television firms: Magnavox in 1975 and Sylvania in 1981. Thomson purchased the consumer electronics operations of RCA/GE in 1987, which made it

the number one producer of televisions in the United States. Thomson marketed and assembled Japanese-designed VCRs for Europe and North America; only Philips had the capability to manufacture its own VCR designs as of the late 1980s.

Table 5.9 Western European Color TV Production, 1986

Firm	*Production (thousands)*
Philips	3,100
Thomson	2,000
Grundig	1,950
ITT	1,305
Nokia	1,000
Thorn-EMI-Ferguson	800
Salora/Luxor	680
Blaupunkt	600
Sony	535
Sanyo	410
Hitachi	370
Toshiba	310
Matsushita	310
Other Japanese	130
Other Asian	410
Other European	2,295
Total	15,195

Note: Philips assumed managerial control over Grundig in 1985 and Thomson acquired Thorn-EMI-Ferguson in 1987.

Source: BIS-Mackintosh as cited in Alan Cawson, "Sectoral Governance in Consumer Electronics in Britain and France," paper prepared for a conference on Comparing Capitalist Economies, Racine, Wisconsin, May 4-6, 1988; Nokia, *Annual Report*, 1987.

Table 5.10 Western European Video Cassette Recorder Production, 1986

Firm	*Production (thousands)*
Philips	800
Grundig	750
JVC-Thomson	750
Hitachi	450
Matsushita-Bosch	335
Sanyo-Fisher	240
Mitsubishi	165
Sharp	160
Toshiba	160
ITT	150
Others	240
Total	4,200

Source: Same as Table 5.9.

The Japanese firms were kept out of the European television market in earlier times by restrictions on the licensing of patents for PAL and SECAM technologies. More recently Japanese firms have avoided local production of televisions because the Europeans made it clear that they would not permit Japanese television plants in Europe to service the not-yet-completed internal market. That is, no Japanese producer could be sure that products assembled, say, in the United Kingdom would be considered sufficiently European to be exported freely to, say, France. Since it was possible to make money by exporting and licensing the production of VCRs and camcorders, the Japanese firms focused their European activities in these areas.[30] European firms, accordingly, are weaker in VCR and camcorder markets than they are in televisions. Japanese firms supply about 40 percent of the European VCR market. Other than Philips, which developed its own VCR technologies in collaboration with Sony, the European firms all have to produce VCRs under joint ventures with Japanese firms. Examples are JVC-Thomson, Matsushita-Bosch, Amstrad-Funai, and Hinari-Shintom.

Production in the Asian NIEs

The reduced trade surplus in Japanese consumer electronics in the late 1980s was due mostly to increased competition from producers in Asia, especially in Korea, Taiwan (China), and Singapore. The largest increase in Japanese imports from Asia between 1985 and 1987 was in audio cassette recorders, but increases also occurred in color televisions and VCRs. Most of the production in Asian newly industrialized economies (NIEs) for export to Japan is by subsidiaries of Japanese firms or by local makers under OEM contracts.[31] Exports to the rest of the world, however, are not so closely tied to Japanese ownership or contractual arrangements. The Asian NIEs are globally competitive in low-end consumer electronics products. They combined favorable labor market conditions (high skill base and relatively low wages) with successful transfer and adaptation of semiconductor and electronics assembly technologies from Japan and the United States to get where they are today. As they come under competitive pressure from lower-wage countries in Asia and elsewhere, the Asian NIEs are moving up-market into more sophisticated and more expensive products, thus increasing the pressure on Japan to promote new generations of consumer products like HDTV.

The three largest Korean firms—Lucky Goldstar, Samsung, and Daewoo—produce their own designs under their own labels, unlike the

smaller electronics firms of Hong Kong and Taiwan (China). Each of these firms has its own semiconductor operations. They all produce their own CRTs for televisions and computer monitors. Korea is beginning to move its product mix up toward the high end. The Koreans, for example, have begun their own program to develop HDTV technologies funded at around $200 million. The two largest firms in Taiwan (China)—Tatung and Sampo—manufacture color televisions. Tatung began manufacturing VCRs in 1982. The electronics strategy of Taiwan (China) is focused more on information technology than on consumer electronics. Hong Kong, in contrast, has focused on the production of small consumer items like portable black-and-white televisions, portable radios and audio cassette recorders, hand-held video games, and the like. Hong Kong producers tend to be small firms working under contract with larger distributors. The People's Republic of China (PRC) is quite interested in becoming a major producer of consumer electronics. The opening of PRC markets to international trade produced initially a major influx of consumer items from Japan and other Asian economies. In 1987 Philips negotiated a joint venture with Novel of Hong Kong and China National Huadong of the PRC to produce 1.6 million color television tubes per year in Jiangsu province. Philips is also working with the PRC on joint ventures for VCRs and bipolar integrated circuits.[32]

The success of the Asian NIEs in becoming internationally competitive in low-end consumer electronics has resulted in a number of attempts by the Western developed countries to erect new barriers to imports. A series of antidumping cases has been brought against Asian NIEs in the United States and the European Community, some of them resulting in the imposition of dumping duties, "voluntary" export restraints, and quotas. The continued access of Asian NIEs to the markets of the wealthy countries cannot be guaranteed, given the current sensitivity of the United States and Europe to their weaknesses in electronics vis-a-vis Japan. Thus, the Asian economies are likely to turn to other regions for outlets for their products. The Asian NIEs, like Japan, are also likely to substitute local production (via investments in overseas plants) for exports of televisions and VCRs in major developed markets.

The Role of HDTV in Future Consumer Electronics Markets

The competitive pressure from the Asian NIEs in low-end consumer electronics is pushing Japanese and European firms to move up-market. Firms in Korea and Taiwan (China) are also moving up-market to deal with the competitive pressures from even lower-wage economies (e.g., Malaysia, Thailand, the Philippines). The response of Japan has been to push for a new generation of audio and video products centered around the concept of HDTV. HDTV is defined in engineering terms as a video experience in which at a viewing distance of three times the height of the display the viewer cannot distinguish between the video image and reality. In practice, however, HDTV is defined in terms of three changes in the current television systems: (a) sharper picture resolution, (b) wider screens, and (c) digital stereo sound. For a new display to be considered an HDTV display, it must have about twice the horizontal and vertical resolution of the U.S. NTSC (National Television Systems Committee) maximum theoretical resolution of 360 by 360 pixels (or picture elements). The screen of HDTV displays will be more elongated with aspect (width to height) ratio of 16 to 9 in contrast with the current aspect ratio of 4 to 3. Digital stereo sound is the type of high-quality sound available on contemporary compact disc (CD) and digital audio tape (DAT) players.

Japan is well in the lead in developing HDTV technologies. The public broadcasting company, NHK (Nippon Hoso Kyokai), has played a central role in this. NHK Laboratories began work on high-definition systems in 1970, and was initially motivated by a desire to overtake the Europeans. The two major European color television standards, PAL and SECAM, permit a somewhat higher degree of picture resolution than is possible with NTSC (the standard that prevails in the United States and most of Asia). NHK believed that a move to higher resolutions was inevitable and wanted to anticipate any such move on the part of the Europeans. Since 1970, NHK and the major Japanese manufacturers have spent approximately $700 million on the development of HDTV technologies. By 1980, they had worked out a transmission system based on a bandwidth compression technique called MUSE (for Multiple Sub-Nyquist Sampling Encoding). In 1984, Japanese transmission equipment manufacturers officially adopted MUSE and embedded it in a set of HDTV standards called "Hi-Vision."

The Hi-Vision production standard calls for an image with 1,125 horizontal lines scanned at a rate of 60 fields per second.[33] For this reason, the Hi-Vision production standard is referred to as the 1125/60 standard. There are also Hi-Vision standards for video tape equipment, editing equipment, broadcasting equipment, and receivers, which all have to be compatible with one another. NHK has been the linchpin for negotiating or imposing these standards on the manufacturers and

private broadcasters. NHK has the ability to do this because it owns most of the key technologies for Hi-Vision HDTV as well as transponders on the broadcasting satellites that can provide HDTV delivery.

NHK initiated broadcasts of Hi-Vision HDTV via direct broadcast satellite (DBS) in 1989. The initial broadcasts were only for one hour per day. These broadcasts were increased to three to four hours per day in 1991 with the launching of a new satellite, the BS3b. NHK wanted the Hi-Vision standard to be adopted outside Japan so that it would be less expensive to convert foreign programs for Japanese broadcasting and to adapt Japanese equipment for foreign markets. So they set about the task of getting broader acceptance for Hi-Vision as a world standard for HDTV.

The Sixteenth Plenary Assembly of the Consultative Committee on International Radio (CCIR) of the International Telecommunication Union (ITU) met in Dubrovnik, (former) Yugoslavia, from May 12-24, 1986. At this meeting, the United States, CBS, Japan, Canada, and the North American National Broadcasters Association (NANBA) proposed that the Japanese 1125/60 production standard be adopted as a global standard. This proposal was firmly opposed by the European Community countries. The Europeans proposed further study of the matter as a delaying tactic and rejected a compromise proposal from the United States, which would have resulted in a *de facto* standardization of production equipment.

The European Approach to HDTV

The Europeans were concerned that adoption of 1125/60 as a world production standard would damage their chances of participating in HDTV equipment markets. The largest European consumer electronics producers—especially Philips, Bosch, and Thomson—therefore supported a European response to the Japanese HDTV initiative. There were two main thrusts: (a) negotiation of an agreement within Europe to do away with the multiple standards within Europe and (b) new funds for collaborative R&D in high-definition technologies.

The Eureka EU95 program was launched in June 1986, at the initiative of French President François Mitterrand, in response to Japanese proposals for the adoption of 1125/60 as a world production standard for HDTV in May 1986. EU95 was one of the first research programs announced under the Eureka rubric.[34] The heads of state of the members of the European Community decided at their summit conference in Rhodes in December 1988 to make EU95 and HDTV a high-priority issue in Europe. The German Chancellor, Helmut Kohl, and President Mitterrand had their own bilateral agreement to push for a European answer to the Japanese HDTV challenge. In April 1989, the EC Council of Ministers adopted a decision on HDTV, which outlined a comprehensive strategy for the launch of HDTV service in Europe starting in 1992.[35] EU95 itself was renewed and expanded in 1990 when its first phase ended. The initial funding for the program was to have been 190 million ECU for the first four years, from a mixture of public and private sources. The actual expenditure for the first phase of the program, ending in December 1989 was 270 million ECU (approximately $350 million). The second phase began in 1990 and was budgeted at 350 million ECU (around $500 million) for three years.

The most important participants from the beginning were Thomson, Philips, and BTS (a joint venture for advanced television technology created by Bosch and Philips in 1986). Peter Bögels of Philips has been the head of the EU95 Directorate in Brighton, the United Kingdom, since 1986. Thomson directs the program's activities in France. BTS directs the program's activities in Germany. Nokia, a Finnish firm, was added to the inner circle of program directors in October 1989. In May 1990, Philips and Thomson announced that they were planning to spend 20 billion francs (around $4 billion) on the development of HDTV products over a five-year period, but this was to be a Franco-Dutch effort and not strictly part of the Eureka initiative.[36]

The purpose of EU95 was to develop technologies and prototype equipment for the processing of high-definition video images and stereo sound. From the very beginning, EU95 focused on the development of a high-definition version of a DBS transmission system called MAC (multiplexed analog components), which came to be called HD-MAC. HD-MAC video images have 1,250 lines per frame (double the 625 lines of PAL and SECAM, the current standards in Europe), an aspect or width-to-height ratio of 16 to 9 (the aspect ratio of PAL and SECAM is 4 to 3), and scanning is progressive or noninterlaced (the current standards are interlaced) at 50 frames per second.[37] Nevertheless, HD-MAC signals are backward compatible with MAC receivers, so people who purchased MAC sets will still be able to view images produced for HD-MAC receivers.

MAC was developed originally by the Independent Broadcast Authority (IBA) in the United Kingdom. MAC signals are suited to satellite delivery because they are analog and fit nicely within

sumer electronics for all major producers since the 1970s. There is clearly more competition in U.S.

opment or commercialization of HDTV products. Thus, there is some logic in a joint U.S.-European

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.

Conclusion

Consumer electronics markets have experienced rapid growth and technological change. Those countries—primarily Japan and the Asian NIEs—that understood the importance of consumer electronics as a generator of wealth, jobs, exports, and technology did well for themselves during the last two decades. In the developing world outside Asia, Mexico was the primary beneficiary of North American growth in consumer electronics thanks to the *maquiladora* program. The failure to appreciate the dynamism of the demand for and the technology of consumer electronics badly hurt many European and virtually all the U.S. firms in this industry. The U.S. industry, with the exception of Zenith, had to abandon the field. The European industry consolidated into four major firms: Philips, Thomson, Nokia, and ITT.[45] While Europe is in a much stronger position than the United States in consumer electronics, it remains vulnerable to competition from Japan in high-end products and from lower-wage countries in low-end products.

Consumer electronics markets will become more interesting as the transition is made from the current generation of audio and video products to the next. Because of the large costs connected with developing the underlying technologies for HDTV, developing countries are likely to be excluded from all but the lowest value added activities in these new markets. There may be some exceptions among the NIEs (in Korea, for example).

There will continue to be rapid growth in demand for the current generation of products in the developing world and in Eastern and Central Europe. Developing countries may play an important role in developing new forms of personal electronics suited to their own environment. Finally, it will always be wise to search for small market niches which the firms of the developed countries are unwilling or unable to exploit. Enterprises in the developing countries may find some consolation in the likelihood that they will not be alone in having to search for the unappreciated niche markets for opportunities. Most U.S. firms will be in the same boat.

Notes

1. *Consumer Europe 1988* (London: Euromonitor, 1988), pp. 394–49.
2. *Electronic Market Data Book* (Washington, D.C.: Electronic Industries Association, 1988), p. 124.
3. Allen Lenz, "Slimming the U.S. Trade and Current Account Deficits," *The AMEX Bank Review, Special Papers*, No. 16 (October 1988).
4. This figure is based on statistics from the Japanese Ministry of Finance as reported in the *Facts and Figures '91* (Tokyo: Electronic Industries Association of Japan, 1991), pp. 36–37 and 40–41.
5. These figures are according to the Electronic Industries Association of Japan (EIAJ). It should be noted that the EIAJ uses a narrower definition of what constitutes consumer electronics equipment than does the EIA: radios, monochrome televisions, color televisions, video tape recorders, prerecorded disks and tapes, and audio equipment. It does not include home computers or video games, which makes its figures smaller than those of the EIA. Using a different classification, Dataquest estimated that in 1986 consumer electronics accounted for about 17 percent of electronics equipment production in North America, Western Europe, and Japan.
6. 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.
7. 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, Mass., April 1988, p. 18.
8. Mexican National Chamber of Industry and American Chamber of Commerce in Mexico as cited in the *San Francisco Chronicle*, February 29, 1988, p. A6.
9. Larry Rohter, "Plants in Mexico Help Japan to Sell to U.S.," *New York Times*, May 26, 1987, p. 25; John Eckhouse, "Japan Finds Mexico a Profitable 'Back Door' to U.S.," *San Francisco Chronicle*, March 1, 1988, p. A8.
10. All of the chassis for Thomson's televisions are assembled in its plant in Juarez, Mexico. Only cabinets and tubes are manufactured in the United States.
11. The five largest Japanese color television 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.
12. See David Yoffie, *Zenith and the Color Television Fight*, Harvard Business School, Case No. 9-383-070, May 1984 revision.

the bandwidth limits of existing satellite transponders. The multiplexing aspect of MAC signals improves the ability of MAC receivers to compensate for errors introduced in transmission. One cannot receive MAC signals on existing PAL and SECAM sets, however, and direct reception in homes is impossible without using higher-power satellites at the transmission end and a satellite dish and decoder at the reception end. MAC was designed to be consistent with an international standard, CCIR 601, negotiated in 1982 at the CCIR plenary. One version of MAC, C-MAC/Packet, was adopted as a European standard by the European Broadcasting Union (EBU) in 1982. The U.K. supported C-MAC because it added data channels that would permit the British Post Office to add a teletext service to the existing television broadcasting services. The French and the Germans opposed C-MAC because of the high cost of C-MAC receivers. They opted for another form of MAC—D-MAC—because unlike C-MAC, it was suitable for delivery by cable and did not require special integrated circuits in the receivers.

The French and the Germans developed yet another type of MAC—D2-MAC—which, like D-MAC, could be delivered either by cable or by satellite, but which could be easily upgraded to higher levels of picture resolution. D2-MAC/Packet was adopted as an EBU standard in April 1985. Distinctive variants of the MAC standard (B-MAC, C-MAC, D-MAC, and D2-MAC) were adopted for use by public broadcasters in the United Kingdom, France, Germany, and the Netherlands, but few MAC receivers were sold initially and there were problems with the launching of DBS satellites. Nevertheless, unlike PAL and SECAM, MAC was designed in such a way as to make it relatively easy to upgrade signals to higher resolutions without losing backward compatibility. This made it possible for Europeans to envision a gradual evolution from PAL and SECAM, to MAC, to enhanced MAC (with wide-screen capability and better sound), and finally to HD-MAC.[38]

The EU95 consortium was successful in developing prototype HD-MAC cameras, video recorders, and transmission equipment only two years after its formation. It successfully demonstrated HD-MAC equipment first at the International Broadcasting Conference (IBC) in Brighton, the United Kingdom, in October 1988, then at the *Funkausstellung* in Berlin in August 1989, and then again at the National Association of Broadcasters meeting in Las Vegas in May 1991.

The technical success of the EU95 Consortium should be juxtaposed with the so far limited success of MAC itself in penetrating European television markets. MAC has been challenged by a group of private broadcasters who have committed themselves to prolonging the life of the PAL standard by moving to enhanced versions of PAL—PALplus and widePAL.[39] Rupert Murdoch's Sky Television, for example, was able to win important increases in European audience shares by directly delivering PAL signals to homes and cable operators via privately-owned medium-power communications satellites, as opposed to the high-power communications satellites owned and operated by the public telecommunications agencies of Europe. All the publicly-owned satellites had been committed to broadcasting MAC signals. Besides the problems connected with launching the high-power satellites, manufacturers had problems producing enough MAC receivers because of shortages of key components.

Not only did Murdoch steal a march on the public telecommunications operating companies (PTTs) and the public broadcasters by broadcasting in PAL, he also provided more international programming, mainly from the United Kingdom and the United States, to Europeans than the public broadcasters had been willing to provide. Thus, many Europeans bought satellite dishes or subscribed to cable services offering the Sky channels in order to get access to greater variety in programming.[40]

When Sky Television merged with British Satellite Broadcasting (BSB) at the end of 1990, the new company, British Sky Broadcasting, announced that it would continue to broadcast in PAL and would drop BSB's former plans to convert its signals to MAC. Since that time, Murdoch, together with his European allies, has argued against efforts of the European Community to require all high-powered satellite broadcasters to adopt the MAC standard. The counterargument of MAC supporters has always been that PAL is incapable of being upgraded to high definition, and that failure to enforce uniformity of broadcast standards will confuse consumers and disrupt the future market for HD-MAC products. In essence, the argument is about whether the already rather large investments in developing HD-MAC technologies should be written off. Predictably, those who have made the investments say no.[41]

Because the Europeans are now firmly committed to HD-MAC and the Japanese are committed to Hi-Vision, the only remaining question in the area of standards is whether the United States will adopt either of these standards or whether it will go its own way. The answer to this question will be given at the end of a standard-setting process still going on under the aegis of the Federal Com-

munications Commission (FCC). If the FCC process arrives at an agreed HDTV standard for the United States, it will do so sometime in 1993. The United States will very likely adopt a third standard incompatible with both the Japanese and European standards, based on a digital version of HDTV technology. It will do so not just because the United States is worried about competitiveness in electronics, but also because neither the Japanese nor the European approach is compatible with the U.S. broadcasting environment (the large number and political power of local broadcasters and cable operators is a key factor here). All the world's equipment makers and program producers, including those in the developing world, will have to adapt their strategies accordingly.

U.S. Reentry into Consumer Electronics Markets

Should U.S. firms reenter markets for the next generation of consumer products? 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). As already argued, there were substantial costs 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 and the Asian NIEs 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 the right vehicle for reentry into consumer markets? Since HDTV requires important advances in integrated circuit and display technologies and because 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."[42]

U.S. reentry via HDTV in the context of Japanese domination of global markets is not likely to be easy for the following reasons: (a) the U.S. market is open, whereas the markets of Europe and Asia are not; (b) there is only one major U.S. firm in high-volume consumer markets; (c) U.S. consumer circuitry production is weak; and (d) U.S. electronics firms are less vertically integrated than those of Europe and Asia. Only the first two points are elaborated on below.

Prices, and therefore profit margins, in the United States have been notoriously low in consumer electronics for all major producers since the 1970s. There is clearly more competition in U.S. markets than in Europe and Japan. This is one of the main reasons why U.S. electronics firms left 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 enforcing 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.

The three biggest high-volume consumer electronics producers in the United States are Thomson, Zenith, and Philips. These three firms control about 50 percent of the U.S. market for televisions. Thomson is French, Philips is Dutch, Zenith is from the United States. Zenith has been losing money in consumer electronics markets for a number of years. Thomson has many advantages in its competition with Japanese firms: (a) a relatively sheltered home market in Europe, (b) the considerable technological resources of its acquisitions in the United States (the old RCA and GE consumer divisions), and (c) its status as a highly diversified, global corporation with the backing of the French government. The main strength of Philips is in 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 few years and have suffered from heavier 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 Hi-Vision standard has been in place since 1984. Japanese firms have all 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. As will be discussed below, the United States is very likely to adopt a digital approach to HDTV that will be incompatible with the analog approaches adopted in Japan and Europe.

A Digital HDTV Standard for the United States?

HDTV standards have been set already in Japan and Europe. The Japanese Hi-Vision standard is incompatible with the European standard, HD-MAC. Both rely primarily on direct broadcast satellites (DBSs) for delivery of HDTV signals. Both are analog standards, in that satellite transmission of HDTV signals requires analog rather than digital encoding of video information (in both standards, the audio is digitally encoded). A variety of HDTV standards have been proposed to the Federal Communications Commission (FCC) for the United States. An organization called the Advanced Television Testing Center (ATTC) began testing proposed HDTV systems in the summer of 1991. The ATTC testing process should be completed sometime in 1993. The FCC will base its decisions on HDTV standards on the results of the ATTC testing process. The lateness of standard-setting in the United States is not necessarily a disadvantage, as the United States is likely to select a standard based on digital HDTV technologies.

It was partly as a result of the embarrassing conflict with the Europeans at the Dubrovnik meeting in 1986 that U.S. officials began to question the wisdom of adopting Japanese production standards for HDTV. The very 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 television 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 television channels. Thus was born the "simulcast" approach adopted by the FCC for the U.S. HDTV standards.[43]

A number of companies and laboratories proposed HDTV systems for the United States, the most important of which were (a) the ACTV and ADTV systems proposed by a consortium made up of the North American Philips Corporation, Thomson Consumer Electronics, NBC, and the David Sarnoff Research Center in Princeton, New Jersey; (b) the Spectrum Compatible system proposed by Zenith and AT&T; (c) the Narrow MUSE system proposed by NHK; and (d) the all digital system proposed by the American Television Alliance (MIT and General Instruments).[44]

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 rather left it up to Thomson USA in collaboration with the Sarnoff Center to come up with a North American answer. Eventually Thomson and Philips teamed up to present a "European" alternative to NHK's "Japanese" solution. The NHK solution was simply to shoehorn the MUSE encoded Hi-Vision signals to fit into the 6 megahertz channels that the FCC insisted on preserving.

As the time came to test the major proposed systems, the FCC, and particularly FCC Chairman Alfred Sikes, expressed a strong preference for all-digital systems. Since both the Japanese Hi-Vision and European HD-MAC standards are analog systems, the U.S. system will necessarily be quite different. It is not clear yet whether the digital approach will work, but Chairman Sikes has leaned strongly in this direction in hopes 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 U.S. market, no matter what standard is selected.

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 U.S. 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.

Conclusion

Consumer electronics markets have experienced rapid growth and technological change. Those countries—primarily Japan and the Asian NIEs—that understood the importance of consumer electronics as a generator of wealth, jobs, exports, and technology did well for themselves during the last two decades. In the developing world outside Asia, Mexico was the primary beneficiary of North American growth in consumer electronics thanks to the *maquiladora* program. The failure to appreciate the dynamism of the demand for and the technology of consumer electronics badly hurt many European and virtually all the U.S. firms in this industry. The U.S. industry, with the exception of Zenith, had to abandon the field. The European industry consolidated into four major firms: Philips, Thomson, Nokia, and ITT.[45] While Europe is in a much stronger position than the United States in consumer electronics, it remains vulnerable to competition from Japan in high-end products and from lower-wage countries in low-end products.

Consumer electronics markets will become more interesting as the transition is made from the current generation of audio and video products to the next. Because of the large costs connected with developing the underlying technologies for HDTV, developing countries are likely to be excluded from all but the lowest value added activities in these new markets. There may be some exceptions among the NIEs (in Korea, for example).

There will continue to be rapid growth in demand for the current generation of products in the developing world and in Eastern and Central Europe. Developing countries may play an important role in developing new forms of personal electronics suited to their own environment. Finally, it will always be wise to search for small market niches which the firms of the developed countries are unwilling or unable to exploit. Enterprises in the developing countries may find some consolation in the likelihood that they will not be alone in having to search for the unappreciated niche markets for opportunities. Most U.S. firms will be in the same boat.

Notes

1. *Consumer Europe 1988* (London: Euromonitor, 1988), pp. 394–49.
2. *Electronic Market Data Book* (Washington, D.C.: Electronic Industries Association, 1988), p. 124.
3. Allen Lenz, "Slimming the U.S. Trade and Current Account Deficits," *The AMEX Bank Review, Special Papers*, No. 16 (October 1988).
4. This figure is based on statistics from the Japanese Ministry of Finance as reported in the *Facts and Figures '91* (Tokyo: Electronic Industries Association of Japan, 1991), pp. 36–37 and 40–41.
5. These figures are according to the Electronic Industries Association of Japan (EIAJ). It should be noted that the EIAJ uses a narrower definition of what constitutes consumer electronics equipment than does the EIA: radios, monochrome televisions, color televisions, video tape recorders, prerecorded disks and tapes, and audio equipment. It does not include home computers or video games, which makes its figures smaller than those of the EIA. Using a different classification, Dataquest estimated that in 1986 consumer electronics accounted for about 17 percent of electronics equipment production in North America, Western Europe, and Japan.
6. 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.
7. 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, Mass., April 1988, p. 18.
8. Mexican National Chamber of Industry and American Chamber of Commerce in Mexico as cited in the *San Francisco Chronicle*, February 29, 1988, p. A6.
9. Larry Rohter, "Plants in Mexico Help Japan to Sell to U.S.," *New York Times*, May 26, 1987, p. 25; John Eckhouse, "Japan Finds Mexico a Profitable 'Back Door' to U.S.," *San Francisco Chronicle*, March 1, 1988, p. A8.
10. All of the chassis for Thomson's televisions are assembled in its plant in Juarez, Mexico. Only cabinets and tubes are manufactured in the United States.
11. The five largest Japanese color television 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.
12. See David Yoffie, *Zenith and the Color Television Fight*, Harvard Business School, Case No. 9-383-070, May 1984 revision.

13. 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, N.Y.: Cornell University Press, 1983), pp. 117-18.
14. Wooster, pp. 162-63. This gradual and incremental improvement of insertion equipment provides an interesting parallel with the incremental improvement of semiconductor manufacturing equipment by Japanese firms later in the 1970s. See Jay S. Stowsky, "Weak Links, Strong Bonds: U.S.-Japanese Competition in Semiconductor Production Equipment," in Chalmers Johnson, Laura D'Andrea Tyson, and John Zysman (eds.), *Politics and Productivity: The Real Story of Why Japan Works* (Cambridge, Mass.: Ballinger, 1989).
15. Wooster, pp. 140 and 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.
16. Wooster, p. 146.
17. Staelin, p. 17.
18. 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*, 2 (1985); James Lardner, *Fast Forward: Hollywood, the Japanese and the VCR Wars* (New York: Norton, 1987).
19. U.S. equipment and tape producers thought that half-inch tape would never be able to match the high-quality standards they expected and they 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 be able to market a video recorder for home use and figured that they did not need to build such equipment to studio- or industrial-level standards. On the battle within Japan between Beta and VHS advocates, see Gregory W. Noble, "The Japanese Industrial Policy Debate," in Stephan Haggard and Chung-in Moon (eds.), *Pacific Dynamics: The International Politics of Industrial Change* (Boulder, Colo.: Westview Press, 1989), pp. 73-77.
20. Presentation by Richard Elkus at a meeting on HDTV at the American Electronics Association, Santa Clara, California, June 6, 1988.
21. Presentation by Richard Elkus 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.
22. See Adam Watson-Brown, "Towards the Triumph of the Matt Black Box," *Intermedia*, 16 (January 1988), p. 24.
23. Data provided to the author by the Semiconductor Industry Association.
24. See Jeffrey A. Hart, "The Origins of the U.S.-Japan Semiconductor Dispute," in Stephan Haggard and Chung-in Moon (eds.), *Pacific Dynamics* (Boulder, Colo.: Westview, 1989).
25. This argument is made most convincingly in Michael Borrus, *Competing for Control* (Cambridge, Mass.: Ballinger, 1988).
26. U.S. International Trade Commissioin, *Liquid Crystal Display Television Receivers from Japan*, USITC Publication 2042, Washington, D.C., December 1987; Michael Borrus and Jeffrey A. Hart, "Display's the Thing: The Real Stakes in the Conflict over High-Resolution Displays," Working Paper 52, Berkeley Roundtable on the International Economy, March 1992.
27. Borrus and Hart.
28. *Facts and Figures on the Japanese Electronics Industry* (Tokyo: Electronic Industries Association of Japan, 1988), p. 51.
29. See, for example, Alan Cawson, Peter Holmes, and Anne Stevens, "The Interaction Between Firms and the State in France: The Telecommunications and Consumer Electronics Sectors," in Stephen Wilks and Maurice Wright (eds.), *Comparative Government-Industry Relations* (Oxford: Clarendon Press, 1987); Rhonda J. Crane, *The Politics of International Standards: France and the Color TV War* (Norwood, N.J.: Ablex, 1979).
30. Interview with a representative of the Electronic Industries Association of Japan in Düsseldorf, Germany, June 1987.
31. *Japan Electronics Almanac 1989* (Tokyo: Dempa, 1989), Chapter 9.
32. "N.V. Philips Enters China Color TV Tube Venture," *Electronic News*, November 23, 1987, p. 7.
33. NTSC images have only 525 lines, while PAL and SECAM images have 625. Scanning rates for NTSC images are 60 per second, while those for PAL and SECAM are 50 per second.
34. Eureka began in July 1985 with the membership of 19 European nations as a way of pooling research efforts across Europe. Eureka was seen as a less bureaucratic alternative to the mechanisms established by the European Commission to conduct joint European research in high technology. It was also, to some degree, a response to inducements from the Reagan Administration to involve Europeans in research for the Strategic Defense Initiative.
35. This decision is labeled 89/337/EEC in European Community documentation. It states five objectives: (a) making sure that European industry develops all the technology needed for HDTV services, (b) promoting the adoption of 1250/50 as a global standard, (c) promoting the widespread use of 1250/50 globally, (d) promoting the introduction of HDTV services in Europe as soon as possible after 1992, and (e) making every effort to ensure that the European film and production industry occupy a competitive position in the HDTV world market. For commentary, see Adam Watson-Brown, "Hype, Hope & Clarity," *Television: Journal of the Royal Television Society*, November/December 1989, pp. 312-15.
36. Philips plans to invest 11 billion francs, Thomson 9 billion. See Office of Technology Assessment, *The Big Picture, HDTV and High-Resolution Systems* (Washington, D.C.: U.S. Government Printing Office, June 1990), pp. 32-34; Patrick Samuel, "High-Definition Television: A Major Stake for Europe," in John F. Rice (ed.), *HDTV: The Politics, Policies, and Economics of Tomorrow's Television* (New York: Union Square Press, 1990); and William Sweet, "Future of Electronics Companies at Stake in De-

velopment of New TV Systems," *Physics Today*, 44 (March 1991), pp. 57-61.

37. "HD-MAC" is frequently used synonymously with "1250/50" in discussion of the European HDTV standard because HD-MAC, which is a transmission and reception standard, requires a studio or production format of 1,250 lines per frame and 50 frames per second. To be more accurate, however, one should note that the 1,250/50 production format may produce digital signals that have not been encoded by HD-MAC encoding methods. The reader should keep this distinction in mind, especially in the section on the case of HDTV Fine Arts Production.

38. See Ronald K. Jurgen, "Chasing Japan in the HDTV Race," *IEEE Spectrum*, October 1991, p. 28; Adam Watson-Brown, "The Campaign for High Definition Television: A Case Study in Triad Power," *Euro-Asia Business Review*, 6 (April 1987), pp. 3-11; Adam Watson-Brown, "Towards the Triumph of the Matt Black Box," *Intermedia*, 16 (January 1988), pp. 21-24; and "How Soon the Super Telly," *Economist* (January 30, 1988), p. 70.

39. PALplus is an improved definition version of PAL, which makes the image clearer by correcting errors introduced in transmission of PAL signals. WidePAL is an enhanced definition version of PAL, which makes the image wider by moving from the current 4-to-3 aspect ratio to the 16-to-9 aspect ratio of HDTV, but without great increases in picture resolution.

40. I am indebted to Adam Watson-Brown and Hans Kleinsteuber for explaining these details to me. See also Alan Cawson, "The Politics of Consumer Electronics: The British and European Industry in the 1970s and 1980s," rough draft of a unit produced for the Open University Social Sciences course Running the Country, University of Sussex, September 1990.

41. Interview materials; Jeffrey Hart and John Thomas, "Corporatism for Competitiveness? Tracing Policy Networks in the New European Community," unpublished manuscript, Indiana University, Bloomington, February 1992.

42. For elaboration of these points, see Jeffrey A. Hart, *Strategic Impacts of High Definition Television for U.S. Manufacturing* (Ann Arbor, Mich.: National Center for Manufacturing Sciences, September 1989), p. 42.

43. The simulcast approach means that all broadcasters would be allocated two 6-megahertz channels, one to continue broadcasting NTSC signals and the other for HDTV. People with NTSC receivers do not have to scrap their sets or buy downconverters, while people buying new televisions have an incentive to buy an HDTV set.

44. See William Sweet, "Future of Electronics Companies at Stake in Development of New TV Systems," *Physics Today*, 44 (March 1991), p. 57.

45. Although ITT is nominally a U.S.-owned corporation headquartered in the Bahamas, its operations and personnel are heavily oriented toward Europe.