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# The Role of DoD's Investment in Electronics on the Decline of the Consumer Electronics Industry


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## ABSTRACT

This paper investigates what role, if any, the Department of Defense's post-World War II investment in electronics may have played in the decline of the US consumer electronics industry in the late 1960s-early 1970s. Prior to and immediately following World War II, US firms were the dominant manufacturers of consumer electronics in the world. Beginning in 1951, imports primarily from Japan, began to gain US market share. By 1974, imports accounted for over 50% of the US consumer electronics market, and many US firms left the market. Many reasons have been given for this change in fortune, including quicker use of new product and process technology and aggressive, if not "unfair", market strategy by Japanese firms. No mention, however, is made of the role DOD's investment in electronics might have played. During the 1950s and 1960s, DOD invested heavily in electronic systems and components. Many of the firms manufacturing consumer electronics were also doing contract work with DOD. The paper investigates whether DOD's investment competed with resources (in terms of investment capital and skilled workers) with the consumer sector. The paper relies on secondary sources, aggregate industry data, and journal articles for data. The data found did not permit a conclusive statement on what DOD's role might have been. However, it would appear that DOD's investment did not directly draw investment capital away from the consumer sector. There was insufficient data to say whether DOD's investment drew skilled workers away from the consumer sector. However, more study is required.

## 1. INTRODUCTION

The purpose of this paper is to investigate what impact (if any) the Department of Defense's (DOD's) investment in electronics following World War II may have had on the decline of the U.S. consumer electronics industry some 30 years later.

Before World War II, U.S. firms led the world in the manufacture of consumer electronics (consisting primarily of phonographs and radios). Many of these firms were called upon during the war to help develop and produce new electronic equipment used to fight the war. Immediately following the war, most of these firms returned to producing consumer products (including new ones like television) bringing to this production experience gained during the war. Many also continued to work on military contracts.

U.S. firms continued to dominate the world manufacture of consumer electronics after the war. However, beginning in 1951 with the introduction of Sony's first transistor radio and continuing into the 1970s, imports of consumer electronics, primarily from Japan, gained significant U.S. market share. In 1955, Japanese imports accounted for 2% of the U.S. radio market. By 1973, Japanese imports accounted for 93%. In 1960, Japanese imports of small transistor monochrome television sets accounted for less than 1% of the U.S.

market. By 1972, Japanese imports of monochrome television sets accounted for 72%. By 1974, no U.S. firms were manufacturing either radios or monochrome television sets[1]. Japanese firms made similar inroads into the color television market and later overwhelmingly dominated the manufacture of video-cassette players and cameras, manufacturing over 90% of the world production of these two products.

Analysts have given several reasons for this dramatic change in fortune. Japanese firms employed new technology quicker and marketed their product better than U.S. firms. They also improved designs and manufacturing operations sooner to reduce costs while improving quality and reliability. Japanese firms also had the benefit of national policies and business practices that protected their domestic market while encouraging exports.

These analyses, however, make little mention of what impact, if any, DOD's substantial investment in electronics during this time period may have had on the U.S. industry. After a sharp decrease between 1947 and 1950, military spending increased rapidly with the advent of the Cold War. Defense-related research and development rose to nearly 75% of the nation's total research and development expenditure. Electronics and aerospace received a large share of that expenditure.

There is a degree of consensus that this expenditure had a positive impact in some areas (especially in computers). However, there is some debate about the effectiveness of

[1] Sobel, Robert. RCA. Stein & Day. NY,NY. 1986. p. 213. Sobel does not give a source for these statistics. A similar statement, also without source, is made in The Competitiveness Status of the U.S. Electronics Sector. Department of Commerce. 1990. p. 94.

DOD's investment in electronics. For example, it is often pointed out that many of the advances in solid state electronics were made independent of DOD programs, although DOD clearly provided a valuable early market for solid state devices. Given the relatively poor performance of the U.S. consumer electronic industry during the same period, it is clear that DOD's investment did not help this industry. The purpose of this paper is to see if DOD's investment may have contributed to the industry's decline.

This paper focuses primarily on whether DOD's investment competed with the consumer market for resources (capital investment and skilled labor). Ideally, one would like to examine primary sources (e.g. board minutes, internal documents, interviews with decision makers of the time) regarding investment decisions of the firms involved. Unfortunately, schedule and resources did not permit even attempting this. Therefore, the analysis relied on secondary sources of information (aggregated industry data, corporate histories, magazine and journal articles, etc.), realizing that much of this data will be circumstantial or anecdotal.

Five sections follow this introduction. Section 2 provides a brief history of the consumer electronics market and industry, primarily to identify the major U.S. firms. Section 3 reviews explanations for the decline in the performance of these firms. Section 4 provides a short overview DOD's investment in electronics between 1950 and 1970 and identifies the involvement of U.S. consumer electronics firms in those efforts. Section 5 reviews information related to capital investment and employment within the consumer and defense electronics segments of the industry. Section 6 summarizes the analysis.

Finally, why is this important? The net effect military spending has on the overall economy and specific industries is a matter of debate and one of strategic importance. While not addressing this strategic issue directly, hopefully the paper provides some useful information toward that debate. Also, the consumer electronics market is large. World production reached $63 billion in 1990. Japan accounted for 49% of that production; the United States 10%[2]. The decline in U.S. market share has led to the dislocation of thousands of jobs and contributes to the U.S. trade deficit. The U.S. trade deficit in consumer electronics reached $13 billion in 1987 before falling to $10 billion in 1990. Also, the market drives technology in some areas of electronics and contributed to Japan's lead in such areas as mass production of composite metal oxide on silicon (CMOS) devices, charged couple devices, liquid crystal displays, etc. As DOD reduces its purchases of end items and finds research and development difficult to maintain at current levels, it may have to rely more on the innovative capabilities of a consumer electronics industry, to the extent that it exists (as it did in World War II).

## 2. HISTORY OF THE CONSUMER ELECTRONICS INDUSTRY

[2] Hart, Jeffrey. Consumer Electronics in Developing the Electronics Industry. A World Bank Symposium. Edited by Bjorn Wellenius, Arnold Miller, and Carl Dahlman. Washington, DC. July 1993. p 59.

For the purpose of this paper, consumer electronics refers to those items associated with SIC 3651 (phonographs, radio receivers, television receivers, audio tape recorders and players, and video taper recorders and players). While personal computers, FAX machines, etc. could also be considered consumer electronics products, they are not considered in this analysis. Computers do enter into the discussion of DOD's investment in electronics and represents a technology and market that many of the consumer electronics firms tried to enter (with mixed success).

Thomas Edison patented the first phonograph in 1878. Sound was recorded by speaking into a mouthpiece equipped with a diaphragm connected to a needle. Sound vibrating the diaphragm moved the needle which made impressions on tin foil wrapped around a cylinder. The sound was reproduced by running the needle back over the impressions and listening into the mouthpiece. Chichester Bell and Charles Tainter improved Edison's original patent in 1887. Jesse Lippincott bought the rights to both Edison's and Bell/Tainter's inventions, formed the North American Phonograph Company in 1888, and began selling phonographs primarily for office dictation. A subsidiary, Columbia Phonograph concentrated on the recording of music.

In 1887, Emile Berliner developed a lateral recording machine using flat plastic records. In 1896, Berliner contracted with Eldridge Johnson to develop a motorized player. The two formed a company in 1901 called the Victor Talking Machine Company, using

"Nipper" the terrier listening to his master's voice as its trademark. Within a year, the company claimed to have sold $2 million in phonographs and records (Red Seal Label) to over 10,000 dealers[3]. In 1906, Victor came out with its Victrola model, with its characteristic horn, which became the industry standard. Other manufacturers included Columbia, Majestic, and Brunswick-Balke-Collender.

In 1919, Bell Labs developed electrical recording (vice direct sound recording). Electrical recording used a microphone pick-up to send an electrical signal that was then amplified and powered a cutting stylus. Bell Labs produced the first such recording in 1924 and licensed the technology through Western Electric to all of the major phonograph manufacturers.

Radio and commercial radio broadcasting, which began in 1919, eventually eclipsed the popularity of the phonograph. In 1919, 2.2 million phonographs were sold. In 1922, only 596,000 were sold[4]. Its popularity returned with the development of long-playing records (developed by Columbia in 1947), the development of stereo recording (developed by Westrex in 1957) and the marketing of hi-fidelity home stereo systems.

Radio has its genesis in the development of wireless telegraphy and telephony at the turn of the century. Wireless telegraphy was demonstrated by Gugliemo Marconi in Italy and Alexander Popov in Russia, both in 1896. Marconi went on to form the Marconi Wireless

[3] Sobel, p. 82.
[4] Ibid.

Telegraph Company, in England, in 1897. The company provided point-to-point communication where wire service was not practical (e.g. ship-to-ship and ship-to-shore). Messages were in Morse code consisting of short bursts of energy generated by a spark gap. Marconi's original apparatus, however, left much to be desired. His wave detector was called a coherer which was a glass filled with loose metal filings connected to the antenna. In the loose state the filings acted as a resistor in a circuit. When the antenna received a signal the filings would cohere, lowering their resistance and completing the circuit. The signal was then relayed to a Morse tape machine. Before the next signal could be received however, a battery operated tapper had to loosen the metal filings. This slowed transmission speed to 15 words per minute (wire telegraphs could transmit 60 word per minute).

A number of independent inventors in the U.S. sought to improve Marconi's apparatus and to compete in the wireless communications business. In 1900, Reginald Fessenden, a professor and former employee at both Edison Works and Westinghouse, developed a more sensitive and quicker electrolytic wave detector. Fessenden is also credited as being the first to conceive of transmitting voice across the airwaves. This, however required continuous wave transmission, not the intermittent transmissions associated with spark gap technology. He set about, with the aid of engineers at General Electric to develop a high powered (100,000 cycle per second) alternator to generate the continuous wave upon which he could add voice messages. In 1904, John Ambrose Fleming invented the diode tube, which could be used to rectify the alternating currents associated with continuous wave reception. In 1906, Lee DeForest developed the audion (a triode tube) that not only rectified signals but could amplify them. In 1912, Edwin Armstrong demonstrated the first effective amplifier using the audion in a regenerative (positive-feedback) circuit. Armstrong also showed that with sufficient feedback the circuit could be used as an electronic continuous wave generator[5]. In 1915, AT&T transmitted the first wireless transatlantic telephone message, using an improved vacuum tube audion and regenerative circuit in both its transmission and reception. Both Fessenden and DeForest had started companies to compete with Marconi in wireless communication, but by 1915 both were out of business.

While the technology had evolved to allow for the transmission of voice messages over long distances, the primary commercial interest was in communications: ship-to-shore, news agencies, company business. Broadcasting music and other types of programs was done primarily by amateurs as a hobby or as a public service. By 1915 there were thousands of such operators in the country and thousands more people with receivers. It wasn't until after World War I that broadcasting became a commercial enterprise. Although DeForest operated a station in New York since 1915 from which he broadcast music on a regular basis and sold receivers to his audience, it was Westinghouse who began operating the first commercial broadcasting station (KDKA, in Pittsburgh). In addition, Westinghouse designed and sold an inexpensive crystal receiving set called the Aeriola.

[5] Although Armstrong is credited with demonstrating the usefulness of these circuits, DeForest challenged the patents based on earlier work he had done. DeForest eventually won the patent for the regenerative circuit.

Also in 1919, with the support of the Government, General Electric bought out Marconi's American operations and patents. These were handed over to a new entity called the Radio Corporation of America (RCA). RCA was to act as the major U.S. operator of wireless communications services. Shortly after, General Electric negotiated a deal with AT&T to buy into RCA, bringing with it its wireless patents. In 1920, Westinghouse acquired Fessenden's patents and negotiated a share of RCA's ownership. Although RCA was suppose to be in the business of providing communication services, it quickly talked its patrons into allowing it to get into broadcasting. RCA started a number of stations, merging them with Westinghouse's and forming the National Broadcasting Company (NBC) was begun.

A similar story took place in Chicago,where two veterans of World War I and former amateur operators formed a radio station called 9ZN (pronounced Zenith). The company called Chicago Radio Lab, began modestly, selling radio systems (transmitters and receivers) to the Chicago Tribune and the North Carolina-St. Louis Railroad. By the end of 1919 they were selling one radio set per week. By 1941 they became the second largest manufacturer of radios in the country.

In 1922, Edwin Armstrong patented another circuit called the superheterodyne. This circuit had a built in local oscillator that could mix with a received signal and reduce the frequency to an intermediate one which allowed for better demodulation. This greatly increased the quality of reception, and radio sales took off. In 1922, 100,000 radio receivers were sold valued at $11 million. By 1924, 1.5 million sets were sold valued at $50 million.

Other manufacturers entered the market . The Philadelphia Storage Battery Company (Philco), formed in 1909, supplied the batteries that were then needed to power radio receivers. In 1928, when another firm called Raytheon and RCA had begun manufacturing power tubes that could accept AC current directly from the wallsocket, doing away with the need for Philco's batteries, the company purchased an RCA patent license and began manufacturing radio receivers. By 1930, Philco became the leading radio manufacturer in the country. Other manufacturers included National Union Corporation, Crosley Radio Corporation, Perryman Electric Company, and the DeForest Radio Corporation. None of these survived the shakeout in the industry that was to come. Major tube manufacturers included General Electric, Westinghouse, RCA, Sylvania, and Raytheon.

By 1929, the radio industry was producing more than it could sell. The industry produced 4.7 million sets, but could only sell 4.2 million. And then the Depression hit. While sales slumped during the 1930s, technical improvements continued. Fidelity improved, smaller portable and less expensive models were developed. By the end of the decade sales began to grow again. In addition, a new market developed around the automobile. Mobile radio sets had been developed for police departments beginning in 1928. Later mobile radio receivers were sold as add-ons to automobiles. In 1931, 100,000 such units were sold. By 1934, 725,000 units were sold. RCA and General Electric began selling mobile radio receivers directly to auto manufacturers in 1936. In 1937, Galvin Electric entered the market with its Motorola (the company later changed its name to Motorola). In 1941 Continental Radio merged with Radio Products Corporation and bought the Admiral trademark. Admiral, holding no important patents of its own, specialized in marketing small table top radio and phonograph combinations. By 1949, Admiral became the number three producer of radios.

Television made its first appearance in the 1930s. Inventors had been trying to send pictures over telephone lines for years. Development had progressed down two paths - electromechanical and all-electronic systems. Early developers included RCA, Dumont, Philco, and Television Laboratory. In 1938, Vladimir Zworykin, head of RCA's Electronics Research Lab, perfected his iconoscope camera (for transmitting images) which he originally had patented while at Westinghouse. Later that year he also patented the kinescope (a image translator based on a cathode ray tube). Both were all-electronic systems. RCA demonstrated this system during the 1939 Worlds Fair in New York, broadcasting off the Empire State Building. In 1940, 6 companies announced their intention to market television systems for the New York market - American Television Corporation, Audrea Radio Corporation, Allen Dumont Labs, General Electric, Philco Radio and Television Group, and RCA - each with their own technologies and no standard between them. It wasn't until 1941, that the Federal Communications Commission (FCC) decided on an industry standard, in favor of RCA. World War II, however, inhibited further developments.

World War II transformed the U.S. electronics industry. Up to this time, electronics and consumer electronics were nearly synonymous. The War turned the industry into an even higher volume producer of tubes and equipment for jammers, direction finders, radar, sonar, proximity fuses, two-way communications, and radios. Miniaturization was required so that radar and radios could fit in tanks and airplanes or be carried by soldiers. Production increased in firms on average 12 times. The Army's Signal Corps granted 80% of their contracts to 5 electronic firms, including RCA, Westinghouse, and General Electric. Western Electric, General Electric, and RCA were first, second, and third in receiving contracts from the Office of Scientific Research and Development (later to become the National Defense Research Committee). In 1941, 55 manufacturers of electronic products produced $240 million in sales. By 1944, radio and radar parts alone accounted for $4.5 billion in sales. Each tank contained $5000 in radio equipment, each heavy bomber contained $50,000 in electronic equipment. By the end of the war, 2000 radar sets were produced each month by firms such as Raytheon, Westinghouse, and Sperry.

The war effort appropriated most of the scientists and engineers engaged in electronics at the time. Their work was coordinated by the National Defense Research Committee. New research facilities were opened, including MIT's Radiation Lab where microwave developments were carried out. Labs at Columbia and University of California at San Diego conducted anti-submarine research, and a lab set up at Harvard studied radio-jamming and jamming countermeasures. Most of the effort, however, focused on radar development. The Navy had been pursuing radar development at a low level since 1931 at its Navy Research Lab. It was the United Kingdom, though, that led the way in radar development, especially in the area of high powered radar based on its development of the magnetron tube. That technology was transferred to the U.S.

The sudden drop and cancellation of military contracts at the end of the war forced most electronic firms to consider plans on how to return to consumer markets. Television was seen as the primary growth market. In 1947, 14 firms engaged in television manufacturing. RCA captured 50% of the market. By 1948, Philco and General Electric had reduced RCA's market share to 30%. In 1948, Raytheon bought Belmont , a radio manufacturer, with the intention to enter the television market. Motorola, too, positioned itself to enter the market. By 1950, 80 firms were involved in manufacturing television sets and parts. Zenith became the number one producer. By 1955, 31 million households owned a television set. Sales flattened in the last half of the decade, bouncing between 7.5 million sets and 5.6 million sets per year. The average price paid for sets dropped from $225 in 1954 to $190 in 1957 as smaller models were introduced. Total consumer electronics sales in 1958 reached $1.3 billion.

Color television had been under development since before the war, but the need for a standard and a lack of desire on the manufacturers part to compete with their own monochrome sales slowed its introduction. The main technical issue was whether color tubes should be able to accept monochrome broadcasts. RCA was developing a compatible system. Columbia was developing an incompatible system. The FCC judged the Columbia's system to be technically superior, but RCA won acceptance for its system in the courts.

RCA began selling its first color sets in 1954, a 21 inch screen model which sold for $895. Other manufacturers followed: Admiral, Dumont, Emerson, Motorola, Olympic, Magnavox, Sentinel, Westinghouse. Most of these firms bought their color tubes from RCA. Color tube manufacturing was very expensive and initially unreliable. Color programming was slow to develop. And, consumers preferred to wait until they had to replace their monochrome sets before buying a new color one. Many firms dropped out of the market, at least for the time being. In 1961, Zenith entered the market, manufacturing its own tubes. In 1964, Motorola pioneered a shorter rectangular tube which became the industry standard. Westinghouse and Sylvania were also tube manufacturers.

Color sales did not reach 1 million until 1964. In 1965, 2.5 million sets were sold and surpassed monochrome sales by value for the first time (monochrome sales started to decline after 1965). Average sales price of a color set dropped to $340. In 1966, color sales doubled monochrome sales in value and represented 46% of the total consumer electronics market. U.S. firms had to add capacity to meet demand for color tubes. Profits in the consumer electronic market were at an all time high[6]. In 1967, 5.5 million color sets were sold surpassing the number of monochrome sets sold for the first time.

Imports of consumer electronics (primarily in radios, monochrome television sets, and audio tape players), which began in 1951 with Sony's first transistor radio, began to increase rapidly in 1966, rising to 10% after having leveled off at about 8% the previous four years. In 1969, imports reached 20%. U.S. firms still held about 90% of the color television market (RCA had 25%, Zenith who led in monochrome production had 21% of the color market, Motorola held 6%), but began moving production off-shore (Tawain, Singapore, Mexico).

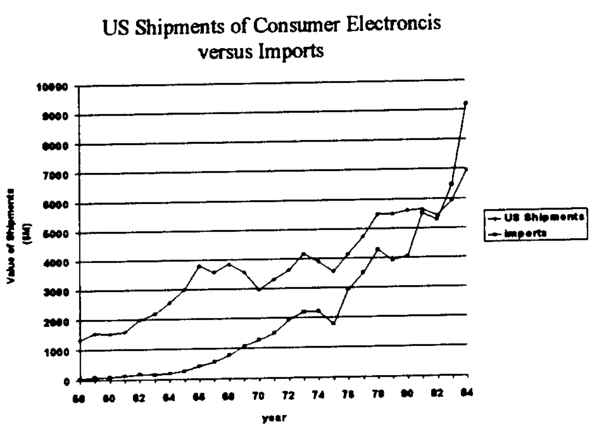



Figure 1

By 1974 imports accounted for over 50% of the total value of theconsumer electronics market, and U.S. color television manufacturing began to fall. Motorola quit making car radios and sold its Quasar television line to Matsushita (Japan) in 1974, making Matsushita the world's largest manufacturer of television sets. Ford, which had bought Philco in 1961, sold its color tube plant to Zenith and the rest of its consumer electronics to Sylvania. Westinghouse, who had left the set business earlier, sold its tube line to Sony. Philips (Holland) bought Magnavox in 1974. Sanyo (Japan) bought Warwick, a private

[6] Department of Commerce. U.S. Industrial Outlook. 1967. p143.

brand manufacturer, in 1976. Rockwell, who bought Admiral in 1973, as a way to diversify into the the commercial sector, sold it in 1977. In 1981, Philips bought Sylvania. In 1982, imports surpassed domestic production for the first time. Finally, in 1988, General Electric bought RCA and sold their combined consumer electronics line to Thomson (France), making Zenith the only U.S. firm manufacturing color televisions. In 1992, Zenith closed its last U.S plant, manufacturing all of its televisions in Mexico.

Increases in Japanese imports of color television sets was temporarily slowed by quotas set by the 1977 US-Japan Orderly Marketing Agreement. The Agreement encouraged those Japanese firms, who hadn't already, to locate operations in the U.S. By 1980 Sony, Matsushita, Sanyo, Mitshubishi, Toshiba, Hitachi, and Sharp had plants located here. About 70% of the total value of their product was being made in these plants, including tubes, cabinetry, and labor. Only 5-7% of the value added resulting from circuitry was done in Japan[7].

## 3. REASONS FOR JAPAN'S SUCCESS

[7] Hart, Ibid.

Analysts attribute Japan's success in penetrating the U.S. consumer electronics market to a number of factors[8]. These include a more rapid innovation to transistors and integrated circuits, marketing strategies, and government policies and business practices. Perhaps the most important, and most interesting to this analysis, is their more rapid innovation to transistors and integrated circuits.

Sony became the first Japanese firm to significantly penetrate the U.S. consumer electronics market with its all transistorized radios beginning in 1951. Texas Instrument was the first U.S. firm to market an all transistor radio in 1954. The firm had just demonstrated the first silicon transistor and used the radio as a way to gain early production experience. Fairchild was the first firm to demonstrate, in 1966, the feasibility of designing and producing an almost all-transistorized television set. But, it was the Japanese who were first to market with an all-transistor television. By 1970, all Japanese television manufacturers were selling all-transistorized televisions. Only Motorola had an all-transistorized model on the market in 1970. RCA was the first to introduce an integrated circuit into its television set. But, again the Japanese pursued the use of integrated circuits more forcefully.

The use of transistors and later integrated circuits had a profound effect on product manufacturing, cost and reliability. First, the assembly process for transistors and integrated circuits were easier to automate. By 1978, the Japanese were inserting automatically 65%-80% of all their components. U.S. firms were automatically inserting

[8] Much of the section is taken from a summary done by the Office of Technology Assessment

40%. Integrated circuits also allowed for far fewer components. Between 1971 and 1975, Japanese firms, on average, reduced the number of components in their sets from 1200 to 480. U.S. firms, in the same time frame, reduced theirs from 1150 to 880.

Fewer components assembled automatically not only reduced costs but increased reliability. In 1974, U.S. sets required 5 times more service calls that Japanese sets. In 1974, Consumer reports tested 11 sets, 9 of them U.S., 5 of which required repairs before the sets could be tested, and one which they never could get to work[9]. Japanese firm, who were actually shooting for zero defects in their designs and manufacturing, on average had to rework 1 in every 100 sets. U.S. firms were reworking up to 50% of their sets. The distinction in philosophy can be seen in their different designs. Japanese firms were putting all of their circuitry on one board. U.S. firms stuck with multiple boards to make repair easier. Taken together, these advances in automation and reliability allowed Japanese firms to manufacture a television set in .8 hours. U.S. firms averaged 2.6 hours.

The increased reliability allowed Japanese firms to avoid having to establish their own sales and distribution networks in the United States. Early market penetration occurred by selling to Sears and Montgomery Ward at a time when U.S. firms preferred to sell their products directly through outlets under their own brand names. In another marketing synergy, Japanese firms first marketed small portable sets, a niche segment of the market

[9] Teitelman, Robert. Profits of Science: The American Marriage of Business and Technology. Basic Books. NY, NY, 1994.

neglected by U.S. firms, and once again made possible by Japan's early commitment to transistors and integrated circuits.

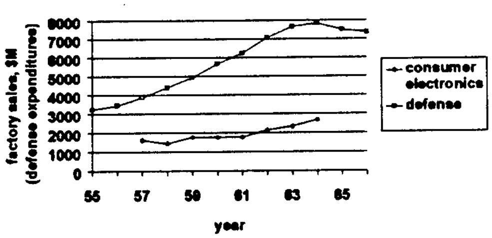
Finally, the Japanese firms benefited from government policies and business practices. Consumer electronics was one of those areas targeted for protection early by Japan's post war industrial policies. Direct foreign investment was limited and tariffs remained high (on the order of 30%). This limited the import of products into the country and the ability of U.S. firms to manufacture in Japan. U.S. firms did not have comparable distribution outlets like Sears in Japan. Also, the efforts by Japanese firms to introduce transistors and integrated circuits, especially into their television sets, were aided by the Ministry of International Trade and Industry (MITI) who set up cooperative programs to demonstrate the feasibility and problems associated with doing so. Finally, the protected Japanese market allowed Japanese firms to undercut U.S. manufacturers in the U.S. market while maintaining high prices for their products in Japan. U.S. firms accused Japanese firms of dumping. U.S. firms also claimed that Japanese firms coordinated their sales agreements with U.S. distributors so as not to undercut each other. The Department of Commerce upheld this view, but the Supreme Court ruled against the U.S. firms.

Absent the above discussion is what role, if any, DOD's investment in electronics may have had on the inability of U.S. firms to compete with Japanese firms during this time. This is particularly interesting given the importance associated with Japan's greater innovation in the use of transistors and integrated circuits at a time when DOD was greatly expanding the use of that technology in their own products, and given that many of the US consumer electronics firms were players in both markets.

## 4. DOD's INVESTMENT IN ELECTRONICS - 1950 TO 1975

It is difficult to determine the extent to which DOD invested in electronics following World War II. According to the Electronics Industry Association, the electronic content of DOD's expenditure in equipment and research and development grew steadily from \$3.2 billion in 1955 to \$7.8 billion in 1964, before declining to \$7.3 billion in 1966[10].

Electronic Content of Defense Expenditures versus Factory Sales of Consumer Electronics




Source: EIA Yearbook 1965 taken from USACDA, see footnote

According to EIA, consumer electronic sales during that time grew slowly from \$1.8 billion in 1957 to \$2.9 billion in 1964. The same document shows the trend in sales of electronics to the government growing from \$655 million in 1950 to \$20 billion in 1979. The Government figures, however, are not broken out between DOD and other agencies (primarily the National Aeronautics and Space Agency, NASA, and the Federal Aviation Authority, FAA). Typically, DOD represents the dominate share. The EIA report referenced above shows DOD's share declining from 89% of government sales in 1963 to 80% of government sales in 1966.

[10] Electronics Industries Association, Yearbook 1965, pp.32-33. Taken from the US Arms Control and Disarmament Agency. The Implications of Reduced Defense Demand for the Electronic Industry. Sept. 1965. p 12.

According to the Department of Commerce's Industry Outlooks, military spending on electronics during the 1960s and 1970s consistently represented over 80% of the product value of shipments in the electronic systems and equipment segment of the industry (SIC 3662). This segment includes electronic detection and navigation and communication systems. Total product shipments in the segment increased from $2.3 billion in 1958 to $11.4 billion in 1977. Assuming an 80% share for DOD, military expenditures on electronics would have risen from $1.8 billion to $9.1 billion.

Product Value of Shipments
for
SIC 3651 and SIC 3662

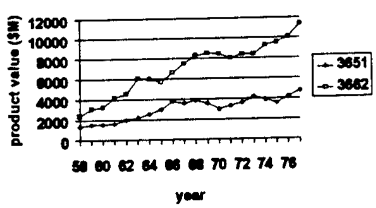



Figure 3

Source: Data accumulated for Dept. of Commerce, Industry Outlook

These figures do not consider electronics not purchased via a prime contract. Nor do they include DOD's expenditures on electronics research and development which, according to the Department of Commerce, ranged between $2.3 and $2.6 billion during most of this time. The Department of Commerce reported that DOD's R&D rose from $9.5 billion in FY1976 to $12.0 billion in FY1978. It did not discuss the discontinuous jump. The change may reflect a different estimating or reporting technique.

While these numbers should be considered cautiously, it is probably safe to say that military expenditures on electronics (purchases and R&D) rose more or less steadily from 1950 to 1978 at a rate somewhat greater than the increase achieved in consumer electronics. A small decline occurred in the mid-1960s before U.S. involvement in Vietnam increased. It is interesting to note that while overall defense spending began to decline after Vietnam, military spending on electronics did not. This is because the electronic content and sophistication of military systems continued to increase.

The figures discussed above do not tell on what DOD was spending its money. The following is a brief sketch of some of the technologies and systems developed and bought by DOD during this time period. U.S. consumer electronics firms took part in a number of these.

In the 1950s, DOD spent a significant amount of money on the development of air defense systems. These included radar guided missiles such as the SPARROW (for ship defense) and HAWK (for ground defense). Raytheon became prime contractor on both of these programs. DOD also developed a continental air defense system (SAGE) that required more powerful and sensitive radar capable of tracking a number of objects simultaneously. The system also required major improvements (greater speeds and volume) in data processing using the latest in digital processing. A number of firms competed for the SAGE contract including Sylvania and RCA. The SAGE system was later superseded by the Ballistic Missile Early Warning System (BMEWS), capable of detecting, tracking and targeting ballistic missiles. RCA was a contractor on that system. Similarly, Philco was involved in space tracking. In addition, new detection techniques were developed like pulse-doppler techniques for picking out moving objects against background clutter. The

Army Signal Corps and the University of Michigan developed a side-looking terrain mapping radar.

DOD also invested in the development of transistor technology. While AT&T developed the basic concept behind transistors, it took some time to develop devices that were reliable and easy to manufacture. Because of their poor yields prices were high, but DOD was willing to pay the price for applications where tubes could not fit. DOD bought its first transistors from major tube manufacturers. In October, DOD signed over $5 million in contracts with Raytheon, General Electric, Sylvania, and RCA to deliver over 5000 units each of point-contact and junction transistors and germanium diodes. 78% of DOD's research and development in transistors went to these firms. However, most of the purchases went new companies, like Texas Instruments and Fairchild. These firms continued to develop new solid states devices, integrated circuits, and manufacturing techniques throughout the 1960s and 1970s. RCA considered itself one of the leading transistor producers in the 1950s. In 1961, RCA was the 10th largest defense contractor and tops among electronic firms. Military work accounted for 38% of its revenues[11].

DOD continued work on computers which it had begun during the war. RCA was a supplier of ultrareliable tubes to the ENIAC program during the war. It went on to develop computers for DOD after the war. In 1952 it developed the Bizmac for the Army to keep track of inventory. RCA formed a new division in 1957 to develop commercial computers based on its military-derived technology. Other consumer electronic firms

[11] Sobel, RCA. Ibid.

entered the computer business as well - Raytheon, General Electric and Philco - based on their component products.

In the 1960s, space and intercontinental missiles provided the big markets for integrated circuits. The Minuteman program demanded production of 4,000 integrated circuits per month. DOD also developed satellites, for communications, surveillance, weather, navigation and remote sensing, increasing the demand for miniaturized electronic equipment and components. Transistors and integrated circuits pushed radar technology to higher frequencies. Funding went toward better signal processing for greater sensitivity and detection against background noise. Phased array radar, electronically steered vice mechanically steered, was also developed. Solid state devices were used to reduce the size, weight and power requirements of existing radar units, and to develop new mobile units, including hand held radar systems. DOD continued to push computer technology during the 1960s as well, further increasing processing speeds, reducing size, developing interactive systems, networking, etc. DOD was also involved in developing optical electronics in the 60s,, including lasers and night-vision.

In the 1970s, DOD supported the very high-speed integrated-circuit (VHSIC) program in an effort to transfer technology from the commercial sector to the military sector. Microprocessors made phased array radar more practical. New high speed processing and high volume memory made synthetic aperture radar more practical. Major systems programs with significant electronic content included A-7E and A-6E attack aircraft; F-14, F-15, and F-16 fighters; P-3C antisubmarine warfare aircraft; E-2C early warning aircraft; Stingers, Maverick and TOW anti-tank, anti-aircraft guided missiles; the Trident ballistic missile submarine; and the Aegis destroyer[12].

## 5. COMPETITION FOR RESOURCES?

The intent of this section is to examine whether DOD's expenditures in electronics drew away resources (namely capital and manpower) from the consumer electronics sector. Ideally, one would like to have primary sources relating to specific investment decisions and the tradeoffs made. This information was not found. Therefore, this section relies on drawing inferences from certain industry data and anecdotal information found in articles and reports and books, primarily to see if investment capital seemed to be unavailable. The author realizes the imperfect nature of these sources and the danger in drawing definite conclusions from the inferences made.

**Investment Capital:** Figure 4 shows the capital invested in new plant and equipment by the industry. It compares data from the Census of Manufacturing for SIC 3651 and SIC 3662, using SIC 3662 as a surrogate for the defense electronics industry.

[12] RCA had a $253 million contract to develop the radar for the Aegis.

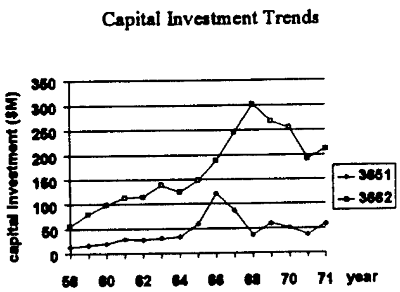



Figure 4

Source: 1978 Census of Manufacturing

Capital investment in consumer electronics grew on average 20% between 1958 and 1972. The large spike in 1965 and 1966 corresponds to the increase color television capacity added to meet the increase in demand at that time. From 1968 to 1972, however capital investment is essentially flat, reflecting the resulting overcapacity that occurred. SIC 3662 capital investment between 1958 and 1972 grew an average of 11% per year. It declined from 1969 to 1971. This data would <u>not</u> indicate that the flat level of capital investment in consumer electronics after 1968 is because defense electronics crowded it out. Again, this inference must be made with caution. Obviously, the capital investment in consumer electronics might have been more if it wasn't for the relatively high level of investment made in the other sector.

From 1958 to 1966, the U.S. Bureau of Labor reported that the television industry improved labor productivity 6.2% per year (double the rate of the economy as a whole). In 1958, the industry spent $200 in new capital per employee or one-third the level of the rest of US manufacturing. In 1966 the industry spent $930 in new capital per employee (roughly the national average). Since employment was increasing during this time period, the industry must have had good access to capital during this time period[13].

[13] Tietleman, Ibid. p.68-69.

There is other anecdotal information to suggest that the consumer electronics industry was not hurting for investment capital, even beyond the time that U.S. market share dramatically declined. According to Sobel, RCA had made a firm commitment to developing television in the 1950s through the mid-1960s, sacrificing larger investments to develop its computer business in order to fully support its efforts in television[14].

In 1968, Motorola expanded manufacturing space 50% (although it was in Taiwan). Motorola had just introduced its all transistorized sets in 1967 and was selling them faster than the market as a whole was growing. The company, however, had introduced this technology into its high end products at a time when the high end market slowed. Unable or unwilling to introduce the technology into its smaller models, the company actually lost money on its product[15]. By 1974, Motorola had lost close to $20 million in four years in its consumer electronics business (which also included auto radios and phonographs). Its military related business represented only 6% of its revenues. Its real growth was in semiconductors and mobile communication systems. Wall Street concluded that it was time for Motorola to sell its television operations[16].

In 1974, Zenith made a major investment to introduce an entire new line of transistorized sets and automation. It was planning to increase plant spending from $15 million in 1973

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[14] RCA invested $150 million in developing its monochrome television technology and did not start earning a net profit on it until 1959. It is also interesting to note that once color television took off, RCA invested much more heavily in its computer business, loosing $570 million before selling it in 1971. According to Sobel and Tietleman, this investment retarded RCA's efforts in video-disc technology.
[15] Why Mitsushita Bought Motorola TV. Business Week, March 16, 1974. p 30-31.
[16] Dead End. Forbes. March 1, 1974. p. 27.

to $47 million in 1974. It was also planning to invest the bulk of its research and development funds in videodiscs, while dropping some of its more highly sophisticated military work[17].

Finally, Westinghouse invested $100 million as late as 1978 in its color tube plant, before eventually closing it down and selling it Sony in the early 1980s. This was after its major customer, Magnavox, had been sold to Philips[18].

Another line of inquiry was to study the relative attractiveness of consumer electronics and defense electronics in terms of profitability. Typically, defense contracting is less profitable in terms of percent of sales. A study done for the Federal Trade Commission compared profitability on sales and return on net worth for a sample of firms in 1961-1962, and 1962-1963. The study indicated firms earned twice as much profit as a percent of sales in consumer electronics than in government (again, using government as a surrogate for defense) - 4% vice 2%. In terms of returns on net worth, the ratio was a little less than twice - 13% for consumer electronics vice 7.5% for government. In both cases, though, government contracts in electronics was below the median for all industry.

Profit as a percent of sales varies widely in the consumer electronics industry subject to market swings. From 1971 to 1981, though, profitability as a percent of sales in the

[17] The Big Winner. Forbes, 1974.
[18] Conversation with Walter Sutcliffe, Westinghouse, now Nothrop-Grumman. April, 1996.

television market declined more or less steadily from 8.7% to minus .1% in 1981. Profitability for all electronics during that time period averaged 7.6%[19].

The inference drawn here is that DOD was not necessarily a more attractive market than consumer electronics at least in the early 1960s. This may have switched during the 1970s, however. Clearly consumer electronics was no longer an attractive place to invest. And, interestingly DOD had just instituted new policies based on its Profit '76 study that increased the level of profitability on defense contracts, without requiring an increase in investment on the part of the contractors[20].

**Employment:** Little information is available on relative employment, wages, etc. between those working in defense electronics and consumer electronics. In 1930, electrical engineers with 5 years experience earned more in the radio industry ($3500/yr) than in the electrical industry ($2800/yr.)[21]. According to a Battelle survey from the 1960s, wages for professionals in the defense sector were 5 to 10% higher than in nondefense sectors. Percentages in the electronics industry were not given, but interviews indicated that the differential might have been even larger in the that industry[22].

## 6. CONCLUSIONS

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[19] Office of Technology Assessment. International Competitiveness in Electronics. Nov. 1983.
[20] Federal Trade Commission. The Impact of Department of Defense Procurement on Competition in Commercial Markets: Case Studies of the Electronics and Helicopter Industries. Dec. 1980.p. 34-35.
[21] An Age of Innovation. Ibid.
[22] U.S. Arms Control and Disarmament Agency. Ibid.p. 28.

Given the data presented here one must be cautious to draw definite conclusions. Nevertheless, the following conclusions are drawn. DOD did make a significant investment in electronics between 1950 and 1975. That investment involved many of the primary consumer electronics firms, especially in the 1950s, especially in the continued development of radar and in the new development of transistors and other semiconductor devices. However, the defense market represented a relatively small share of those firms' overall revenue. The primary exception was Raytheon whose defense business during the 1950s and 1960s was roughly 80%. The consumer electronics industry appears to have had access to investment capital throughout this period, at least until the competition from imports forced a shakeout among those serving a smaller share of the market. Competition for investment capital, if anything, seems to have come from efforts to enter the computer market or other areas within the commercial sector. Those firms leaving the consumer electronics market in the 1970s, did not appear to increase their defense business, but invested in other areas. In short, it is difficult to see how DOD's investments might have directly impacted the consumer electronics industry.

Having said that, more work might shed better light on the topic. A more thorough study of the specific programs that the major consumer electronics firms were engaged in and how that affected internal resource management is needed. In addition, a more thorough examination of the relationship between DOD's use of transistors in electronics, especially in those technologies most similar to consumer electronics - radio, radar, etc. - and how that might have affected the industry's decisions to introduce transistors more slowly than the Japanese is needed.

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