Inventing the Electronic Century

THE EPIC STORY OF THE CONSUMER ELECTRONICS AND COMPUTER INDUSTRIES

Alfred D. Chandler Jr.

with the assistance of
Takashi Hikino and Andrew von Nordenflycht

Ch. 1 Introduction
Ch. 2 Consumer Electronics – U.S.

The Free Press
New York London Toronto Sydney Singapore

were among several of the major industries that shaped the Industrial Age, consumer electronics and computers were the primary reshapers of life and work during the second half of the twentieth century.

Because the evolution of the electronic-based industries was historically unique, because they have so changed the ways of life and work since World War II, and because their story remains almost unrecorded, I decided with Robert Wallace, Senior Editor of the Free Press, to publish two separate books, Book One on consumer electronics and computers, and Book Two on chemicals and pharmaceuticals.

Of the four major electronics industries, I chose to focus on consumer electronics and computers rather than on telecommunications and industrial electronics. Telecommunications had had a long history before the coming of electronics. Established in the 1880s, it was one of the major industries that laid the foundations of the Industrial Age. Moreover, the operations of telephone systems were, until the latter part of the twentieth century, government monopolies or, in the case of the United States, a government-regulated natural monopoly. The evolution of industrial electronics had a less unique pattern of evolutionary growth and less obvious impact on everyday life and work than consumer electronics and computers.

The decision to write a book on these two industries had risks. It meant that I had to accept the hazards of writing about current events rather than history, thus depriving myself as a historian of the advantage of knowing how the story came out. Indeed, a significant part of the epic told here occurred after I began recording this story in the early 1990s. Moreover, my understanding of the details of the technologies adopted was almost nonexistent. Nevertheless, to be the first to have the privilege of recording this epic story outweighed the risks.

This initial sketch of the evolution of these two industries world-wide will certainly be filled in, reshaped, and reinterpreted as historians, economists, and other researchers focus on the histories of the two. But the epic story remains. The basic infrastructure of these two increasingly technologically integrated industries was completed by the beginning of the twenty-first century, which I refer to as the Electronic Century. That infrastructure was the product of the successes and failures of a small number of players during the crucible of the competitive battles of the 1970s and 1980s. Those crucial battles—which resulted in Japan's conquest of world markets in consumer electronics, Japan's continuing challenge to the United States in information technology, and the collapse of both industries in Europe—have and will continue to shape the competitive landscape of the two industries in the Electronic Century.

1

INTRODUCTION:

CONCEPTS AND APPROACH

Consider the title. "The Electronic Century" is the twenty-first century. The "inventing" refers to the creation of the technological and institutional foundations—the "infrastructure"—during the latter decades of the twentieth century, which was the Industrial Century.

Inventing the infrastructure for the Electronic Century became an epic story because some national industries died while others conquered. By the end of the twentieth century, no European-owned and -operated enterprise had the capabilities of commercializing—that is, bringing into widespread public use—major new products of either consumer electronics or computer hardware with their essential software technologies. In the United States, no enterprise had the capability to commercialize new consumer electronics technologies. On the other hand, in Japan, the four leading enterprises in consumer electronics had conquered world markets. And the five leading Japanese computer companies were seriously challenging the U.S. computer industry worldwide.

This epic story of the consumer electronics and computer industries has its tragic aspects. By the time the infrastructure of the Electronic Century was completed, Europe had lost both its computer and consumer electronics industries, and the United States no longer had its consumer electronics industry, with all that this meant in terms of employment and the growth of ancillary and supporting industries. In addition, RCA's Princeton Laboratories had been dismantled, and only remnants of Philips's once great electronics laboratories at Eindhoven remained. Of the three primary builders of the technological foundations of the consumer electronics industry, only Sony remained.

The epic story also has its heroic achievements. The worldwide triumph of the Japanese consumer electronics industry took place in a period of less than a decade, 1975 to 1985, largely on the basis of technologies developed by the Sony Corporation. In this same astonishingly brief period, Japan's computer makers had become Europe's dominant suppliers of large computer systems and had captured the U.S. market in memory chips.

International Business Machines (IBM) provides another epic in terms of defining the computer industry's products. In large computer systems its most successful competitors were those enterprises that produced and sold IBM-designed "plug-compatible" hardware and "unbundled" software. In personal computers they were those that made and sold IBM clones.

The concepts and approach I use to understand and explain the evolving historical story follow.

Basic Concepts

In market economies the competitive strengths of industrial firms rest on learned organizational capabilities. That is my basic premise—a premise that is based on the findings of this historical study. The capabilities are product-specific in terms of technologies used and markets served. These product-specific capabilities are learned and embodied in an organizational setting. Individuals come and go, but the organization remains. Thus, in modern industrial economies the large firm performs its critical role in the evolution of industries not merely as a unit carrying out transactions on the basis of information flows, but, more importantly, as a creator and repository of product-specific embedded organizational knowledge.

The process of organizational learning in industrial enterprises begins with the building of a viable profit-making enterprise, and this is done

through the creation of organizational capabilities based on three types of knowledge—technical, functional, and managerial.

1. Technical capabilities are those learned by applying existing and new scientific and engineering knowledge. Such capabilities include those in well-defined scientific and engineering disciplines, professional organizations, and the like. Technical capabilities are knowledge related. They involve the knowledge used in basic and applied research to create new products and processes. They are the capabilities required for the R in R&D.

2. Functional knowledge, on the other hand, is product-specific. It results in organizational capabilities of the following kinds:

Development capabilities. These are created by learning the product-specific know-how required to transform an innovation into a commercial product to be sold in national and international markets. These capabilities are the D of R&D.

Production capabilities. These come from learning how to build and operate large-volume production facilities for the new product and to recruit and train the labor force essential to operating these facilities efficiently. A somewhat similar but less important set of capabilities is that of purchasing in volume the necessary materials for production.

Marketing capabilities. These are acquired in learning the nature of the product's markets and building extensive distribution systems to reach them.

The evolving relationship between technical and functional capabilities is a basic theme of this study. In addition to those two major types, there is one more:

3. Managerial capabilities. This third set of organizational capabilities, based on management knowledge and experience, is essential to the creation and continued existence of a viable profit-making enterprise. These capabilities are learned in order to administer the activities of the functional operating units, to integrate their activities, and to coordinate the flow of goods from the suppliers of raw materials through the processes of production and distribution to the retailers and final customers. Most essential to the successful maintenance of the long-term health and growth of the enterprise are the learned capabilities of *top* management. These managers make the critical decisions in allocating personnel and financial resources that determine the fate of an enterprise and often of the entire industry of the country in which it operates.

As important as managerial capabilities are, they are not a central focus of my two books that go under the blanket title *Paths of Learning*. One reason is the difficulty in generalizing about managerial capabilities. They are affected by different types of operating structures, national educational systems, and broader cultural patterns in which they have been learned and in which their enterprises have evolved. So capabilities differ from nation to nation, industry to industry, and often from company to company in the same industry. For example, the broader environment in which Japanese managers learn and work is quite unlike that in the United States and Europe.

The first enterprises whose managers learn to develop, produce, and sell in national and then world markets—that is to *commercialize*, to bring to market, a product of new technical learning—become the initial builders of the high-technology industries whose evolution is the subject of both volumes. I term such enterprises *first-movers*. They were not necessarily the first to produce and sell the new product. They were the first to develop an integrated set of functional capabilities essential to commercialize the new product in volume for worldwide markets.

Once the new enterprise's competitive power has been tested, its set of integrated organizational capabilities becomes a *learning base* for improving existing products and processes and for developing new ones in response to changes in technical knowledge and markets, and in response to macroeconomic developments, including wars and depressions.

Besides having the learning base, these firms as first-movers have available their retained earnings (one of the cheapest sources of long-term capital) for investment to expand and improve their facilities and personnel.

The creation of such an integrated learning base in a technologically new industry, together with the resulting continuing flow of funds, creates a powerful *barrier to entry*. Start-up firms have to begin to develop their basic set of capabilities while competing with first-movers who are enhancing their operations through continuing learning and through income from the sale of their initial products. Within each national economy only a small number of challengers succeed in building comparable learning bases. The first-movers and their successful challengers become what I term an industry's *core companies*.

Once these core companies establish a viable national industry, entrepreneurial start-ups are rarely able to enter. Instead, the core companies' competitors are either foreign core companies or domestic core companies in other industries—that is, industries with comparable technical knowledge and/or processes of production, distribution, or product development.

First-movers, of course, cannot create an industry by themselves. They have to develop close relationships with supporting enterprises—with suppliers both of capital equipment and materials to be processed, with research specialists, distributors, advertisers, and providers of financial, technical, and other services. Thus the needs of the core firms lead to the creation of a supporting *nexus*—interconnected and complementary (rather than competitive). The nexus may contain small, medium, and even large firms in supporting lines of products and services. It soon becomes a source for the creation of numerous "niche" firms, but only rarely do core companies emerge from the nexus.

In this way the competitive strength of national industries depends on the abilities of the core firms to function effectively and to maintain and enhance their integrated learning bases. If those bases begin to deteriorate, so too does the industry's supporting nexus and its competitive strength versus that of other countries.

Once an industry is established, however, learning continues with powerful momentum. The integrated learning bases of the first-movers become the primary engines for the continuing evolution of their industry through the commercializing of new technical knowledge. The integrated learning base embodies within the enterprise the procedures to integrate the enterprises' technical and functional organizational capabilities—to integrate and to coordinate those of applied research, product development, production, and marketing. The development of such integrating and coordinating procedures becomes a basic function of top management if the enterprise is to benefit from the internal economies of scale and scope and continuing advances in proprietary knowledge. Such integrated learning bases thus define an industry's continuing path of organizational learning. They set the direction in which an industry evolves.

The learning base not only sets the direction, but also, because of barriers to entry, defines the *boundaries* of the path. The concentrated power of technical and functional knowledge embedded in the first-movers' integrated learning bases is such that only a small number of enterprises defines the evolving paths of learning in which the products of new technical knowledge are commercialized for widespread public use.

The Approach–The Paths of Learning

My basic purpose in this volume is to carry out the fundamental task of the historian: to record where, when, how, and by whom technical knowledge was commercialized into the new products that laid the foundation for the Electronic Century and, in so doing, transformed life and work in the second half of the twentieth century. I chronicle the evolution of the new high-tech industries from their beginnings by the first-movers until the end of the twentieth century. I do this by focusing on the competitive success and failure of the national industries in Europe, the United States, and Japan. The continuing evolution of both consumer electronics and computers resulted from continuous learning in the commercializing of new technologies and enhancing of existing ones. To repeat: The initial first-movers who created their learning bases had competitive advantages by being first in developing their technical and functional capabilities that provided barriers to entry.

The Evolving Paths in Consumer Electronics

In consumer electronics, the commercializing of a new technology was based on the learning that created the previous innovation. The first-movers in radio were the Radio Corporation of America (RCA), a joint venture of the three leading United States producers of electrical and telecommunications equipment, and the German company Telefunken, a joint venture of the two foremost producers in Europe. They led the way in commercializing radio in the 1920s. The same two companies began the process of commercializing television in the 1930s. Telefunken, housed in Berlin, lost its learning base during World War II. So in the 1940s RCA took the lead in commercializing black-and-white television. In the 1950s it became solely responsible for the introduction of color television. Then in the late 1960s and early 1970s, the two Japanese first-movers, Matsushita and Sony, and the Dutch company Philips, all of which had created strong learning bases after World War II, began to move into global markets. Philips's home market was small, but its impressive learning base defined the evolution of consumer electronics in Europe.

In the late 1960s the remaining four of these first-movers (RCA, Matsushita, Sony, Philips) began a race to commercialize the videocassette recorder (VCR), a market that television had created. Matsushita's Video

Home System (VHS) captured the world market on the strength of that firm's functional capabilities. The failure of RCA's videodisk contributed to the company's collapse and with it the collapse of the U.S. national industry whose path it had defined. Although Sony and Philips had lost to Matsushita in the VCR battle, they, because of their technical capabilities, defined the evolving path of learning based on a disk technology. Together they commercialized the audio compact disk (CD) and the compact disk-read only memory (CD-ROM) and, again with Philips, the digital videodisk (DVD).

By the 1990s Philips's functional capabilities were unable to meet the Japanese competition. Its technical capabilities had been weakened by the failure of its attempt to commercialize a new video product on its own, the CD-interactive (CDi). So by the late 1990s Philips could no longer commercialize major new consumer electronics products. By then the Japanese first-movers and followers and their strong supporting nexus completely dominated markets worldwide. By then only Japanese companies had the integrated technical and functional capabilities required to commercialize products of new technologies.

The Evolving Paths of Learning in Computers

The evolution of the digital data-processing computer industry differed sharply from that of the consumer electronics industry. In consumer electronics, the managers of five enterprises—Telefunken, RCA, Philips, Matsushita, and Sony—determined the direction in which the industry's paths of learning evolved from its beginnings in the 1920s until the 1990s. But in computers, the managers of a single firm, IBM, played a determining role from the industry's beginning in the 1950s to the 1990s.

When the computer was invented, IBM was already the world's largest producer of punched-card tabulators, the most advanced data-processing device prior to computers. The company became the new electronic computer industry's first-mover in commercial markets, when in 1954 it applied an electronic device to its previously electrically driven punched-card data processors. Within less than a decade, its long-established punched-card functional capabilities in product development, production, and marketing, learned over three decades, permitted its new product, the mainframe computer, to capture close to 80 percent of the world's markets.

On the basis of the continuing learning and high financial returns, IBM developed its System 360, which in terms of prices charged and performance expected was a full line of compatible mainframe computers, primarily for commercial and business markets. The commercializing of the System 360 required half a decade, at the cost of nearly $7 billion. That extraordinary learning experience immediately defined the computer industry worldwide. By the 1970s, with its System 360 and its successor, the System 370, IBM was competing at home and abroad with companies that primarily produced "plug-compatible" products based on IBM-licensed hardware and IBM-licensed software. By the end of the decade the European computer makers were buying their IBM imitations from Japan.

In the mid-1960s, when IBM was concentrating on developing the Sys-tem 360, Kenneth Olsen's Digital Equipment Corporation created a second path of computer learning by commercializing an inexpensive, stripped-down "minicomputer" for more specialized and smaller engineering and sci-entific markets. Within a brief period a small number of followers entered the new path.

Then in the 1980s the microprocessor transformed the industry with the introduction of computers for use by individuals rather than corporations or other large institutions. Here again, IBM defined the recast industry by be-ing the first to mass-produce and mass-market its personal computer (PC). By the end of the 1980s IBM's PC, its clones, and their two primary suppli-ers, Intel (microprocessors) and Microsoft (operating system software), had defined the computer industry as effectively as the IBM 360/370 and its plug-compatibles had done in the 1970s. Soon IBM was only one of a siz-able number of personal computer makers. But because every IBM PC and its clones had to use an Intel processor and a Microsoft operating system, those two companies became the path definers in personal computers in the 1980s.

The inability of the British, French, Italian, and then German companies to compete with IBM's mainframes and the plug-compatibles in the 1970s and IBM and its PC clones in the 1980s brought the death of the European industries. On the other hand, the ability of the Japanese to produce and im-prove competitive IBM plug-compatible mainframes in the 1970s permitted them to take over their own domestic market and then that of Europe for large systems. Although the Japanese industry lost out in personal comput-ers, their strength in large systems permitted them to meet the greatly in-creased demand for computing power called for in the 1990s. This demand

for more power grew out of the coming of private networking systems for cor-porations and other institutions and the coming of the public Internet. Those developments enabled the Japanese to become and remain effective challengers to the U.S. industry.

Chart 1:1 indicates the evolutionary paths of learning within the con-sumer electronics and the computer industries. The chart's classifications are comparable (but not identical, because they are my classifications) to the Standard Industrial Classification (SIC) of the U.S. Office of Management and Budget, in which a product sector is defined by four numbers. The first two indicate the large industrial category in which it belongs. The third number indicates an industry within that category, and the fourth, the prod-uct sector within that industry.

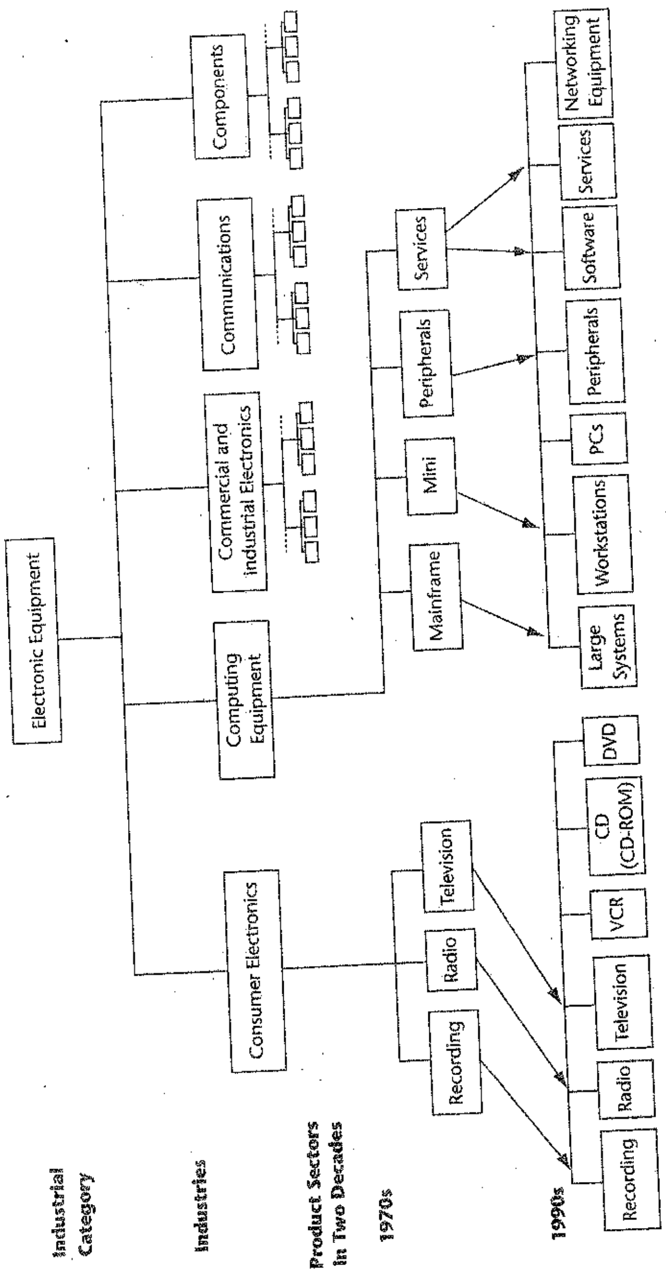
In the consumer electronics industry, radio and television (including color television) were still the leading sectors in 1970. By then RCA and the two Japanese leaders had already entered the recording industry, the one long-existing preelectronic sector, based on the vinyl disk. By 1990 the VCR, the CD (and CD-ROM), and the DVD had become major product sectors.

In computers, the mainframe and minicomputer were the primary prod-uct sectors in 1970. By then the growing activities to which the new com-puter could be applied and the complexities of its operation led to the beginning of a third, nonmanufacturing sector, services.

In the early 1980s the coming of the microprocessor and IBM's mass pro-duction and mass marketing of the personal computer opened up a huge new market for commercial purposes as well as a new one for the home. The resulting massive expansion of the industry led to the formation of new prod-uct sectors—personal computers, peripherals, and operating system and ap-plication software. At the same time, the producers of minicomputers used the microprocessor to develop the workstation for its engineering and scien-tific customers. The new array of product sectors that existed in the 1990s is shown as the bottom row in the chart.

Within a sector, therefore, the learning base of a successful profit-making enterprise, either as a division within a multisector corporation or as an inde-pendent company, tied a specific technology to a broad national and inter-national market. The enterprise had embedded within it the technical capabilities needed to commercialize products of new technology. Embed-ded, too, were the basic functional capabilities—product development, pro-duction, and distribution and marketing—that were needed in order to

CHART 1.1. "Paths of Learning"
Electronics Industries and Product Sectors, 1970s and 1990s



continue to improve existing products and processes and to maintain the company's long-term share of its markets.

A Unique Epic in Industrial and Business History

The evolution of the consumer electronics and computer industries has been historically unique. It differs from the evolution of the capital-intensive and technologically advanced industries that during the last two decades of the nineteenth century and into the twentieth century had laid the foundations for the Industrial Century. Those earlier industries were based on a number of basic technological innovations: the electricity-producing dynamo, which brought the electric lighting that transformed urban life, and electric power, which so transformed industrial production techniques; the telephone, which brought the first voice transmission over distances; the internal combustion engine, which produced the automobile and the airplane; the new chemical technologies that permitted the production of man-made dyes and, of more significance, a wide range of man-made therapeutic drugs; and other man-made materials ranging from silicon and aluminum to a wide variety of plastics.

In these industries a small number of core companies—first-movers and their followers—created national industries that competed for worldwide markets. In electric light and power equipment, the U.S. and German first-movers led the way. Others soon followed in other European nations and Japan. In metals, the Aluminum Company of America built a monopoly in the United States; but it had effective competition from European counterparts. In motor vehicles, Ford was the initial path definer, but General Motors replaced it in the 1920s and was in turn replaced by the Japanese leaders in the 1970s. Nevertheless, the U.S. motor vehicle industry revived as a strong competitor and the European producers lived on. In electrical and telecommunications equipment, the U.S. and German first-movers continue to dominate, but followers appeared in other European nations, including Sweden and Switzerland, and continue to do so today. In chemicals and pharmaceuticals, the initial German and Swiss leaders were shortly challenged by American companies and those of other European nations.

In none of these industries did a single enterprise become the definer of its national industry's evolving paths of learning in the manner of RCA and IBM in consumer electronics and computers. Nor did a single national industry conquer the world as Japan did in consumer electronics through the elimination of the competing national industries. Nor did two national industries dominate world markets in the manner of the U.S. and Japanese computer industries. The point is that the national industries that invented the infrastructure for the Industrial Century did not compete, conquer, or die in the manner of the national industries that created the infrastructure of the Electronic Century.

The underlying reason for these differences is clear. The creation of the infrastructure for the Industrial Century rested on a broad variety of technological innovations. The unique epic story of the consumer electronics and computer industries was based on the invention of four small, closely related electronic devices—the vacuum tube, the transistor, the integrated circuit, and the microprocessor.

2

CONSUMER ELECTRONICS: THE UNITED STATES—THE CREATION AND DESTRUCTION OF A NATIONAL INDUSTRY

I begin with consumer electronics because it came first, before computers. It began in the first and second decades of the twentieth century. I also begin with consumer electronics because it dramatically defines the causes of the success and/or failure of national industries. Indeed, it was the management decisions at the Radio Corporation of America in New York that led to the creation and then destruction of the U.S. industry. Those decisions made by the managers of Matsushita and Sony in Tokyo were responsible for Japan's global conquest.

Moreover, the evolutionary story illustrates in a straightforward manner the significance of cumulative learning, as the commercializing of one technology becomes based on the learning acquired in commercializing the previous one. The radio sector, appearing in the 1920s, evolved from the learning acquired in the initial commercializing of modern electrical and telephone equipment in the 1890s. The technical knowledge learned in commercializing the radio, in turn, laid the foundations for the commercializing of television in the 1940s and 1950s. That knowledge, in turn, provided the base for the innovative tape and disk technologies of the 1970s and

1980s. The one preelectronic sector in what became the consumer electronics industry was recordings, based on the phonograph. The phonograph, like so many electrical and telecommunications devices, evolved from the inventions of Thomas Edison.

The critical turning point in the evolution of the global consumer electronics industry came with the battle of the four first-movers—RCA, Europe's Philips Incandescent Lamp Works, and Japan's Matsushita Electric Industrial and Sony Corporation—to commercialize the videocassette recorder for world markets. RCA's defeat in this contest marked the demise of the U.S. consumer electronics industry and the dawn of Japan's hegemony. For that reason, chapter 2 takes the U.S. story up to the global VCR contest and then concludes with a brief consideration of the causes of the industry's death. Chapter 3 begins with a brief outline of the history of Matsushita and Sony before the VCR battle and then reviews the highlights of that battle and its broader impact on Japan's industry. The chapter concludes with a review of the ingredients of Japan's paths to global conquest.

Creating the American Learning Base

The initial radio technology was the two-way wireless telegraph invented by the Italian Guglielmo Marconi, first demonstrated in 1899 and based on a spark transmitter that could send only telegraph-type signals. Marconi then formed the Marconi Wireless Company with headquarters in London. In 1904 the two German leaders, Siemens & Halske AG (Siemens) and Allgemeine Elektricitäts-Gesellschaft (AEG), formed Telefunken to commercialize the new spark transmitter technology. Somewhat later, amateur hobbyists began to use the technology to communicate with each other on homemade "crystal sets," much as hobbyists in the late 1970s began to use the microprocessor to build their own computers.

It was, however, the continuous wave voice transmission technology, powered by the electronic vacuum tube that replaced the spark transmitter. It did so because it could transmit continuous voice and other sound, which brought into being the radio broadcasting and receiving industry. That technology began to evolve during the second decade of the twentieth century. In its evolution in Europe, Telefunken played the major role, Marconi only a minor one.

In the United States the technology emerged from the U.S. counterparts

to the German pioneers, General Electric (GE), American Telephone and Telegraph (AT&T), and Westinghouse. General Electric contributions came before and during World War I, largely through the efforts of Irving Langmuir and his associates to improve the light bulb and the X-ray tube, both of which the company had been producing since the 1890s. At AT&T Lee DeForest's work on a line amplifier to improve long-distance telephony research led to commercializing the Audion tube. At Westinghouse technical capabilities came more from its World War I–related production of electronic tubes and voice transmittal equipment developed by GE, AT&T, and an independent inventor, Reginald Fessenden, than from its own inventions. In March 1921, Westinghouse and AT&T joined GE to use GE's newly formed Radio Corporation of America as a patent pool. One of RCA's initial purposes was to hold and allocate radio-related patents.[1]

RCA, which over time became independent from its sponsors, led the way under the guidance of David Sarnoff to the commercializing of the vacuum tube–based equipment for radio broadcasting and receiving, then to commercializing black-and-white television, and after World War II to the broadcasting and receiving of color television. So I begin the history of the U.S. consumer electronics industry with the coming of RCA.

RCA Created

RCA's formation was a complex affair. Its story begins in October 1919 when Owen D. Young, General Electric's general counsel and vice president, working with senior naval officers, acquired for $3.5 million the Marconi Wireless Company of America, a U.S. subsidiary of the British-owned and British-managed Marconi Wireless and Signal Company. Wireless spark technology for ship-to-ship and ship-to-shore transmissions had greatly increased in importance during World War I. The U.S. Navy wanted to assure that further research and production as well as operational learning would be in the hands of an American enterprise.[2]

Young next formed the Radio Corporation of America as a GE subsidiary, which then acquired American Marconi (the Marconi Wireless Company of America) and issued five million shares of RCA common stock and three million preferred. He then turned over GE's radio-related patents to the new subsidiary. The twenty-eight-year-old David Sarnoff, who had joined American Marconi in 1911, became its assistant chief engineer in 1913 and rose to commercial manager, a post he continued to hold in GE's new RCA subsidiary. During the war, patenting had been held in check in deference to wartime radio needs. But after war's end in November 1918, the advance of wireless technology and the rapid expansion of the continuous wave technologies brought forth a plethora of patents.

Westinghouse, for example, had begun to manufacture vacuum tubes and was beginning to make small-scale, low-powered radio transmitters and receivers. It made a major move into radio by acquiring the patents of Professor Edwin Armstrong of Columbia University, a leading noncorporate inventor in both the spark transmitting technology and the still-developing vacuum tube continuous wave voice transmitting technology. By that time, too, the company had developed four different types of radio receiving sets. On November 2, 1920, Westinghouse began to operate at its Pittsburgh plant the nation's first broadcasting station, KDKA. That venture resulted from work done earlier on spark technology by Frank Conrad, who headed much of the radio design and development work at Westinghouse during the war. In these same years United Fruit had pushed ahead on wireless technology, using it to link its banana boats with its Central American plantations.[3]

Owen Young believed that the growing number of legal battles over patents could only slow the continuing development of radio technologies. His solution was for RCA, which already held GE's patents and those of the navy, to obtain those of GE's competitors in exchange for obtaining shares of stock in RCA and having representatives on its board. Young delegated David Sarnoff to handle the negotiations. The final agreement was signed in March 1921. GE retained 30.1 percent of RCA's equity, Westinghouse received 20.6 percent, AT&T 10.3 percent, and United Fruit 4.1 percent. The remaining 34.9 percent went primarily to the stockholders of American Marconi, but also to individual patent holders. The U.S. government had no financial or managerial presence in this corporate venture.

According to the March 1921 agreement, AT&T was to concentrate on "radio-telephone" systems and on producing broadcasting transmission equipment. It would purchase other radio equipment from GE and Westinghouse. GE and Westinghouse were to concentrate on radio receivers, and RCA's Marconi unit would continue to focus on wireless spark technology. In addition, RCA would market the receivers produced by GE and Westinghouse under its own label. By this agreement, as pointed out by Hugh Aitken

in his outstanding history of the beginnings of the United States radio industry, RCA "controlled continuous wave technology in the United States as it evolved up to that date. . . . And, beyond this, because it was backed by the formidable scientific and engineering resources of Western Electric, General Electric, and Westinghouse, not to mention the foreign firms such as Marconi, Philips, and Telefunken with which it had signed patent agreements, this group appeared likely to control developments in the future also." Aitken's statement makes clear why the industry remained dominated for the rest of the century by so very few firms.[4]

Young's timing was fortuitous. In March 1921 he and Sarnoff believed that RCA's immediate task was to build the American strength in wireless spark technology. They saw radio broadcasting and receiving based on continuous wave technology as a long-term potential only. Few persons anticipated the latent demand for radio broadcasting. But that demand came with dramatic and transforming speed. In October 1921, seven months after the signing of the agreement, the Department of Commerce licensed Westinghouse's KDKA broadcasting station. Twenty-six licenses were issued in 1922.

Amazing growth followed. By the end of 1923, 556 stations had been licensed. Then, as most of the available frequencies had been allotted, the number of new stations leveled off in 1925. During the next ten years the total number of stations remained between six hundred and seven hundred. These new broadcasting stations were established by a large number of enterprises—RCA, GE, Westinghouse, and other electric machinery makers; a variety of other manufacturers; newspapers; commercial enterprises; and individual entrepreneurs.[5]

With broadcasting facilities assured throughout the nation, hundreds of firms swarmed into this unexpected and swiftly growing market for radio receivers, much as they did in personal computers between 1982 and 1985. Like the personal computers of the early 1980s, radio receiving sets were easy to assemble. Receiver sales rose from $50.3 million in 1923 to $206.7 million in 1926, then dropped back to $181.5 million in 1927 and bounced up to $366.3 million in 1929.

When the radio receiver market leveled off around 1926, the death rate of their producers was even higher than that of personal computer makers when their market stabilized in 1985. According to Rupert Maclaurin, a historian of the radio industry before World War II, of the 648 radio manufacturing companies established during the four years of the boom (1923 to 1926), only 18 were still alive in 1934. Eleven of these had been started in 1923.

What is historically most significant in terms of learned organizational capabilities was that the most successful survivors were existing producers of electrical devices that had built their functional capabilities before the coming of the new radio technologies. Indeed, by the late 1920s the leaders were firms that had been established before 1920. They had been makers of auto batteries (Philco), auto ignition systems (Atwater Kent), telephone equipment (Stromberg Carlson), and light bulbs and electrical equipment (Sylvania and Magnavox). The only long-term survivors of that first boom that were start-ups, with no previous industrial experience, were Zenith and Raytheon in receivers and in tubes respectively. The others had already built their learning bases, integrating production and distribution, and had enjoyed a steady flow of income from their existing businesses that helped to finance a new one.

David Sarnoff's Challenges

For Sarnoff, who had been promoted to RCA's general manager in 1921 at the age of thirty, and to general manager and vice president in 1922, this unexpected explosive growth of radio receiving and broadcasting equipment brought daunting challenges. He remained responsible for maintaining the company's leadership in two-way radio wireless. At the same time, he had to create a marketing organization for the sale of radio receivers produced by Westinghouse and GE. A far more difficult task was to shape a response to the powerful outcry against the new "radio trust" by finding a licensing policy that satisfied the surge of new entrants into the radio broadcasting and receiving markets. Still another challenge was to work out the complex arrangements of the March 1921 agreement with its three major stockholders, AT&T, GE, and Westinghouse, so as to fulfill the unexpected profit potential of the new broadcasting and receiving markets. In meeting these challenges, David Sarnoff, working closely with chairman of the board Owen D. Young, more than any other person shaped RCA and the U.S. radio industry during the 1920s. RCA's president, General James G. Harbord, the retired chief of staff of the American Expeditionary Force in France during World War I, a public figure of high integrity, remained little more than a figurehead.[6]

Of his challenges, the creation of a marketing organization was relatively straightforward. In 1921 RCA had fourteen people in the sales organization. By the end of 1922 Sarnoff had built a nationwide network of more than two hundred distribution outlets. Sales grew from $11 million in 1922 to $50 million in 1924. By 1925 RCA had also built and operated four broadcasting stations.

At first Sarnoff hoped to enforce RCA's patents by allocating its receiving sets, tubes, and components only to distributors that agreed to handle RCA's entire product line, forbidding them to carry radio sets of unauthorized assemblers. The resulting protest immediately brought an investigation in 1922 by the Federal Trade Commission that made public all the details of the complex cross-licensing arrangements involved in RCA's formation. In 1924 the commission followed up its investigation by filing an antitrust suit against RCA.[7]

By then Sarnoff was coming to appreciate the difficulties and the resulting high cost of attempting to monitor patent violations in a swiftly growing industry. In 1927 Sarnoff defined RCA's new licensing policy. The company would liberally license its patents at 7½ percent on the wholesale value of a set. Through a system of "packaged licensing," royalties were paid on patents of all parts in a complete set even if only one was used. As a result, royalties became a major source of RCA's revenues, rising from $136,000 in 1926 to over $3.2 million in 1927, and to a peak of $7 million in 1929 and 1930, before the industry felt the full impact of the Great Depression. As important this all-or-nothing packaged licensing agreement assured continued dominance in the production of components manufactured by GE and Westinghouse, which required more complex and costly equipment than did the assembling of the final radio receiving sets.

Profiting on sales from components, rather than on completed receiving sets, became a standard RCA policy. In radio and then television, RCA's share of the receiving sets dropped quickly as the revenues from licensing fees and from components soared. The licensing revenues provided a major source of funding for RCA's continuing research and development. In addition to shaping RCA's market strategy, packaged licensing satisfied its major competitors. In 1928 the Federal Trade Commission, also satisfied, dropped its antitrust suit.

As Sarnoff and his managers were formulating a licensing policy—and so defining the industry's product standards—they had an even greater challenge in adjusting the March 1921 agreement to the sudden and unexpected transformation of the radio industry. As AT&T's executives had interpreted that agreement, its manufacturing unit, Western Electric, had exclusive rights to produce broadcasting equipment, and GE and Westinghouse had exclusive rights to produce broadcasting receivers and components. GE and Westinghouse, in turn, challenged AT&T's belief that "public telephony for toll" gave AT&T the right to operate broadcasting stations. The companies turned to arbitration in 1923, a process that dragged on until 1926. In the end, the parties agreed that AT&T would retain exclusive rights to public service telephony but "would withdraw from broadcasting; while GE, Westinghouse, and RCA would enjoy exclusive rights in the fields of wireless telegraph, entertainment broadcasting, and the manufacturing of tubes for public sale."[8]

As part of this 1926 agreement, RCA acquired AT&T's broadcasting stations, including its flagship in New York. It then formed the National Broadcasting Company (NBC), into which came the stations of GE and Westinghouse as well. RCA held 50 percent of the equity of the new broadcasting system, General Electric 30 percent, and Westinghouse 20 percent. That network grew from 19 stations in 1926 to 69 in 1929 and to 103 in 1936. From the start Sarnoff divided NBC into two networks, the Red concentrating more on commercial broadcasting and the Blue leaning more toward public service in terms of educational and cultural broadcasting. In 1942 RCA, under pressure from the Federal Communications Commission (FCC), sold the Blue system, which became the independent American Broadcasting Company (ABC).

NBC's major competitor, however, appeared in 1927 less than a year later when the twenty-seven-year-old William S. Paley put together a somewhat smaller network of stations in his Columbia Broadcasting System (CBS). There he followed what had become the RCA strategy of providing programs to local affiliates as a way of assuring advertisers with national audiences. NBC became and remained a major source of income for RCA. As the first-movers in national broadcasting systems, NBC, its spin-off ABC, and CBS long remained the nation's three leading broadcasting networks.

In this manner Sarnoff solidified the position that he and Young had established in 1921. In the words of Rupert Maclaurin, RCA by 1928 "had thus established a strong position in all major branches of the radio industry, and an RCA license was considered essential for the manufacturing of any

up-to-date set or modern vacuum tube. No one challenged this for many years to come."[9] Retained earnings from sales of products still manufactured by GE and Westinghouse, royalties, and radio broadcasting from NBC made RCA the dominant enterprise in the U.S. radio industry. But as yet it did not have its own integrated learning base.

Sarnoff's Drive for Integration and Independence

After 1926 Sarnoff focused on freeing RCA from the control of GE and Westinghouse so that RCA could become a fully integrated industrial enterprise. During the 1920s RCA remained severely handicapped by its dependence on GE and Westinghouse for the design and production of the receiving sets it sold. Indeed, its performance provides a valuable example of the importance of the integration of production and distribution in modern industrial enterprises. Even though its smaller competitors had to pay RCA royalties and, with some exceptions, rely on it for components, they moved more quickly than RCA to meet changing market demands through innovative design and production engineering. Moreover, their smaller size and their smaller investment needs enabled a quicker response. Thus handicapped, RCA saw its share of the U.S. market for receiving sets drop even more than anticipated down to between 18 and 20 percent in the late 1920s. Of much more long-term significance was that it marketed products developed and manufactured only at General Electric and/or Westinghouse. Therefore, RCA did not even have the learning base on which to develop technical and functional capabilities in research, product development, and manufacturing of radio products.

Sarnoff's first move to achieve the necessary integration was to convince RCA's principal owners, GE and Westinghouse, to permit his company to purchase the Victor Talking Machine Company. That firm, a U.S. first-mover, was established in 1901 to commercialize Thomas Edison's invention of the phonograph but had been suffering from radio competition. Victor's managers and Sarnoff saw the potential of combining their closely related radio and phonograph learning paths into a single enterprise. Thus for Sarnoff, the primary attraction of the acquisition was the critical set of facilities that Victor offered. These included its impressive manufacturing facilities in Camden, New Jersey, and its long-established worldwide sales and distribution organization for phonographs and records operated by full-line subsidiaries in Britain, Canada, Latin America, and Japan. Through this acquisition then, RCA entered the only preelectronic sector, a sector dominated since the turn of the century by Victor and one other American company, Columbia Phonograph. In addition, Sarnoff persuaded the senior managers at GE and Westinghouse to turn over their manufacturing facilities and personnel to RCA.

On April 4, 1930, the RCA board approved the acquisition of Victor. At the same time, GE turned over its Harrison tube plant in New Jersey and Westinghouse its lamp works and radio products plant in Indianapolis. RCA also received GE's and Westinghouse's patents and the royalties in the fields of radio equipment, phonographs, and motion pictures. Finally, GE and Westinghouse relinquished their stock holdings in RCA and NBC, and canceled internal loans that they had made to RCA for the purchase of the Victor Company. In exchange, GE and Westinghouse received RCA securities valued at $6.5 million.[10]

With the transactions recorded on April 4, 1930, Sarnoff had achieved his goal of having an integrated independent enterprise with its own product development, production, marketing, and distribution. But RCA still did not have a learning base that integrated the technical and functional capabilities, for these had been learned under the auspices of three different enterprises. For this reason, the managerial staff in the radio production unit at the Indianapolis works, that at the tube and component plant in Harrison, New Jersey, and that of the recording and phonograph activities at Camden, New Jersey, remained relatively independent of one another. Moreover, RCA's only research organization had been part of its small licensing program housed in New York City.

Three weeks after RCA had acquired this worldwide, still to be fully integrated learning base, the U.S. Justice Department indicted it for antitrust violations and thus precipitated the final step in achieving RCA's corporate independence. That step came in November 1932 when RCA, GE, and Westinghouse finally agreed to a consent decree, By that decree, GE and Westinghouse agreed to reduce by one-half RCA's debts to them and to distribute their equity holdings in RCA to their own shareholders. They were to have no representation on the RCA board and were not to compete in radio or related products for two and a half years. Finally, they agreed to give RCA unrestricted, albeit nonexclusive, rights to all of GE's and Westinghouse's radio-related patents. The agreement was an impressive win for Sarnoff. RCA's

complete independence was assured. In addition, RCA retained control of the licenses it held.

The Impact of the Great Depression

By the time the consent decree was signed, RCA, the industry, and the country were engulfed in the nation's most serious economic crisis of the twentieth century. After the stock market crash at the end of 1929, national sales of radio receiving sets fell from $842.5 million in 1929 to $300 million in 1934. Every major firm reported losses. RCA, with the industry's largest factories, suffered the most from the cost of unused capacity. It sold off its British and continental European (but not its Japanese) holdings that had come with the acquisition of Victor, including 50 percent in Britain's Gramophone and 29 percent in Britain's Electrical & Musical Instruments (EMI). As early as 1930 NBC had become RCA's most profitable division. However, broadcasting and licensing carried the company through to the economic recovery that began in 1934.[11]

With the onslaught of the Great Depression, the radio industry's structure matured. The collapse of its market drove out hitherto successful firms like Atwater Kent and Grisby/Grunow. Those that remained were already industry leaders before the Crash. RCA's most successful challenger in receiving sets was Philco (formed in 1893) and, in components, Sylvania (formed in 1901).[12]

During the 1930s marketing became central to competitive success in radio manufacturing. The Philco Corporation, RCA's most successful U.S. rival, was a newcomer, having entered the industry only just as the Depression struck, again indicating the value of long-established and market-tested functional capabilities. As the Philadelphia Electric Storage Company, Philco had come of age with the auto industry. It made batteries for electric cars, then batteries for self-starters in motor vehicles, and then radio batteries, which is why in 1928, when Philco began to produce radio receiving sets, it marketed them through its large national distributing network of more than 300 wholesalers and 175 large retailers. During the 1930s the Philco Corporation focused on the high end of the market. Its console sets "made a radio an ambitious piece of furniture."[13]

Second to Philco as an RCA competitor was the Zenith Radio Corporation, one of the very few successful start-ups. Like Philco, it focused on the high end of the market, concentrating on product design and aggressive advertising. Crosley competed in much the same manner, while Emerson concentrated on the lower end of the market, developing a "pee-wee" clocklike radio that sold for less than $10. Another successful challenger, Galvin Radio, took the lead in a niche market—radios for automobiles—changing its name to Motorola. Colonial produced for Sears, Roebuck. In 1935 General Electric returned to the market, first selling RCA products under its label and then producing its own name-brand radios. By 1940, ten leaders accounted for just under 75 percent of the total sales in radio receiver sets (listed in Appendix 2:1).

The more costly and complex production of tubes and other components remained even more concentrated than radios themselves. Of the fifteen RCA tube licensees in 1930, only eight remained in 1941. Sylvania Electric Products, a long-established producer of light bulbs and other electrical equipment, became RCA's primary challenger in vacuum tubes and other components. By having smaller plants in small towns, Sylvania benefited from lower wages and less scale dependence. Despite royalty payments to RCA, it prospered by becoming the major supplier of radio tubes to Philco and Zenith. The only other tube maker that survived, and barely did so, was Raytheon. A 1922 start-up refrigerator maker that turned to the production of tubes, Raytheon made a profit in only two years between 1930 and 1940. In speakers, the most successful producer was Magnavox, established in 1910, which competed in much the same manner as Sylvania. Except for Zenith, none of these firms was an entrepreneurial start-up. They had established their integrated learning bases before they began to produce radios.[14]

Nevertheless, RCA remained the industry's only enterprise producing a broad range of products. The makers of receiving sets did not produce components in large quantity, nor did the component makers produce receiving sets. RCA, in addition to its profitable tubes and components, its licensing, and its successful NBC, produced broadcasting equipment and remained the leading maker of phonographs and records. It also was still the leader in wireless telegraphy, an activity that kept RCA in the business of global communications. In addition, through its investment in Radio-Keith-Orpheum (RKO), it began in 1928 to produce sound equipment for motion pictures. RCA's Photophone system was second in this field to Western Electric's Vitaphone, which provided in 1927 the first talking film, Al Jolson's *The Jazz Singer*.[15]

Although World War II was to bring technological breakthroughs in electronics plus mass funding and the commercializing of new products, RCA and its competitors that had made it through the Great Depression continued on as the industry's leaders until they and their industry succumbed to the Japanese onslaught of the 1970s. In the 1930s, these enterprises began to use their technical and product development capabilities learned in the commercializing of radio to begin the process of commercializing video broadcasting and receiving technology.

The Coming of Television

During the 1930s television became the focus of the industry's development of new products and the enhancement of corporate organizational capabilities. In the early 1920s AT&T's Bell Laboratories and the R&D facilities of GE and Westinghouse had concentrated on developing electromechanical devices, as had the most prolific of television's noncorporate inventors, C. Francis Jenkins. The electronic breakthrough came in 1928 when Vladimir K. Zworykin, a Russian émigré who had been working on television at Westinghouse since 1923, developed the basic electronic photo tube (the iconoscope). With the transfer of Westinghouse's facilities to RCA in 1930, and the centralization of RCA's research activities at Van Cortland Park, New York, Zworykin carried on there. By 1932 he had sixty persons working under him.[16]

In 1930 Philco entered the arena by hiring an inventor/entrepreneur, Philo Farnsworth, who had invented an essential component, a cathode ray camera known as the image dissector. But as Philco had neither the necessary funds nor the research personnel, its managers dropped the project in 1932. Farnsworth proceeded on his own with the continuing support of his original backers, a group of California bankers, until 1938, when his company cross-licensed patents with RCA and AT&T. After 1938, Farnsworth moved beyond patenting into product development. Another inventor/entrepreneur, Allen B. Du Mont, who invented a cathode ray oscilloscope, created a comparable enterprise, his Allen B. Du Mont Laboratories, after cross-licensing with RCA.

The long-term challengers to RCA in the development of TV, however, were not entrepreneurial start-ups. The barriers to entry (as described in Chapter 1) had become too high. Instead the challengers were major competitors of the 1920s: Philco, William Paley's CBS, and Zenith, all of whom obtained licenses for RCA's patents. Philco, revived by financing from the investment banking firm of Kuhn, Loeb & Company, acquired the Capehart Corporation, one other small radio manufacturer, and returned to its earlier television project. CBS began to make a major development effort in the late 1930s. Zenith began to work seriously on television only in 1940. With the recovery of the U.S. radio market—the number of sets sold rose from 4.4 million in 1934 to 10.7 million in 1939—RCA, Philco, and CBS had the profits to reinvest in the commercializing of TV sets and components. They had the necessary production facilities and, as important, the marketing capabilities that new entrants lacked.[17]

As the commercialization of television became a reality, the need to set standards for screens, circuits, and other components became urgent. Although committees of the Radio Manufacturers Association (RMA) were expected to determine these standards, they were in fact defined during the battle between the leading manufacturers—between RCA, on the one hand, and Philco, Zenith, and CBS on the other. In 1936 an engineering committee of the RMA, supported by the recently established Federal Communications Commission, recommended standards for channel allocation and bandwidth attuned to those advocated by RCA. Philco immediately disowned this standard and was joined by Zenith and CBS. The RMA committee then called for further field testing.

RCA Leads the Way

In October 1938 Sarnoff decided to go it alone. In the spring of 1939 he used the New York World's Fair as a platform to announce and demonstrate RCA's first television set. But the rush of customers he expected failed to materialize. The television sets were expensive, programs were limited, and television's future was still uncertain—a very different situation from the beginnings of radio and, later, of personal computers. In April 1940 the FCC urged the resumption of further testing on an experimental basis and encouraged the RMA to set up a National Television Systems Committee (NTSC) to define the standard.[18]

Again, RCA pushed ahead aggressively. The chairman of the FCC, James L. Fly, an ardent New Dealer, responded by attacking Sarnoff as a dangerous monopolist. This charge brought a Senate investigation. By then, however, television sales were rising and the demand for standards was becoming

more urgent. So in April 1941 the NTSC produced a set of standards close to those of RCA, despite the outcry from Philco and its allies. "Amidst a wealth of claims and counter-claims," Sarnoff's biographer writes, "an unfettered NBC launched commercial telecasting in the United States on July 1, 1941." Less than six months later the nation was at war. In April 1942 commercial production of television equipment was officially banned.

The Impact of World War II

It would be difficult to overstate the impact of World War II on the young electronics industry, much as it impacted other high-technology industries such as the young aircraft and the older chemical and pharmaceutical industries. The extended and varied uses of electronics by the United States and its allies and opponents dramatically increased national learning, nowhere as much as in the United States. RCA became a major contractor in military electronics. With production contracts of $84 million, it was one of the Big Five, albeit the smallest, behind Western Electric (AT&T's manufacturing arm), GE, Bendix (the nation's largest maker of motor vehicle parts), and Westinghouse. In terms of the dollar value of research contracts granted by the Office of Scientific Research and Development (OSRD), it ranked fourth behind Western Electric, GE, and the Research Construction Company (a research consortium) and was followed by Du Pont (whose primary task was building the first atomic bomb fabrication plant).

Huge military demands quickly expanded RCA's production facilities and, of a more long-term significance, transformed the nature of its research and product development. The massive military contracts for radios and radio tubes brought a major expansion of RCA's existing production facilities at Indianapolis, Harrison, and Camden. Before the war's end, RCA acquired a government-funded complex at Lancaster, Pennsylvania, of twenty thousand different types of components that produced a total of twenty million tubes.[19]

The wartime research was carried out primarily by the laboratories that Sarnoff had built in 1941 in Princeton, New Jersey, financing its costs from the income from military contracts. Research became an independent department called the "RCA Laboratories." It was given the responsibility for "all research, original development and patent and licensing activities of the corporation . . . and financial control over all of RCA's research work."

The OSRD research contracts led the new department to work on radar, sonar, navigation systems, and the development of television-guided pilotless planes. It became involved in electronic devices for directing antiaircraft guns, proximity fuses, and other specialized tubes for military purposes.

War-related television research brought, in the words of historian Margaret Graham, "the replacement of the iconoscope with the much more sensitive orthicon that became the basis for the postwar camera technology." Other wartime television developments at RCA "included the high-power vacuum tube, other special tubes as display devices, mass production techniques for cathode ray tubes, and better network relay and microwave techniques."

When the war ended, RCA and its limited number of competitors gave highest priority to the introduction of long-delayed television projects. Sarnoff's strategy was twofold. First, during the transition from military to civilian products, when TV receiving sets were not yet available in volume, RCA expanded both its television broadcasting network and its still tiny portfolio of broadcast programs. Second, RCA announced in 1946 that its television technology would be open to all—thus making it the industry standard. In June 1947 Frank M. Folsom, who had just become CEO as Sarnoff moved up to be chairman, invited RCA's competitors to Camden. He wanted them to view RCA's new postwar model, the 630TS, selling at $375, and to take with them detailed blueprints of the product. In addition, to assure reliability of the new, still-untested device, Folsom created an RCA service force to maintain and repair purchased machines.[20]

Folsom's strategy worked. U.S. television sales soared in a manner comparable to those in radio between 1922 and 1925 and personal computers between 1982 and 1985. RCA's market share in receiving sets fell off, but its income from tubes, other components, and licenses took off sensationally. Even in 1948, the year after the Camden demonstration, its share of television sets was only 42.6 percent. At the same time, its total revenues from manufacturing soared from $271 million in 1948 to $476 million in 1950. Then the shakedown began. U.S. sales of television sets, which had risen from just under 1 million in 1948 to 7.5 million in 1950, fell back to 5.4 million in 1951, leveling off to an average of 6 million a year in the decade after 1953. RCA's strategy of defining the television standard through its demonstration at Camden in 1947 brought a sizable number of new entrants into the industry, but when the demand leveled off very few survived.

By 1958 RCA's U.S. market share in television sets had leveled off at 17 percent, where it remained for a decade. In these same years RCA enjoyed

close to 70 percent market share of the high-volume tube and component businesses. Therefore RCA benefited from tubes and components through both licensing as well as scale economies in manufacturing. By 1950 half of RCA's income came from manufacturing television components, receiving sets, and broadcasting equipment. As growth from hardware leveled off, NBC's television broadcasting unit increased its cash flow. Until the late 1960s RCA's revenues came primarily from television-related activities.

During the 1950s RCA's major competitors remained largely the radio producers of the 1930s—Philco, Zenith, and Motorola in receiving sets, Sylvania in tubes, and CBS in broadcasting. Other competitors included Atwater Kent, which had returned to radio during the war; Magnavox, which had expanded its line during the war by making receiving sets as well as components; and one newcomer, Admiral, a wartime producer of radios and radar established in 1940, one of the very few start-ups created to exploit wartime opportunities in electronics. By 1958 the seven firms (by then CBS had turned from television production to broadcasting) accounted for 86 percent of market share for black-and-white television.

The Drive for Color Television

In the early 1950s, as black-and-white television settled into maturity, color television became the next challenge. Here the leading players were again those that had built their research organizations and their technical capabilities before their wartime expansion—RCA, Philco, CBS, and, to a lesser extent, Zenith. But the two primary contestants, those that would determine the standards for the new technology, were RCA and CBS, the two that had begun research on color before the coming of war. In 1940 CBS announced a system based on electromechanical color techniques developed by Peter Goldmark, a member of the CBS research team since 1936. Because this system was electromechanical, it was not compatible with the electronic black-and-white and NTSC standards that Sarnoff had done so much to shape. In 1941 RCA had announced a color system that used electronic technology and was potentially compatible with black-and-white television.[21]

By the time RCA and CBS returned to concentrating on color television after the war, their managers had persuaded the FCC to take over the high-frequency channels originally allocated to FM (frequency modulation) radio. FM, a major innovation, had been developed during the 1930s by

Edwin H. Armstrong, initially with the support of Sarnoff, and had reached the market by 1940. But, as in the case of color TV, the war postponed this technology's further development.

In 1944 Sarnoff persuaded the FCC to shift FM radio broadcasting to UHF—that is, the ultrahigh frequencies of 88–108—thus opening up to color television the bands originally assigned to FM radio. Shortly afterward, with a push from CBS, whose electromechanical color technology relied on these same UHF frequencies, the commission limited FM broadcasting to a relatively small local area. FM stations usually joined local AM stations, and producers equipped their products to receive the local FM and AM channels. Nevertheless, between 1947 and 1954 only 6 percent of the thirty-four million radio sets produced were equipped with both AM and FM receivers.

On completing the development of its noncompatible color television, CBS applied in 1947 to the FCC for a license. Sarnoff urged the commissioners to hold off until RCA could present the compatible system to black and white that it was developing. RCA's presentation, made in 1949, was, in historian Margaret Graham's words, "a disaster of legendary proportions." So in July 1951 the FCC approved the CBS standard. In anticipation of that approval, CBS had expanded its production facilities, integrated backward by purchasing Hytron, the nation's fourth largest tube maker, and reorganized its operating structures for large-scale production.[22]

Once again external events intervened. The Korean War of the early fifties caused the government to allocate all electronic equipment development to military purposes. However, the manufacture of black-and-white televisions continued. By the time that war was over, the number of televisions sold had grown so fast that CBS's noncompatible color receiving set could no longer become an industry standard. Between 1950 and 1952 a total of twelve million new black-and-white sets had been produced. At Philco, Zenith, and other U.S. competitors, and at those abroad, primarily Philips Incandescent Lamp Works (Philips), a shift to electromechanical technology for their color television made little commercial sense. Late in 1951 the FCC appointed a second National Television Systems Committee. In December 1953, in Graham's words, "the committee produced proposals for television systems that were compatible with, though not identical to, the system RCA had proposed in 1949." CBS made no further attempt to promote its product. Indeed, it moved out of the production of radio and television products altogether but continued to own and operate radio and

television stations, to expand the CBS broadcasting group, and to enlarge its recording enterprise, Columbia Records, which it had formed in 1938.

Nevertheless, the acceptance of RCA's system did not assure RCA a market for its color TVs, even though it made a valiant effort to begin one. Its products and those sold by its competitors were large and expensive, priced at $700 to $800 a set. (In the year 2000 that would be in the thousands of dollars.) Even RCA's expanded service organization had difficulty maintaining performance. As Ralph Cordiner, General Electric's CEO, quipped: "If you have a color set, you've almost got to have an engineer living in the house." In 1956 *Time* called the color TV the year's "most resounding flop." Soon Philco, Zenith, and the somewhat smaller firms such as Motorola and Admiral withdrew their color models from the market. But RCA persisted.

The development of color television compatible for use in existing black-and-white sets was an extremely complex technological challenge. Its success was Sarnoff's supreme achievement at RCA. He pushed the scientists and engineers at the RCA Laboratories to complete a task that they often told him was impossible. He took the responsibility for the growing high costs involved. The color tube compatible with the black-and-white television set was an outstanding achievement in both basic scientific research and the resulting product development.

But the cost had been high. As Margaret Graham reports: "While competitors enjoyed the proceeds from strong black and white sales, RCA bore the entire burden of keeping the color system alive. . . . Unable to attract advertising support for color, NBC paid a substantial premium to broadcast color programming; the RCA manufacturing organizations carried large unabsorbed overheads for color tooling; and the drain on finances robbed other enterprises, such as computer development, of necessary capital."

The payoff was slow in coming. In 1959 RCA made its first profit from color television. Both RCA Labs and the consumer electronic division continued to concentrate on improving performance and lowering costs, particularly in the production of tubes. But success was heady when the payoff came, for RCA completely dominated the new technology. In 1961 Zenith broke what had become an industry boycott on color by ordering fifty thousand RCA color tubes. The next year a million sets were in use with an average retail price of $600.

As RCA's management expected, they repeated the success patterns of both the radio and black-and-white TV markets. High profits came from licensing and components, not from receiving sets. As table 2.1 indicates, by

TABLE 2.1. Shares of the U.S. Market for Color Television Sets, 1964, 1975, 1986

Brand	1964 Share	1964 Manufacturer	1964 Nation	1975 Share	1975 Manufacturer	1975 Nation	1986–1987 Share	1986–1987 Manufacturer	1986–1987 Nation
RCA[1]	42	RCA	U.S.	19.0	RCA	U.S.	17.5[2]	GE -> Thomson	France
Zenith[1]	14	Zenith	U.S.	24.0	Zenith	U.S.	15.8	Zenith[3]	U.S.
GE[4]	–	GE[4]	U.S.	6.2	GE[4]	U.S.	6.3[2]	GE -> Matsushita	Japan
Sears (10%)	1	RCA	U.S.	0.9	RCA	U.S.	0.6[2]	GE -> Sanyo	Japan
Sears (90%)	8	Warwick	U.S.	7.8	Warwick	U.S.	5.5	Sanyo	Japan
Emerson	4	Emerson	U.S.	–	Emerson	U.S.	1.5	Sanyo	Japan
Quasar	8	Motorola	U.S.	5.9	Matsushita	Japan	3.9	Matsushita	Japan
Magnavox	6	Magnavox	U.S.	6.6	Philips	Neth.	5.0	Philips	Neth.
Curtes Mathes	–			–		,	1.0	CMM Co.	U.S.
Sylvania	4	GTE	U.S.	4.4	GTE	U.S.	3.8	Philips	Neth.
Philco	–	Ford	U.S.	2.0	GTE	U.S.	1.0	Philips	Neth.
Admiral	7	Rockwell	U.S.	3.0	Rockwell	U.S.	–		
Sony	–			5.8	Sony	Japan	6.0	Sony	Japan
Panasonic	–			2.3	Matsushita	Japan	4.2	Matsushita	Japan
Sharp	–			–			3.2	Sharp	Japan
Hitachi	–			–			3.0	Hitachi	Japan
Mitsubishi	–			–			2.8	Mitsubishi	Japan
Toshiba	–			–			1.8	Toshiba	Japan
Sanyo	–			–			1.6	Sanyo	Japan
Fisher	–			–			0.5	Sanyo	Japan
NEC	–			–			0.5	NEC	Japan
JVC	–			–			0.5	Matsushita	Japan
Teknika	–			–			0.4	158. Itoh	Japan
Sampo							0.5	Sampo	Taiwan
Tatung	–			–			0.4	Tatung	Taiwan
Samsung	–			–			1.6	Samsung	Korea
Gold Star	–			–			1.5	Goldstar	Korea
National Shares								(1987 Manufacturer)	
United States	94.0			67.3	United States		16.8	United States	
Japan	–			14.0	Japan		42.3	Japan	
France	–			–	France		17.5	France	
Netherlands	–			6.6	Netherlands		9.9	Netherlands	
Taiwan	–			–	Taiwan		0.9	Taiwan	
South Korea	–			–	South Korea		3.1	South Korea	
Other/Unknown	6.0			12.1	Other/Unknown		9.6	Other/Unknown	
	100.0			100.0			100.0		

Source: "Decline of U.S. Consumer Electronics," *The Working Papers of the M.I.T. Commission of Industrial Productivity*, vol. 2, p. 45, with permission from MIT Press.

[1]Some sets and components supplied by owned offshore factories.

[2]Brands transferred to Thomson (France) or other suppliers in 1987.

[3]Heavy losses in 1986.

[4]Matsushita supplied GE sets on an OEM basis, that is, sets were sold over the GE label.

1964 RCA's market share of color television receiving sets in the United States had dropped to 42 percent, with Zenith a distant second at 14 percent. By 1975 RCA's share had come down to 19 percent and Zenith's had risen to 24 percent. But until the late 1960s RCA dominated globally in tubes and components. As the sole supplier of the tricolor tube, a product that became a symbol of U.S. mass production during the sixties, RCA made a profit of $35 on every tube sold. "RCA was soon back-ordered in all its color plants—from cameras and studio equipment to receiving tubes and components." Between 1960 and 1965 RCA's average profitability was three times the average of all U.S. manufacturing enterprises, and its ratio of profit to revenue doubled. Its sales passed the $2 billion mark, making it the nation's twenty-sixth largest industrial enterprise in terms of sales.[23]

Yet within less than two decades RCA and the U.S. industry were no longer able to compete at home or abroad. The search for a new strategy of growth destroyed RCA's all-powerful learning base in consumer electronics.

The Search for a New Strategy

Sarnoff, his son Robert (the heir apparent), and RCA's senior managers began to search during the early 1960s for a strategy to provide growth in the manner of radio and television in the past. That search was shaped by three major developments. The first was an antitrust consent decree of October 1958. The second was the increasing independence of the RCA Laboratories from the companies' operating divisions. The third was an increasingly popular management belief in the United States that the successful path to profit was to obtain new product lines through acquisition, even if they were not closely related to a firm's existing business.

The 1958 consent decree was part of the drive by the Justice Department's antitrust division to open the new electronic-based industries to competition by making the patents of IBM, AT&T, and RCA available to all (a drive described in chapter 4 for IBM). That decree ended RCA's packaged licensing agreement that it made with the Federal Trade Commission in 1924. Not only did it end packaged licensing, but it also made licenses available to domestic companies without charge. Foreign buyers would continue to pay full freight. For RCA's Princeton Research Laboratories, the consent decree had two important consequences. First, because the decree covered all products for "radio purposes" including television licenses, it discouraged continuing

research in radio-related devices. Second, and of more significance, RCA Labs, in order to maintain licensing income after the consent decree, began to concentrate on licensing to Europe's Philips and Japan's leading consumer electronics makers. These two changes sped up the transfer of RCA's achievements in color TV technology to its two major competitors.[24]

In the following years, licensing fees did remain a significant source of income for RCA. Until the late 1960s, most of the postwar Japanese consumer electronics industry was built with RCA vacuum tube technology. Not surprisingly, when Sarnoff toured Japan in 1960 he was given a hero's welcome, including the Order of the Rising Sun from the emperor. During the 1970s royalties from consumer electronics patents reached $100 million a year. The profits from such licensing may have deterred RCA from building plants or even marketing aggressively abroad.

Government contracts dropped off after 1945, but with the coming of the cold war, RCA's government business boomed. These contracts pulled the RCA Laboratories even further away from research on radio-related products. For example, RCA joined with GE and Bendix to build radar for the SAGE air defense project (mentioned in chapter 4). It also provided communications facilities primarily for military and government agencies by developing and operating a common carrier network for overseas voice and sound transmission, a heritage from its initial wireless business. That business continued to be a significant source of income, particularly after RCA orbited two satellites in the 1960s.[25]

In addition to the claim on RCA's R&D activities through government and communications contracts, Sarnoff himself had further expanded the activities of the RCA Laboratories in the late forties by asking them to develop three quite different new products—an electronic air conditioner, a light amplifier, and a videotape recorder used for delayed television broadcasting (to permit repeated broadcasting from the use of a single film presentation). All three projects ultimately failed. The air conditioner turned into an electronic refrigerator, which its developers soon termed "the most expensive ice cube in the world." (This project resulted from a postwar plan to diversify into consumer appliances that began with the acquisition of a 20 percent holding in Whirlpool, the country's leading producer of household appliances. RCA sold off its Whirlpool holding between 1962 and 1964.) The light amplifier, feasible in principle, was too costly to produce.

Of more significance was the failure of the videotape recorder, for that experience was a foretaste of a growing conflict between the RCA Laboratories in Princeton and the Advanced Development Groups of the operating divi- sions. The Advanced Development Group at Camden had devised a new technology for this device. RCA Labs then decided that the Advanced De- velopment Group's technology was too complex and shut the project down. But the RCA Labs were unable to invent a satisfactory product of their own. Later another firm, Ampex, developed one similar to that of the Camden Group that became the basis of the technology used in commercializing the videocassette recorder, the contest that would determine the future of the in- dustry, as told in chapter 3.

This controversy between the RCA Laboratories at Princeton and the Ad- vanced Development Group at Camden revealed an essential weakness in RCA's postwar learning base: the difficulties of integrating the technical ca- pabilities at Princeton, those of basic and applied research, with the func- tional capabilities developed in the operating divisions. Since their establishment in 1941, the Princeton Laboratories controlled RCA's re- search and funded its development activities at Princeton. And from its wartime beginnings it had been involved in a wide range of research activi- ties besides consumer electronics projects. Moreover, since their income was based on licensing, the researchers at the RCA Laboratories preferred to concentrate on developing new nonproprietary products and processes.

On the other hand, the Advanced Development Groups were located in the operating divisions at the major plants—Indianapolis in radio and television re- ceivers, Harrison in tubes and components, and Camden in recording and broadcasting equipment. Their task was to integrate the product development with processes of production and above all to the market for whom the im- proved product was destined. Not surprisingly, the divisional advanced develop- ment groups began to look to the Japanese companies, especially Matsushita, to provide technical engineering capabilities for the products for which they were responsible. Tension was heightened by a growing broader generational conflict between the younger scientists whose training had turned them to concentrate more on basic research and the engineering and problem-solving veterans whose focus had long been on product development.

Strategies Defined

Despite these tensions, after extended discussions, top management had basically agreed by 1965 on "two fields of applied research identified as having 'the most impact on RCA's future prosperity.' These were consumer electronics and electronic data-processing."[26] David Sarnoff and his son Robert, who succeeded him as CEO in 1968, and also most of the com- pany's senior managers, agreed that the major effort should be on data- processing computers.

By 1970 close to half of RCA's R&D expenditures and 40 percent of its research personnel were allocated to electronic data processing. At the same time, RCA's continuing commitment to overseas voice/recording communications systems that had evolved from its initial commitment to the wireless spark technology called for substantial allocation of research funds and personnel.

Therefore consumer electronics received a much smaller portion of fund- ing and attention than had radio before the war and television in the 1940s and 1950s. Moreover, this downgrading of consumer electronics at RCA came just as the large Japanese firms and Europe's Philips were beginning to concentrate on improving their electronics products and processes, many of whose technologies they had initially received from RCA.

Then, as Robert Sarnoff took command, he was persuaded by André Meyer, a member of the RCA board of directors and senior partner of Lazard Frères and one of the most respected investment bankers of his day, to em- bark on a second strategy of growth. That was one of product diversification through acquisition of companies whose businesses were only distantly re- lated, if related at all, to the learned technical, functional, and managerial capabilities. In his first annual report as RCA's CEO, that for 1968, Robert announced: "In its formative years RCA's growth depended primarily on a single product or service. . . . The word that best characterizes the modern RCA is diversity." Thus, from the start of his administration Robert Sarnoff embarked on a twofold growth strategy: to challenge IBM's lead in comput- ers; and to make RCA into a conglomerate.[27]

By the early 1970s the implementation of these twin strategies began to demonstrate their inherent weaknesses. What might be termed "the lure of the computer" and the "curse of the conglomerate" provide telling examples of the ways in which learned organizational capabilities define the direction and the limits to growth of industrial enterprises. The lure of the computer emphasizes the difficulty in a high-technology industry of catching up to the first-mover in the technology involved. The curse of the conglomerate indi- cates how misguided was the assumption that managing a portfolio of companies with different production technologies was similar to managing a portfolio of the securities of such companies. By 1980 it was apparent that together both strategies destroyed RCA and with it nearly all the U.S. consumer electronics industry.

The Lure of the Computer

RCA had developed technical capabilities in electronic data processing before the Sarnoffs decided to challenge IBM. But the learning process had been sporadic and tenuous. Like other high-tech postwar contractors, RCA had built computers for the government, delivering in 1947 an analogue computer to solve simultaneous equations. In 1956 it shipped its first digital analytical computer, the Bizmac, to the U.S. Army to "provide speedy and accurate information on inventories . . . and to compute forecasts of future requirements." Although only six Bizmacs were delivered, the move caused David Sarnoff to set up the Industrial Electronic Data Processing division as a way to begin to build a learning base in this new technology. In 1958 came a radically redesigned Bizmac, RCA's first transistor-powered computer. The next two product lines, based on the Bizmac, were the first designed for the nongovernmental market. Of these, the smaller 501 was a modest operating success, but it was used primarily within RCA itself. The larger 601 mainframe was a technical and financial disaster. After $100 million in development costs, only four machines were delivered. In 1963 came the 3301, "an interim product" to "take the place of the 601."[28]

In December 1964 RCA began its first full-scale move into computers by announcing its new Spectra 70 to supersede the 3301 and to be similar to IBM's System 360, which had been announced earlier that year (as described in chapter 4). The Spectra would be powered by true integrated circuits, perfected after IBM had frozen the design of those used in the System 360. RCA's strategic plan was to build Spectra models that performed at levels between those of the different IBM System 360 models at prices that made their price/performance characteristics superior to those of the IBM model below them. Because the Spectra followed IBM's overall systems layout, its designers hoped that its development costs would be lower and its production time schedule shorter.

For a time the strategy was moderately successful. IBM personnel were hired. Indeed, John Burns, who became president of RCA in 1957 (Sarnoff

remained the chief executive), was a leading computer consultant who had worked closely with IBM. The Spectra ran on IBM software, except for its input-output instructions, which had to be "translated." Its processor and much of its other hardware were more advanced than those of IBM. But, as its managers soon learned, IBM's functional capabilities in production and particularly in marketing created formidable barriers to RCA's entry into the computer path of learning.

Nevertheless, because RCA was able to ship its initial products as early as 1966, before IBM's 360 was in full production, the revenues of its computer division rose from approximately $89 million in 1965 to $211 million in 1968. But during those years losses continued. When IBM in 1970 announced its System 370, based on its well-established commercializing processes, RCA countered with a new series, essentially yesterday's technology at lower prices.[29]

It was a futile gesture. Early in 1971 an internal review reported that the company needed an additional $1 billion in new capital by 1976 if it was to remain profitable, and $500 million of this would have to go to computers. One executive responded: "I can think of two dozen things I would rather spend $500 million on." As the senior managers knew, IBM in 1970 had spent $400 million on R&D, about twice the total revenues that RCA received from computers. So in September 1971 Robert Sarnoff sold the company's computer venture to Sperry Rand's UNIVAC division for $250 million.[30]

Clearly RCA simply had neither the time nor the financial resources to create an integrated learning base with the production and marketing capabilities necessary to compete with IBM. The cost of failure was high. At the critical moment when the integrated learning bases of its foreign competitors, Matsushita, Sony, and Philips, were moving into high gear, RCA's consumer electronics were deprived of both essential personnel and funding. As William Webster, the head of the RCA Laboratories after 1968, noted: "We shot a whole generation of research engineering on computers and starved the real cash-cow—color television—to do it."

On a much smaller scale, General Electric's unsuccessful move into computers (also described in chapter 4), at much the same moment and for much the same reasons, also held back the development of General Electric's consumer electronics business. That company had returned to the making of its own radio sets in 1935 and then went into television sets after

World War II. But with the failure of its computer venture, it came to rely increasingly on other manufacturers, particularly Japanese, to produce radio and television products that were sold under the General Electric label.[31]

The Curse of the Conglomerate

The lure of the computer helped to bring down RCA, the definer of the consumer electronics path of learning, and drove out GE, a significant player since the industry's beginning. The curse of the conglomerate finished off RCA, and with it the U.S. consumer electronics industry. In addition, somewhat less blatant unrelated diversification brought down Philco and Sylvania, RCA's two foremost competitors since the 1920s. These two companies were victims of acquisition by diversifiers.

Philco, before its acquisition by the Ford Motor Company in 1961, had made a successful entry into the computer business. Philco, like RCA, had expanded its electronics capabilities in World War II and then had gone into data processing for the military during the Cold War. Philco, unlike RCA and Sylvania, had not been a major producer of vacuum tubes, but after 1952 it began to develop and commercialize transistors on license from AT&T. In 1955 it pioneered in developing the first transistor airborne computer for the air force, and in the next year the "world's first all-transistor computer" for the National Security Agency. Improved products quickly followed. By 1960, writes Kenneth Flamm: "The Philco 210 and 212 were among the largest most powerful computers of their day." Philco not only pioneered in supercomputers for the scientific market, but it also produced transistors, peripherals, and other components for the fledgling computer industry. For example, an infant, Digital Equipment Corporation, used Philco transistors in the first of its PDP series. Philco also continued to be an effective competitor in the related businesses that it had entered in the 1920s—air conditioners and refrigerators—as well as the nation's number two producer of radio and TV sets.[32]

When the Ford Motor Company acquired Philco in 1961, it did so as a means to increase its defense business. Ford placed Philco computer activities in its Space and Defense Division but kept Philco's consumer electronics and household appliances in separate operating units. As Ford managers had little incentive to fund fully the acquired radio and television business, and as they had much less experience than GE and RCA in those fields, Philco's competitive strength in consumer electronics quickly disintegrated. In 1973 Ford managers decided to spin off most of Philco's activities. They sold its U.S. brand name and its national sales and distribution organization and two of its plants to GTE Sylvania, a wholly owned subsidiary of General Telephone & Electronics (GTE), but they kept Philco's operations in Canada and Latin America. In this way Ford's acquisition of Philco dissolved the organizational capabilities of what was becoming one of the nation's most innovative learning bases in electronics.[33]

Sylvania Electric Products, the nation's second largest producer of consumer electronics components after RCA, had been acquired in 1958 by General Telephone, which had then changed its name to General Telephone & Electronics. General Telephone had begun by merging scattered local phone systems in rural areas during the 1920s and 1930s. By 1950 it had become the largest independent telephone service provider, although it still had only 5 percent of the nation's business. It acquired Sylvania as part of an effort to produce its own switches and other telephone equipment.[34]

As in the case of Ford, GTE's managers paid relatively little attention to Sylvania's R&D and had little commitment to funding it. But unlike the Philco operations at Ford, Sylvania remained an autonomous operating subsidiary, GTE Sylvania Incorporated. It continued to produce lighting products and electrical components and defense communications electronics, as well as to carry on the Philco television activities it had acquired from Ford in 1973. Nevertheless, with little financial and managerial support and commitment during the seventies, Sylvania's television capabilities deteriorated and profits turned into losses. In 1981 GTE sold its holdings in both Philco and Sylvania to Philips North America, the subsidiary of Europe's standard-bearer.

By then RCA's own strategy of diversification through acquisition had decimated the nation's core technical learning base in consumer electronics—the learning base that had since 1920 led the world in commercializing new products and processes. The Sarnoffs had embarked on the strategy of diversification even before Robert took his father's place as chairman and chief executive officer on January 1, 1968. At a time when RCA's research organization was focusing on the Spectra, the Sarnoffs concurred with André Meyer that such acquisitions could provide funding for the computer venture as well as supporting research and development in the company's other high-tech activities. They also agreed that a portfolio of operating companies, like a portfolio of securities, would balance risks involving different businesses and different fluctuations of demand, income, and profits.

In May 1966 the father, David, made the first acquisition, Random House, one of the best-known American publishing houses, headed by Bennett Cerf. Here Sarnoff did make the argument that RCA's business, broadly conceived, was communications and entertainment, so publishing was an activity that RCA understood. But this rationale could hardly cover the purchase early in 1967 (by NBC) of Arnold Palmer Enterprises, marketer of golfing gear and a line of sports clothing. In May of 1967 came a much more massive acquisition, Hertz, the nation's largest car and truck renter. After an attempt in 1968 to take over the St. Regis Paper Company, one of the nation's largest in that industry, RCA in 1969 purchased Alaska Communications Systems from the U.S. Air Force for $28.4 million. Becoming part of RCA's Global Communications Unit, it was the only one of these acquisitions that related closely to RCA's existing capabilities.[35]

Still committed to the computer, RCA management carried out another round of acquisitions in 1970. In March it acquired F. M. Stamper Co. (renamed Banquet Foods), a leading producer of frozen-food packages. In April it acquired Cushman & Wakefield, a New York enterprise with large real estate holdings. In 1970, too, negotiations were begun for the purchase of Coronet Industries, a leading carpet manufacturer, a transaction that was completed in February 1971. With the write-off of the computer venture later in 1971 and the coming of an economic recession, RCA called a halt to major acquisitions except for adding in 1974 two British frozen-food industry producers—Oriel Foods and Morris James Jones, Ltd. But even as early as 1970, RCA's acquisitions, although paid for by exchanges of stock and the sale of bonds, had raised the company's debt from $266.4 million in 1966 to $973.5 million in 1970.[36]

By 1974 RCA's balance sheets began to reveal the disastrously high costs of implementing the two strategies of growth. Appendix 2:2 indicates their impact on the nation's leading consumer electronics enterprise. Net income from consumer electronics dropped from $57.7 million in 1972 to $48 million in 1973. After plummeting to $11.1 million in 1974, it rose again to $25.1 million in 1975, out of a total net income of $158.1 million, $183.7 million, $111.3 million, and $111.0 million. Thus by 1975 consumer electronics accounted for only slightly less than a quarter of RCA's net income, Hertz slightly more, and broadcasting equal to their combined income (appendix 2.2). The rest came from communications systems, a small amount of government business, and "others" (not defined), including Coronet and other smaller acquisitions.[37]

Its declining income and rising debt were accompanied by loss of market share. The most severe losses occurred in "commercial electronics," which included broadcasting equipment, TV tubes, and components for color and cable TV and communications systems. At the same time, interest expenses rose, reaching $55.6 million in 1974 and $62.0 million in 1975. More ominously, Japanese firms were launching their powerful drive into U.S. and then European markets, as described in detail in chapter 3.

The collapse of Robert Sarnoff's strategies of growth led the RCA board to remove him as CEO in November 1975. His immediate successor, Anthony Conrad, planned to sell off most of the recent acquisitions except Hertz, but he was forced to leave the company in September 1976 because of his failure to pay his personal income tax. His successor as CEO, Edward Griffiths, who had been the head of the electronics division, focused on cost cutting and downsizing. He sold off RCA's X-ray business, aircraft radar, land mobile radios, and some of its commercial products. But, in his cost cutting, Griffiths concentrated on consumer electronics, including the closing down of the Harrison, New Jersey, tube plant (taking a $40 million write-off). He did so just at the moment that RCA's Japanese competitors, led by Matsushita, were investing heavily in both physical and human capital in the improvement of existing consumer products. Griffiths's efforts did, however, succeed in impressively raising RCA's revenues and profits in 1977 and 1978.[38]

Nevertheless, Griffiths remained a conglomerator. His model was Harold Geneen, whose doctrine of management by the numbers and growth through unrelated acquisitions had made him an icon in the financial community. (In passing, I mention that Geneen's use of this strategy at ITT, the 1926 spin-off of Western Electric's international operations, led to the quick demise of this company's integrated learning base in international telephone equipment.) In 1978 Griffiths hired Maurice Valente, a fourteen-year veteran of ITT and its executive vice president, to be RCA's president. At the same time, Griffiths was planning to purchase a financial services company, which, like Hertz, would be a source of retained earnings to finance current and future operations.

Valente lasted only a few months as president, but the search for another major acquisition led Griffiths to the purchase of a financial conglomerate, CIT Financial Corporation, a purchase that included taking over CIT's debt of $4.7 billion. That enterprise operated several savings and loan companies, a major life and health insurance firm, a maker of office furniture and electric outlet boxes, and a leading greeting card company. To fund this transaction, Griffiths sold off Alaska Communications in June 1979 and Random House in early 1981, then the frozen-food businesses, and then the greeting card and electric outlet box companies. These sales did little to reduce RCA's huge consolidated debt of $2.6 billion in 1981 ($1.4 billion of which belonged to Hertz), which contrasted sharply with RCA's listing of $1.1 billion (including Hertz's $422 million) of consolidated debt in 1975.

By 1981 the board had had enough. On July 1, 1981, it replaced Griffiths as chairman and chief executive officer at RCA. His successor was Thornton Bradshaw, a longtime board member and the chairman of Atlantic Richfield, a corporate descendant of John D. Rockefeller's Standard Oil. By then RCA's core learning base in consumer electronic products was collapsing. In 1980 it accounted for only 13 percent of RCA's profits. That year 43 percent came from Hertz and CIT's financial services. The rest came from broadcasting, commercial electronics and communications, government business, and licensing.[39]

Nevertheless, the consumer electronics division's top executives still had high hopes of recovery. Their hopes rested on success in commercializing a videocassette recorder based on their new videodisk technology, even though by the mid-1970s RCA had fallen behind its competitors—Philips, Matsushita, and Sony—in this critical technological race.

In reality, RCA had already lost that race by 1981. Because the outcome of that contest assured Japan's overwhelming dominance in today's consumer electronics business and because RCA's role and its ultimate failure can be understood only in relation to the activities of its major competitors, I review in chapter 3 the details of that path-defining story. The remainder of this chapter describes the evolution of RCA and the U.S. consumer electronics industry in the aftermath of this contest.

RCA Disintegrates: The Japanese Move In

When Thornton Bradshaw took office at RCA in 1981, he and his managers were still optimistic. One of Bradshaw's main objectives was "to refocus the

company on its three core businesses—electronics, communications, and entertainment." To do so, Bradshaw would put CIT Financial, Hertz, and Coronet Industries up for sale. But first he had to fight off a takeover threat headed by William Agee, whose takeover talents as head of the Bendix Corporation had led to Allied Chemical's disintegration as a major chemical company. In 1983 Bradshaw successfully disposed of Hertz and CIT. But by then it was far too late to revive RCA's core capabilities in consumer electronics. Early in 1984 Bradshaw had shut down its VideoDisc project, on which the company had lost more than $500 million.[40]

Bradshaw, who had already announced his coming retirement, began negotiations in the autumn of 1986 for the sale of RCA's consumer electronics division and NBC to General Electric. This acquisition was arranged by Felix Rohatyn, the senior partner of Lazard Frères. The sale price was $6.28 billion—$66.50 a share. Jack Welch, GE's CEO, remarked: "Maybe two American manufacturers can together beat the competition. . . . We will have the technological capabilities, the financial resources, and the global scope to be able to compete successfully with anyone, anywhere, in every market we serve."[41]

Eighteen months later, in 1988, Welch swapped RCA's consumer electronics division for the medical diagnostics business of France's Thomson SA plus $800 million in cash from the French company. By then Welch had shut down or sold off the RCA units that Bradshaw had not been able to dispose of, including Coronet, Nacolah (a life insurance business), RCA Records, the existing NBC radio network, and the RCA New Products division. He retained the profitable NBC division. Welch then donated the RCA Laboratories at Princeton to Stanford University and added a commitment of $250 million spread over five years to support research.

Welch's biographer reports, "The Thomson-S.A. swap was, Welch said, 'the chance of a lifetime.' The opportunity to dump one of the businesses Welch liked least, Consumer Electronics, and to pick up a potential jewel for GE's crown."[42]

Welch's evaluation, made without a note of irony in the light of his comments upon acquiring RCA, was a fitting epitaph for the U.S. consumer electronics business. After 1981 only one sizable American producer of TV sets remained, Zenith. Between 1984 and 1994 Zenith showed a net income in only one year, 1988, when it reported income of $5 million on sales of $2.7 billion. In 1986 Zenith, the one remaining U.S.-owned and -operated company, enjoyed all of 15.8 percent of the U.S. color television receiving set market; France's Thomson SA, 17.5 percent; Philips's U.S. acquisitions, just under 10 percent; the Korean companies, 3.1 percent; and the Japanese companies, close to 50 percent (table 2.1, page 32—it does not record Matsushita's sales of sets to GE to be sold over the GE label). As Zenith had neither the technical nor the functional capabilities needed to remain a profit-producing enterprise, Welch's sale of RCA's consumer electronics division to Thomson SA marks the death of the U.S. consumer electronics industry.[43]

The rest of the U.S. consumer electronics industry had already succumbed to the foreign onslaught by the time Bradshaw had become chairman and CEO of RCA. Between 1974 and 1981 the smaller U.S. radio and television firms were swallowed up by foreign competitors. The buyouts began in 1974 when Philips acquired Magnavox (as well as Philco and Sylvania in January 1981) and Matsushita acquired Motorola's Quasar production and distribution facilities. By then Japan's giant Matsushita, which had in the 1960s and early 1970s built an extensive organization in the United States to distribute and market its Panasonic brand, was supplying GE with its television products on an OEM (original equipment manufacturer) basis. In 1976 Sanyo, which since 1963 had been Sears Roebuck's primary supplier of television equipment, acquired full control of Warwick, which had replaced Colonial as Sears's U.S. assembler. In the same year Emerson Electric sold Sanyo the controlling interest in its Fisher Radio Division (chapter 3, page 68). Emerson had acquired Fisher in 1969 but had been unable to stay Fisher's rapidly increasing loss of market share and revenue. In 1978 Rockwell International, a defense-related conglomerate, spun off parts of Admiral (which it had acquired in 1974), selling off Admiral's Mexican operations to a Mexican company, those in the Far East to a Taiwanese company, and the rest to a Canadian company.[44]

Acquisitions provided one form of entry into the U.S. market. The other was direct foreign investment. In these same years several Japanese producers were building American manufacturing facilities. Sony led the way in 1972 with the construction of a large color television plant in California with an annual output of 450,000 units. The leading multipathed Japanese electrical engineering computer companies, which were already moving into the production of color television, entered a little later. In 1978 Toshiba built its

200,000-unit color television plant in Tennessee, and Mitsubishi Engineering built its 120,000-unit plant in California. Three years later Hitachi completed its 100,000-unit works in California, and the Sharp Corporation, the strongest Japanese challenger to Matsushita and Sony, built a 120,000-unit facility, also in California. By the end of the decade the Japanese-owned companies equipped with the newest manufacturing and processing equipment dominated American consumer electronics (see pages 58–59).[45]

These Japanese companies were much larger than the U.S. firms they purchased. Unlike the Japanese companies and Philips, the U.S. makers (except for RCA) were largely single-product enterprises, makers of receiving sets or tubes or other components. Their functional capabilities were based on that one product or very limited product lines. They did not benefit from economies of scale and scope or from the financial resources that their acquirers enjoyed. Because of RCA's long-established licensing policy, that enterprise remained the source of the U.S. industry's technical capabilities. For much the same reasons, no large supporting nexus of small independent enterprises developed in the United States. So when RCA collapsed, so did the U.S. consumer electronics industry as a whole.

The Causes of Death

RCA's attempt to challenge IBM's System 360 and at the same time to follow the corporate fashion of the time by becoming a conglomerate were the major factors in the disintegration of RCA and, with it, the death of the U.S. consumer electronics industry. Nevertheless, there was a more fundamental reason that reflects the basic concepts of this book. In market economies, the competitive strength of industrial firms rests on learned organizational capabilities. These capabilities in turn begin with the creation of a learning base that integrates the technical and functional capabilities required to commercialize for global markets the products of a new technology and to enhance those of existing technologies.

RCA did not have an integrated learning base until the 1930s, after its acquisition of Victor Talking Machine. From its beginnings in 1919 until the 1930s, it controlled the flow of U.S. radio technology through its monopoly of patents; yet it had no research facilities essential for the development of its own technical capabilities. It sold radios but had no development or manufacturing facilities essential to building its functional

capabilities. That learning occurred at the radio production units of Gen-
eral Electric and Westinghouse. Since RCA only marketed its products,
produced in different distant locations, it acquired little learning in the es-
sential activity of guiding the flow of products from their initial concept to
its final market.

In addition, RCA's control of patents had deprived other U.S. enterprises
of the application of new technological learning from developing new prod-
ucts or processes. As a result of this limited learning base, most U.S. compa-
nies remained single-sector specialists producing receivers or components.

Once it had an integrated learning base, RCA did begin in the 1930s to
commercialize new technologies by expanding the former Westinghouse re-
search unit in New York City. Nevertheless, the continuing enhancement of
product development and production capabilities remained based in the
leading operating units of its predecessors, at the plants that it had acquired
from General Electric, Westinghouse, and Victor.

At the moment that television reached the market in 1940, the demands
of World War II transformed the RCA research learning base by expanding
the number and variety of products produced. Of critical importance, to
meet these war demands, Sarnoff built the RCA Laboratories in Princeton;
its plural name signifies the range of the electric products initially devel-
oped. For during their initial years, they developed military and industrial as
well as consumer electronics. As significant, the new RCA Laboratories from
the start were given the responsibility for and financial control over all RCA's
research work. Although the budgets of the operating units allocated funds
for product development, this sharply defined administrative and financial
distinction between the roles of the central laboratories and those of the op-
erating divisions clearly hindered the essential integration between research
and development so critical to commercializing a new technology for global
markets.

During Sarnoff's focused commitment to commercializing black-and-
white television, reflecting his total drive, his betting of the company, on
color television, the potential inherent conflicts with RCA's management
rarely appeared. But with the search for new strategy, the entrance into the
computer path, and the decision to become a conglomerate, the coordina-
tion of this division of administrative and financial control raised continuing
sets of difficulties that were at the base of the failure of RCA's videodisk proj-
ect. If RCA had resisted the lure of the computer and avoided the curse of

the conglomerate, if it had continued to concentrate, as did its Japanese competitors, on the consumer electronics market, the one that it knew best, then it might have remained the industry's path definer. Instead, RCA failed and the Japanese quickly ascended as the dominant commercializers of consumer electronics.