APPENDIX B
Offshore Manufacturing*

During the past two decades, many American electronics firms have moved portions of their manufacturing operations overseas in search of lower labor costs. Offshore production has been a major element in cost reduction strategies, particularly in price-sensitive portions of the industry such as consumer electronics and semiconductors. Labor-intensive components and subassemblies for computers and many other products are also made in low-wage developing countries. In electronics, as in automobiles, foreign investment has been a major force in transforming national industries into international industries. Transfers of technology as well as capital contribute to internationalization.

American electronics firms invest in overseas plants to serve foreign markets, as well as reimporting goods to the United States (ch. 4). The former are often termed point-of-sale plants, the latter offshore manufacturing or offshore assembly plants. It is offshore investment to serve the U.S. market that is the primary topic of this appendix. Other arrangements—for instance, subcontracting with foreign firms—will not be covered. Offshore manufacturing thus implies ownership and management control by an American corporation, Virtually all the major U.S.-owned consumer electronics and semiconductor companies have offshore plants, mostly in Mexico and the Far East.

In both consumer electronics and microelectronics, the driving force for offshore investment has been cost reduction. U.S. consumer electronics firms—principally television (TV) manufacturers—have moved overseas to meet competitive pressures and preserve existing markets (ch. 5). Foreign investment has been largely a defensive tactic, a reaction to import penetration at home, In microelectronics, competition *among* U.S. firms has led to transfers offshore.

From the perspective of the United States, offshore production has both positive and negative impacts. Compared to the plausible alternatives, the net effects appear to be positive in most cases, much more so in the case of semiconductors.

*This appendix is based largely on "Effects of Offshore and Onshore Foreign Direct Investment in Electronics: A Survey," prepared for OTA by R. W. Moxon under contract No. 033-1400.

Economic Impacts of Offshore Manufacture

Offshore investments in electronics affect domestic employment, the balance of payments, national income, and the future competitive abilities of American industry, The many studies of U.S. foreign direct investment, while seldom focusing on offshore manufacturing per se, yield insights into such investments. Even so, the evaluation of costs and benefits remains controversial, and the evidence gives no clear guide to public policy. Immediate impacts generally get the most attention, although longer term effects often prove quite different than short-term consequences. Table B-1 classifies the impacts.

Table B-1 .—Possible Effects of Offshore Manufacturing Investments

Effects within the Industry making the Investments

A. Domestic employment
   1. Total U.S. employment in the industry (up or down).
   2. Changes in skill mix in the industry (increase or decrease in blue-collar job opportunities, expansion in professional categories, etc.).
   3. Regional employment shifts.

B. Domestic value added by the industry
   1. Changes in total wages and salaries paid to domestic employees of the industry.
   2. Profitability of companies in the industry.
   3. Tax payments by firms in the industry.

C. U.S. balance of payments
   1. Shifts in trade balance involving products of the industry.
   2. Other current account flows.
   3. Capital account flows.

Effects In related Industries (suppliers as well as customers)

A. Domestic employment (with same subcategories as above).

B. Domestic value added (with same subcategories as above).

C. U.S. balance of payments (with same subcategories as above).

Longer term effects

A. Shifts in international competitiveness of U.S. industries.

B. Changes in concentration and structure of U.S. industries.

SOURCE" "Effects of Offshore and Onshore Foreign Direct Investment in Electronics A Survey, " prepared for OTA by R W Moxon under contract No 033.1400, p. 5

Immediate Employment Impacts in the Industry Making Foreign Investments

Offshore investment by U.S. firms creates jobs in foreign countries. To what extent do such jobs replace employment opportunities in the United States? When a U.S. TV manufacturer moves its assembly operations offshore, some Americans lose their jobs. But *if* the firm stays in business as a result of the cost savings from offshore assembly—and if it might have failed without this move—then the net effect can be to preserve *some* U.S. jobs, In general then, if foreign investment improves the competitive position of the American firm, the effects on domestic employment can be positive; the investment may create foreign jobs while saving domestic jobs.

Demonstrating unambiguously that this has or has not happened is, unfortunately, seldom possible. The matter turns on a counterfactual question: *What would the outcome have been if the foreign investment had not been made?* Largely because of this, past studies of the employment impacts of the same investment have resulted in estimates ranging from losses in employment opportunities of more than a million to *gains* of half a million.[1]

Foreign investment may also affect the mix of jobs available domestically. Even if net employment increases, certain job categories may suffer. Most of the foreign workers in offshore manufacturing plants perform unskilled production tasks. These are the kinds of jobs that tend to be lost in the United States. Thus, the domestic skill mix generally shifts in the direction of the more highly skilled and professional jobs—technicians, engineers, managers. Unfortunately, unemployment in the United States is concentrated in the ranks of unskilled and semiskilled workers. Moreover, since the electronics industry is geographically rather concentrated, offshore investment can have significant local and regional impacts.

Immediate Effects on Domestic Value Added

Closely related to employment is the impact on U.S. national income, or value added. Value-added effects can, in turn, be divided into several categories: wages and salaries, profits, tax payments (table B-l). Offshore investments generally substitute foreign for domestic value added. The *magnitude* of these effects depends, however, on changes in the competitive position of the firm making the investment. In some cases value added may increase both in the United States and abroad.

Foreign investments can also affect the distribution of income among the categories of wages and salaries, profits, and taxes. If offshore manufacturing substitutes foreign jobs for U.S. employment, value added will tend to move from wages and salaries toward profits and tax payments. But a sharp enough swing toward highly paid skilled and professional workers in the United States could reverse this effect. Offshore manufacturing may also create opportunities for firms to reduce their U.S. tax bills. On the other hand, if the company's competitive position improves sufficiently as a result of offshore manufacturing, net tax revenues could go up.[2]

Effects on the Balance of Payments

Offshore investments are reflected in the U.S. balance of payments through both the current and capital accounts, Foreign manufacturing generates imports, which show up on the current account, but these will be partially offset by exports of materials or components to the offshore plant. In the semiconductor industry, wafer fabrication has generally remained in the United States, with wire bonding and other labor-intensive assembly operations moving overseas. The wafers shipped to offshore plants by American firms later return as finished integrated circuits (ICs); the latter are counted as imports, the former as exports. A substantial fraction of U.S. trade in semiconductor devices—roughly three-quarters in the case of imports (ch. 4. table 28)—represents intrafirm transfers of this type.

The U.S. capital account shows outflows when American firms invest abroad, but moneys may gradually return in the form of profits or other payments flowing back to the United States. Once again, the primary question is: What would have happened in the *absence* of the investment? Has it enhanced the competitive position of an American firm? Or has U.S. competitiveness declined? These questions are central to any evaluation of costs and benefits.

Some of these questions are seemingly imponderable—or at least subject to widely differing answers

[1] J. Segall, "Introduction to the Conference," *The Impact of International Trade and Investment on Employment: A Conference on Department of Labor Research Results* (Washington, D.C.: Department of Labor, 1978), p. 5.

[2] While overseas investment by American firms often displaces U.S. investment, resulting in losses of domestic. output and decreases in U.S. tax payments, foreign earnings remitted to the United States can offset these losses The net result may be only a small net decrease due to the foreign Investment Perhaps more important, the *distribution* of national income tends to be shifted toward capital, and away from labor. See P B Musgrave, *Direct Investment Abroad and the Multinationals: Effects on the United States Economy*, Subcommittee on Multinational Corporations, Committee on Foreign Relations, U.S. Senate, August 1975.

—thus estimates of the net impacts of foreign investment on the balance of payments cover a range just as broad as for employment effects.[3] Again, the crucial points involve the extent to which investment overseas displaces investment at home, and the extent to which offshore production may displace or, alternatively, stimulate U.S. exports. Such matters can seldom be addressed on other than a case-by-case basis.

Indirect Impacts on Supplier Industries

Offshore manufacturing in consumer electronics or semiconductors generally cuts into the sales of U.S. firms that supply these industries. Overseas plants normally buy expendable supplies and materials locally; they may also purchase parts, components, and subassemblies from foreign rather than American firms. U.S. firms supplying such components as switches, circuit boards, resistors, and capacitors to the TV industry suffered heavy losses in sales as American consumer electronics manufacturers moved overseas.[4] U.S. suppliers have seldom been able to meet price competition in overseas markets; when they lose sales to foreign companies, domestic employment and value added suffer. As their customers have moved offshore, some U.S. component manufacturers have, not surprisingly, followed.

Technology Transfer and Other Longer Term Impacts

Most of the effects outlined above have long-term, as well as more immediate, aspects. Beyond direct employment or financial consequences, what possible shifts in the competitive position of U.S. industry could result from transfers of technology through offshore plants? If U.S. investments accelerate processes of technology acquisition by other countries, the competitive advantages of American firms in electronics and related industries could erode. Such a result is more likely in rapidly industrializing countries like South Korea and Taiwan, which have already emerged as significant competitors in consumer electronics, helped to considerable extent by transferred technology.

When multinational corporations invest in developing countries, they must generally train workers, typically drawing on the local population not only for blue- and grey-collar employees, but for foremen and, often, middle managers. In electronics, the experience that these people get has proved to be a substantial benefit to indigenous firms; not only does a pool of workers, both skilled and unskilled, become available for locally owned companies to hire, but the managers of these companies are often people who got their start in a foreign-owned plant.

While it is easy to point to examples of this sort, where foreign investment has accelerated industrial development, technology diffusion is in any case inevitable. Offshore investments may speed the process, but consumer electronics technology was accessible to firms in Taiwan regardless of U.S. investments there. Technology moves internationally by multiple paths, some of which are quite independent of investment patterns. Furthermore, American electronics firms are not the only ones to invest in developing countries, Japanese companies have been quite active in moving electronics operations—particularly those that are lower technology and/or more labor intensive—to other Asian nations. In consumer electronics, developing countries can probably learn more from companies like Matsushita or Toshiba than from American manufacturers, Technology transferred abroad via U.S. investments often helps to build foreign competitiveness, but the recipients could generally get the same technology from other sources.

Evaluating Impacts

As pointed out at several places above, the underlying difficulty in trying to evaluate the consequences of offshore investment comes in the comparison of what did happen with what *would have* happened if the investment had not been made. The answer to such a question depends on judgments about how markets would have been served without the investment, which in turn calls for analysis of comparative costs and other factors in the competitive environment. Reaching conclusions on what has taken place can be difficult enough—witness the length of this report. But it is easier than determining what would have happened if a given investment had not been made. Still, logic and the available information can yield some insights.

Critics of offshore manufacturing by U.S. firms often assume, perhaps implicitly, that the products made abroad could have been produced here instead, contributing not only to domestic sales but to U.S. exports. If true, U.S. employment, national income, and balance of payments would all have benefited from continued domestic production. Critics also tend to assume that American compa-

[3] G. C. Hufbauer and F. M. Adler, *Overseas Manufacturing Investment and the Balance of Payments* [Washington, D. C.: Department of the Treasury, 1968).

[4] L. Marion, "TV Parts Makers Face Offshore Threat," *Electronics*, May 24, 1979, p. 102.

nies choose foreign investment over domestic manufacturing in order to increase their own profits, and that the company's competitive position would not be seriously threatened if it chose not to invest abroad.

Most defenders of offshore investment acknowledge that jobs are transferred abroad in the short run, but argue that the situation would in the longer run be even worse without these investments. They emphasize that most such investments are defensive reactions to competitive threats, domestic or foreign. When the primary competitors are foreign, and American firms do not respond by moving offshore, supporters of offshore manufacturing argue that the United States would end up importing the same goods from foreign-owned rather than U, S.-owned plants. Offshore investment thus preserves at least some benefits for the United States, because exports will go to the offshore facilities, professional and skilled jobs remain here, and the balance of payments will look better than it otherwise would have.

The counterresponse of the critics is generally as follows. If the primary intent of the offshore investment is to help U.S. firms meet import competition, then the proper response is simply to restrict imports. Interest groups that accept this argument may then combine, as they did in the Burke-Hartke bill, a call for protection against imports with a call for restrictions on offshore investment. As in so many questions involving shifting comparative advantage and the consequences for industrial policies, when the economics of the situation are cloudy—as they are here—political considerations tend to become dominant.

Motivations for Offshore Investments

American electronics firms establish offshore manufacturing facilities to take advantage of low-cost foreign labor. Investing companies see cost reductions as critical for meeting competitive threats from foreign enterprises, or to expand output and sales in competition with other domestic firms, or both.

Cost Savings for Products Manufactured Offshore

American TV firms make monochrome sets offshore, as well as subassemblies and complete chassis for color receivers. Production is labor-intensive, with low skill requirements, involving such tasks as inserting components in printed circuit boards, assembling tuners, winding coils, and making subassemblies for picture tubes. Offshore semiconductor manufacturing has generally been limited to assembly, primarily wire-bonding and encapsulation. In recent years, some testing has been performed overseas as well, usually as an aid to quality control. Many U.S. semiconductor firms also subcontract to local companies in developing countries,

As table 18 (ch. 4) indicated, wages are much lower in developing countries than in the United States or even Japan. Although labor productivity in such countries may also be low compared to domestic plants, large savings also can still result. In 1980, the average hourly compensation for American workers in the electrical and electronic equipment industry was $9.59; in the more popular locations for offshore American subsidiaries, it ranged from $1.13 in Singapore to $2.40 in Mexico.[5] Although wages have been increasing more rapidly in offshore locations than here, offshore production has continued to be attractive in making both TVs and semiconductor devices. To some extent, firms have responded to wage increases by moving on to other countries. For instance, two American companies have announced plans to invest in Sri Lanka, where wage levels remain very low.[6]

Because costs for wafer fabrication and testing make up a much larger percentage of the total for complex devices, offshore manufacture yields greater savings for discrete semiconductors and simple ICs. Table B-2 illustrates this, based on rough cost structures for simple and complex devices, and applying two arbitrary ratios of U.S. to offshore wage rates. Substantial savings are possible at either a 10-to-1 or a 5-to-1 wage ratio, but the margins are much larger for the simple device.

In TV manufacture, the net savings are smaller as a percentage of total production costs. Nevertheless, for some kinds of subassemblies they can be substantial, and in a highly price-competitive market—as TVs have been—any saving can be important. Zenith estimated in its annual report for 1977 that the transfer to Mexico and Taiwan of circuit module and chassis assembly for color sets would lower its unit costs by $10 to $15.

Strategic Implications

In consumer electronics, offshore manufacturing was a reaction to severe import competition, pri-

[5]Information from Bureau of Labor Stat] stics, Off Ice of Product ivity and Technology. Hourly compensation in Japan averaged $515.

[6]L Antelman, "Harris to Construct $19 (sic) IC Facility in Sri Lanka," *Electronic News*, Feb 8, 1982, p. 39 Motorola is the second U.S. firm planning a factory there,

Table B-2.—Cost Comparison for Offshore Assembly of Semiconductors[a]

	Discrete devices or simple integrated circuits			Large-scale integrated circuits		
		Domestic assembly			Domestic assembly	
		Wage ratio[b]			Wage ratio[b]	
	Offshore assembly	10:1	5:1	Offshore assembly	10:1	5:1
Cost of chip	$0.015	$0.015	$0.015	$1.00	$1.00	$1.00
Assembly cost	0.050	0.500	0.250	0.15	1.50	0.75
Packaging cost	0.050	0.050	0.050	0.50	0.50	0.50
Testing cost	0.020	0.020	0.020	0.75	0.75	0.75
Reject cost	0.015	0.015	0.015	1.00	1.00	1.00
Total	*$0.150*	*$0.600*	*$0.350*	*$3.40*	*$4.75*	*$4.00*

[a]The basic costs used in this table are from *A Report on the US. Semiconductor Industry* (Washington, D. C.: Department of Commerce, September 1979), p. 73 These costs do not apply to specific devices, nor are they necessarily current The purpose is simply to i l lustrate the magnitude of the cost savings available through offshore assembly

[b]Assumed' ratio of U S wages to wages in offshore plant

SOURCE "Effects of Offshore and Onshore Foreign Direct Investment in Electronics A Survey, " prepared for OTA by R W. Moxon under contract No. 033-1400, p 29

marily from Japan. Sales had been lost, and profits cut to low levels or to losses; a number of smaller American TV manufacturers succumbed during the period that RCA, Zenith, and GE were moving offshore. The story in microelectronics is quite different. Imports—exclusive of those from subsidiaries of American firms—were not a major factor while U.S. firms were transferring production overseas; in the 1960's, imports from foreign-owned companies accounted for only 1 or 2 percent of U.S. sales.

For semiconductors, the primary motives behind offshore assembly were:

1. *Cost Reduction as a Stimulus to Sales.* Price declines have led to a continuous stream of new applications of semiconductors—in other words, demand is highly price-elastic. As sales mount, costs drop through learning curve effects. Offshore assembly accelerated price declines still more, opening further markets.
2. *Capital Investment Constraints.* Semiconductor firms have had to continually increase capital spending to keep up with exploding demand and advancing technology, but have not always generated the profits needed to fund capital investment internally (ch. 7). Given the need for investment in costly wafer fabrication and testing equipment, offshore assembly offered an attractive way to expand capacity while conserving capital.
3. *Risks of Large Capital Investments.* Especially during the 1960's, when many offshore plants were established, semiconductor firms were wary of capital investments in automated production equipment, The fear was that technological change might quickly make them obsolete, For example, semiconductor packaging has changed a good deal, first as discrete devices gave way to ICs, later as ICs grew more complex. Several companies suffered as a result of automating at the wrong time. Offshore assembly offered flexibility without the risk of technological obsolescence. When technology and/or demand stabilizes for a given product, automation becomes more attractive, and assembly is occasionally brought back to the United States.

Once some American firms succeeded in cutting costs by moving offshore, others were forced to follow; later, Japanese semiconductor manufacturers did the same.

Alternatives to Offshore Manufacture

American firms invest overseas because to them this seems the best course of action given their competitive situation, If this possibility were foreclosed —e.g., by Government policy—what other avenues are open? The following appear to be the primary choices:

1. Maintain production in the United States, using labor-intensive processes similar to those that have been followed in offshore plants.
2. Maintain production in the United States, investing in automated equipment.
3. Subcontract production to an independent foreign manufacturer.
4. Discontinue production and sales of the product or products in question.

These four possibilities are briefly examined below.

Maintain U.S. Production on a Labor-Intensive Basis

For some consumer electronics products, where the savings from offshore sourcing have been relatively small, this would probably be the alternative chosen. Nevertheless, the loss of the cost savings from offshore assembly would hurt the competitive position of U.S. firms, some of which would probably move to lower cost areas within the United States.

This alternative has little to offer for semiconductor companies faced with increasing competition from foreign manufacturers. Substantial cost penalties would hurt sales, especially for mature products,

Automate Domestic Production

For many products that are now assembled offshore, automat ion is technically feasible. American TV manufacturers already use automatic component insertion to a considerable extent (ch. 6); investments in this and other automated manufacturing methods could be accelerated. Automation has been spreading rapidly in the semiconductor industry. Although automation is not at present feasible for all types of semiconductor products-sometimes for technical reasons, other times because production runs are short—finding the capital required is a more central issue for many firms in the industry. Smaller firms especially would have trouble financing extensive automation. As chapter 7 pointed out, funds are scarce and capital-intensity increasing in semiconductor manufacturing; managers' priorities place automation fairly low as long as there are feasible alternatives. Investments in automat ion would divert funds from advanced wafer fabrication equipment, as well as from research and new product development—without which, in this fast-moving industry, automated production equipment would be useless.

Subcontract Manufacturing to Foreign Enterprises

Subcontracting labor-intensive production operations to foreign firms has short run consequences for the United States not unlike those of direct foreign investment, and the U.S. semiconductor industry has in fact made considerable use of foreign subcontracting, Some American consumer electronic; s firms do the same. Subcontracting contributes to flexibility in responding to competitive pressures. Disadvantages come with respect to coordination in matters such as production schedules and cost or quality objectives. And while subcontracting saves capital compared to direct investment, direct production costs will be higher because oft he profits sought by subcontractors.

Especially in the semiconductor industry, but also in consumer electronics, this option might well be the first choice of American companies unable to establish their own foreign subsidiaries. The attractions are especially great for low-volume products where a foreign subcontractor with several customers might be able to achieve scale economies.

Discontinue the Product

Unless a firm had already decided on such a step, this would not be the first choice—but it might not be the last. Whether American companies would stop making some products if prevented from moving offshore depends on the extent to which their other opt ions are practicable and cost effective.

Offshore Manufacturing Compared to the Alternatives

Of the four options, U.S. consumer electronics firms would probably adopt a mix of the first three, depending on their product lines and competitive circumstances, In particular, the smaller consumer electronics manufacturers are much more limited in investment possibilities—i.e., in automation--than companies like GE or RCA. In the semiconductor industry, the cost savings from offshore production are so large—table B-Z—that most American merchant firms would no doubt subcontract to foreign enterprises if they could not invest overseas themselves. Some production would be transferred back to the United States, probably high-volume products made by larger companies.

What would be the impacts on the U.S. economy of the four alternatives compared to offshore investment? To address this question, the effects on domestic employment, balance of payments, and the other categories listed in table B-1 could be compared. At least in principle, scenarios could be constructed for the alternatives, singly or i n combination, most likely to be chosen by a given company or industry. ideally, estimates would cover a period of years, because an offshore investment might, for instance, initially cause an outflow of capital which in later years could shift to an inflow. In any such procedure, assumptions would have to be made concerning the *future* competitive environment for American firms,

A Case Example

Rather than pursuing an abstract analysis like that outlined above, the methodology can be applied to a simple example, a real company which, for purposes of the case study, has been renamed Systek.[7]

Systek, in 1969, decided to build a plant in Taiwan for assembling both complete automobile radios and subassemblies. All production was to be sold to Systek's U.S. operations, where final assembly and testing would take place. The company's management chose to make this investment because of a deteriorating competitive position; by moving offshore, the company felt that it could cut its production costs and prepare for upcoming battles with Japanese producers. Automobile radios sold largely on the basis of price, and Systek's major customers, U.S. auto manufacturers, continually solicited and compared price quotations from various suppliers. By the late 1960's, the automakers had begun to receive bids from Japanese electronics companies; Systek's management felt that the company would soon begin losing sales to the Japanese unless it could significantly lower its own costs and prices.

Systek evaluated several alternatives before building its Taiwanese plant. The company had already automated its U.S. factories as much as it judged practical; the only option it saw for cutting costs while remaining in the United States was to move production from its urban site in the north to one of the Southern States, where costs would be lower. Management judged this to be no more than a temporary solution. Systek also considered subcontracting the assembly of its line of auto radios to a Japanese firm, but could see little advantage in this choice because Systek had the resources and expertise to establish its own foreign subsidiary, which would have lower costs than a subcontractor could offer.

After a detailed feasibility study, the offshore alternative was chosen; Systek-Taiwan began production in late 1969. Operations went smoothly for the first few months, but then sales began to suffer because of a decline in the U.S. economy. Production had to be cut back in Taiwan. As sales continued to fall, the manager of Systek's U.S. plant placed fewer orders with Systek-Taiwan; finally these orders stopped entirely, and most of the workers in Taiwan had to be laid off. At this point Systek-Taiwan's management was authorized to seek other business, and by mid-1971 had begun doing electronic assembly work for a number of Canadian and European companies.

Tables B-3 and B-4 examine the balance of payments and employment effects of Systek's investment in Taiwan. The tables are based on the company's pro-forma projections for the first 5 years of operations to illustrate the expectations of Systek's management at the time the decision was made. The actual results in terms of both employment levels and flows of funds turned out to be

[7]The case was originally published, first in 1969 and in revised form in 1973, as "Systek International" by the Harvard Business School

Table B-3.—U.S. Balance of Payments Flows With and Without Systek Investment

	Capital flow (thousand of dollars)[a]								
Fiscal year	Capital outflow	Loan repayment	U.S. exports of capital equipment	U.S. exports of components	U.S. imports	Royalties and fees	Dividends and interest	Other payments to the United States	Net flow
With Investment *(Systek projection)*									
1969 (4 months)	-$5,900	+ $1,440	+ $1,140	+ $528	-$2,930	–	+ $41	+ $319	-$5,360
1970	—	+ 850	–	+ 1,580	-14,000	+ 238	+ 147	+ 1,140	-10,000
1971	–	+ 1,010	—	+ 1,310	-17,100	+ 237	+ 147	+ 1,360	-13,000
1972	–	+ 700	—	+ 773	-19,900	+ 238	+ 174	+ 1,580	-16,400
1973	—	—	—	+ 858	-22,000	+ 242	+ 220	+ 1,760	-18,900
1974	–	—	—	+ 946	-24,200	+ 272	+ 241	+ 1,930	-20,800
Total	-$5,900	+ $4,000	+ $1,140	+ $6,000	$100,000	+ $1,230	+ $970	+ $8,090	-$84,500
Without investment (estimated)									
1969 (4 months)	—	–	—	—		—	—	—	
1970	–	–	—	—	$5,700	—	—	+ $570	$5,130
1971	—	—	—	—	13,400	—	—	+ 1,340	12,060
1972	—	—	—	—	- 23,000	—	—	+ 2,300	- 20,700
1973	—	–	—	—	-33,700	—	—	+ 3,370	-30,300
1974	–	—	—	—	-45,900	—	—	+ 4,590	-41,300
Total	–	—	—	—	-$121,700	—	—	+ $12,170	-$109,000

[a]Plus indicates inflow to the United States, minus indicates outflow

SOURCE "Effects of Offshore and Onshore Foreign Direct Investment in Electronics A Survey," prepared for OTA by R W Moxon under contract No 033-1400, p 44, based on company records and author's estimates

Table B-4.—U.S. Employment Levels With and Without Systek Investment

Fiscal year	Systek employment in the United States (number of workers): Production workers	Other employees	Total
With investment (Systek projection)			
1969 (4 months)	1,480	452	1,932
1970	1,283	393	1,676
1971	1,204	368	1,572
1972	1,124	341	1,465
1973	1,120	341	1,461
1974	1,115	339	1,454
Without investment (estimated)			
1969 (4 months)	2,021	641	2,662
1970	1,767	554	2,321
1971	1,439	472	1,911
1972	1,025	340	1,365
1973	542	181	723
1974	—	—	—

SOURCE 'Effects of Offshore and Onshore Foreign Direct Investment in Electronics A Survey,' prepared for OTA by R W Moxon under contract No 033-1400, p 44 Based on company records and author's estimates

heavily influenced by the business downturn in the United States. In tables B-3 and B-4, Systek's projections are compared with estimates by OTA's contractor of the probable consequences if the investment in Taiwan had not been made. Table B-3 gives the estimated flows of funds, table B-4 the employment comparison. The assumptions forming the basis for the estimates are discussed in detail below. The net effect of the investment in Taiwan, obtained by subtracting the ''without investment'" case from the "with investment" case, appears in table B-5.

Based on the assumptions made, the initial impacts of Systek's investment are negative—both capital and jobs are transferred to Taiwan—becoming positive as time passes. This is typical of foreign investments for purposes of offshore assembly; the short-term impacts tend to be negative, but over the longer term the trend reverses, provided the investment is assumed necessary for maintaining competitiveness.

In table B-3 the major flow of funds category is that associated with imports; other financial flows are much smaller. imports have been assumed to increase much more rapidly in the absence of Systek's investment in Taiwan; in fact, as can be seen in table B-4, by 1974 it has been assumed that Systek would no longer be making automobile radios in the United States under the "no investment" scenario, and its domestic employment would fall to zero. How realistic is this scenario?

Table B-5.—Net Effect of the Systek Investment in Taiwan on U.S. Balance of Payments and Employment

Year	Balance of payments flows[a] (thousands of dollars)	Employment (number of employees)
1969 (4 months)	-$5,360	–730
1970	-4,870	645
1971	-940	339
1972	+ 4,300	+ 100
1973	+ 11,400	+ 738
1974	+ 20,500	+ 1,454

[a]Plus indicates inflow to the United States, minus indicates outflow.
SOURCE: Derived from tables B-3 and B-4

Photo credit: *RCA*

Consumer electronics assembly

The assumptions, based on events elsewhere in the consumer electronics industry, are as follows:

- If Systek had not invested in Taiwan, it would have moved the same manufacturing operations to a lower cost region of the United States.
- If Systek had done so, foreign manufacturers would have had a cost advantage.
- Because of Systek's market knowledge, reputation, and established working relationships with U.S. automakers, it would have been able

at first to hold on to part of the market even with a cost disadvantage.

- Although foreign-owned firms suffer initial disadvantages in terms of proven ability to delivery high-quality radios on schedule, they would manage, over time, to penetrate Systek's market.
- Once the foreign producers gained a substantial foothold in the U.S. market, their takeover would be swift.

Past rates of penetration in products like monochrome TVs or radios for home use indicate that it might have taken Japanese and other foreign-owned companies about 5 years to penetrate Systek's market more-or-less completely, This is the assumption behind the estimates in tables B-3 and B-4, Of course, the actual rate of penetration by foreign auto radio manufacturers might have been somewhat faster or slower, but in the end this would not make much difference.

As a result of these assumptions—that the Taiwan plant helped Systek retain markets that it otherwise would have lost completely—the long run impact on U.S. employment and balance of payments turns positive. The Systek investment still results in jobs being transferred overseas; it even accelerates the process somewhat. But job losses, and increased imports, would most likely have occurred in any event, and could have been much greater.

The Systek case is also an example in which U.S. management acted to preserve American jobs by keeping some production in the United States. Faced with falling sales as a result of recession, and the need to cut output and lay off workers, Systek chose to stop production in Taiwan—where the average wage was less than one-tenth that in the United States—rather than reduce its domestic operations still further. The plant in Taiwan was shut down, with only the supervisors retained on the payroll, until the company's management found outlets in Canada and Europe for products that could be made in Taiwan.

Typical Impacts of Offshore Manufacturing

The Systek case by itself cannot be generalized, but it is suggestive; together with the earlier discussion of offshore sourcing compared to four alternatives, it points to some tentative conclusions. Table B-6 summarizes in a qualitative way the alternatives to offshore assembly outlined earlier, The table indicates the probable effects if alternatives *other*

Table B-6.—Likely Effects of Alternatives to Offshore Manufacturing

	Labor-intensive production in the United States	Automate domestic production	Subcontract to foreign enterprises	Discontinue the product
U.S. *employment* in *electron/es* ***and related industries***				
Total domestic employment	Positive in early years, probably negative later	Small positive in early years, probably negative later	No major change	Negative
Proportion of skilled jobs	Small possible decrease	Small increase likely	No major change	Not relevant
Geographic distribution of jobs	Move to low-wage areas	No major change	No major change	Not relevant
U.S. value added in electronics and related industries				
Wages and salaries	Positive in early years, probably negative later	Positive in early years, possibly negative later	No major change	Negative
Profits	Negative	Possibly negative	Probably negative	Negative
Tax payments	Negative	Possibly negative	Probably negative	Negative
U.S. ***balance of payments for electronics and related Industries***				
Trade balance (exports-imports)	Positive in early years, probably negative in later years	Positive in early years, possibly negative later	No major change	Negative
Other current account items (principally investment income)	Negative	Negative	Negative	Negative
Capital account flows	Positive in early years	Positive in early years	Positive in early years	Positive in early years
Long-term effect on competitiveness of U.S. industry due to technology transfer				
	Slightly positive	Slightly positive	Slightly negative	Domestic industry eliminated
Changes in structure of domestic electronics industry				
	Weaker firms threatened	Smaller firms weakened	No major effect	Domestic industry eliminated

SOURCE—Office of Technology Assessment, based on "Effects of Offshore and Onshore Foreign Direct Investment in Electronics A Survey, " prepared for OTA by R W Moxon under contract No 033-1400, p 47 than offshore assembly were chosen by a company under pressure to reduce manufacturing costs. The impacts follow the classification presented in table B-1 .

As table B-6 indicates, the labor-intensive domestic *manufacturing* alternative would keep production and employment in the United States, and therefore have *initially* positive effects, but these would become negative in later years, the result of a gradual decline in the ability to compete with low-wage foreign countries. This was the situation Systek anticipated. Employment would drop, profits deteriorate, and tax payments fall. Positive effects on the trade balance (the result of lower imports in early years because of the absence of offshore production] would soon be offset by shipments from foreign competitors.

On the other hand, the domestic manufacturing alternative(s) would probably slow the migration of U.S. technology overseas. Developing countries get both tangible and intangible benefits from offshore plants, including learning and experience that strengthens local industries, Over the longer term, the result could be a relative weakening of the position of U. S. firms. How serious is this possibility?

For offshore plants that ship most of their production hack to the United States, labor-intensive operations, mostly assembly, are performed overseas. Although the general skills learned by production workers and supervisors are relevant, assembly technology itself is of little significance competitively. The situation is rather different for point-of-sale semiconductor plants, but most of these are in Europe, where local firms already possess much of the technology associated with wafer fabrication and related processing steps.

Automating domestic manufacture might have somewhat similar results, but evaluation of this alternative is more problematic because the technology of automated production has been advancing rapidly, Electronics firms have guessed wrong at various times in their own evaluations, and the second column in table B-6 should be viewed tentatively. Employment would probably decline, but the competitive positions of U.S. firms that chose to automate might or might not improve, depending on circumstances. Purchases of automated manufacturing equipment would stimulate the U.S. capital goods industry to the extent that this equipment was purchased domestically.

This is a difficult alternative for smaller companies with limited capital for investment, In consumer electronics, RCA has been perhaps the most active U.S. firm in automating; it is no accident that this company is one of the largest and most diversified in the industry.

Most of the effects of the *foreign subcontracting* option would be similar to those of offshore manufacturing, as table B-6 outlines. This choice would harm domestic suppliers, who would have difficulty selling to overseas subcontractors.

Discontinuing production, the last alternative, has negative consequences for the U.S. economy, although the capital released could be invested in other industries.

Summary and Conclusions

American manufacturers in many industries are moving some of their production overseas. At the same time, foreign firms—for various reasons--have begun to invest more heavily in the United States. In general, the advantages and disadvantages of either type of investment—from the standpoint of impacts on U.S. employment, and the U.S. economy in general—can only be evaluated on a case-by-case basis. In most instances, the net impacts of offshore manufacturing by U.S. electronics firms seem to be relatively small. But even if the net effects are small, the consequences for the individuals and firms affected can be serious—for workers who lose their jobs, for suppliers who lose sales, for communities and regions where industrial activity has diminished. To call these short run adjustment problems does nothing to mitigate them.

Moreover, the shift of unskilled and semiskilled jobs overseas seems in the end detrimental to U.S. interests. This country already has a large number of unemployed job-seekers, many of whom are realistic candidates for unskilled or semiskilled manufacturing jobs but not for work demanding high skill levels. That overseas investment may sometimes help maintain the competitiveness of American firms and industries seems small recompense for those who lose jobs or job opportunities. Onshore investments by Japanese and other foreign electronics companies may provide something of a counterweight, but thus far many more jobs have been lost than gained. On the other hand, policies that would restrict overseas investments by U.S. firms seem generally counterproductive. As discussed at some length i n chapter 8, the alternative of choice would appear to be a strong commitment to upgrading the U.S. labor force so that transfers of unskilled work overseas will be less damaging.

APPENDIX C

Case Studies in the Development and Marketing of Electronics Products*

Consumer Electronics: The 700-Watt Power Amplifier

The Product

In early 1970, Robert Carver, an engineer turned entrepreneur with a passion for music and high fidelity sound reproduction founded a small company—Phase Linear—in Seattle to manufacture high-power, state-of-the-art stereo amplifiers. The firm began as a limited partnership but was incorporated later that year. Carver became the majority stockholder, while his partner and an SBIC (Small Business Investment Corp. see ch. 7) were minority shareholders. During the early years of the company Carver made all the major decisions, Phase Linear Corp. 's first product was a 700-watt power amplifier for use as a component in home audio systems. Carver tried to bring out one new product each year, and by 1974 Phase Linear had three amplifiers on the market.[1]

Stereo amplifiers range in power output from a few watts per channel on up to 350 watts per channel—the Phase Linear 700's capability—or more. The main feature differentiating the Phase Linear 700 from others on the market was its great power; one of the first advertisements touted it as "the most powerful, most advanced high-fidelity solid state amplifier in the world. " In a February 1972 article in the magazine *Audio*, Carver described several of the design problems overcome in achieving this power level. The main obstacle had been transistor voltage breakdown, While 350 watts at 8 ohms for each of two channels requires a power supply capability of more than 200 volts, the best existing audio transistors had sustaining voltages of only 120 volts. Carver solved the problem by working with a major semiconductor manufacturer to modify a 600-volt television horizontal sweep transistor so that it would be suitable for use in audio amplifiers. z

Crossover distortion created another barrier. In small, low-power amplifiers, this form of distortion can be avoided by allowing an "idling current" to flow continuously from the output transistors. At lower powers, the idling current does not generate much heat, but in a 700-watt amplifier with 24 output transistors this approach is impractical. A novel biasing circuit, eliminating crossover distortion while operating without idling current, solved the problem.

The Industry

Market Growth.–During its early years, the high-fidelity industry catered to a small market consisting mostly of the wealthy. The cost of early high-fidelity equipment made it a sign of status. In the *1930's,* few could afford the $3,000 to $10,000 price of a Capehart record changer. As the price of audio components fell during the 1940's and 1950's, a new market for high-fidelity equipment grew, centered on hobbyists—audiophiles and music enthusiasts willing to spend several thousand dollars to assemble systems built around separate tuners, amplifiers, turntables, and speakers. Sales levels remained modest, but continuing technological improvements led eventually to the present mass market. Factors contributing to the expansion of high-fidelity equipment sales in the United States since 1960 include:

- rising levels of disposable income;
- the introduction of stereophonic sound recordings in 1959;
- approval by the Federal Communications Commission of FM stereo-multiplex broadcasting in 1962;
- solid-state equipment designs beginning in the mid-1960's, which sharply reduced manufacturing costs as well as improving reliability; and
- progressively lower tariffs on imports, leading to more intense price competition (duties on speakers and amplifiers were cut from 15 to 7,5 percent, and on tuners and receivers from 12.5 to 10.4 percent, between 1968 and 1972).[3]

Demographic trends helped catalyze demand during the 1960's and 1970's. Fifteen to thirty-five year olds buy most high-fidelity equipment; at the time this was the most rapidly growing segment of

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*These case studies are based on reports prepared for OTA by J. J. Wheatley, D. M McKee, S. R. Barnes, L. E. Hartmann, and D.]. Keith under contract No. 033-1190.

[1] Interview with Robert Carver.

[2] R. Carver, "A 700 Watt Amplifier Design, " *Audio,* February 1972

[3] E. Ashkenazi, "The Executives' Corner, " *Wall Street Transcript,* June 11, 1973.

the U.S. population. The flowering of the music-oriented youth culture in the 1960's also boosted sales. In the latter part of that decade, audio products became the fastest growing portion of the consumer electronics industry, with demand especially strong in the 15 to 24 age bracket. Few American manufacturers were able to capitalize on this growth, as imports made major inroads into the U.S. market. Japanese equipment often surpassed the products of U.S. companies in performance, while selling for less. Continued technological improvements, creative new product developments, and lower foreign labor costs helped imports eat away at the market shares of American firms.

Amplifier Technology.—The evolution of the power amplifier is marked by a long series of incremental design improvements aimed at reducing distortion in the reproduction of music. Amplifiers create two kinds of distortion. Clipping is the most serious; it occurs when the music being reproduced demands a higher instantaneous power level than the system can deliver. Normally, these extraordinary power demands are fleeting: the high C in an aria, the climax of a thundering crescendo in a baroque score. On an oscilloscope display, clipping appears as a flattening of the peaks and valleys of the waveforms.

The second type, crossover distortion, occurs at low instead of high volume levels. Crossover distortion gets its name from the small notches in waveforms seen on an oscilloscope as the polarity crosses from plus to minus or vice versa. Resulting from nonlinearities in transistor characteristics at low current values, this form of distortion produces harmonics that are approximately constant in level regardless of output power, hence only audible during quiet passages.

Consumer Behavior.—Buyer psychology was one of the keys to the market for the Phase Linear 700, as illustrated by the opening paragraph of an article in a 1976 issue of Saturday Review:[4]

> When I first got into hi-fi nearly 20 years ago, everyone knew that you needed a minimum of 10 watts of amplifier power for good high fidelity. And so I swapped my table radio, with the serviceman installed phono input (one watt of power, if I was very lucky), for a fashionable 10 watt amplifier. After that came a 25 watter, then my first stereo amplifier (35 watts in each of its two channels), then a 60 watt per channel amplifier. Today I have one with two 200-watt channels. At each step of the way, I've been perfectly in fashion. But what else, if anything, have I gained from my power hunger?

The author goes on to point out that sound quality did in fact improve, but in small increments and at high cost.

The Phase Linear 700.—When" introduced, the Phase Linear amplifier was not only more powerful than others on the market, but offered more power for the money. In 1971, the Crown DC 300 (150 watts per channel) listed at $685, compared to the Phase Linear's $749. s The Phase Linear stood out as a bargain, offering more than twice as many watts per dollar, and helping establish a new market category. In the early 1970's, a "super-power" amplifier was considered to be anything delivering more than 50 watts per channel. The entrants in this class included, in addition to the Crown DC 300: the Pioneer SA-1000 (60 watts per channel, $230); the Harman-Kardon Citation 12 (60 watts per channel, $298); the SAE Mark 111 (120 watts per channel, $700); Sony's TA-3200F (130 watts per channel, $359); and the C/M 911 (120 watts per channel, $540,[6] The Phase Linear 700 surpassed all these by a large margin. So successful was Phase Linear in opening up a new market niche that it faced no direct competition—from either American or foreign firms—during its first 3 years.

The Competition.—To the extent that it provided more power at a lower price, the Phase Linear 700 was able to capture buyers from other companies. These competitors were mostly large or medium-large, and well-established. Crown—maker of the DC 300—was a division of International Radio and Electronics. The privately held firm sold most of its products to professional musicians and institutional purchasers such as churches. Marantz, producer of another powerful amplifier, was a wholly owned subsidiary of the Superscope Corp. Superscope had been incorporated in California in 1954, and in 1966 purchased the Marantz Co., Inc., adding 50-percent interest in Marantz Japan, Inc. in 1971. Marantz products were manufactured in the company's Tokyo plant. Superscope had also served as exclusive U.S. distributor of Sony products since 1957. A third maker of high-power amplifiers was the McIntosh Corp., also privately held. A small company compared to Crown or Superscope, McIntosh produced high-end stereo equipment almost exclusively,

From an international perspective, that the Japanese presence in the super-power category was small may seem remarkable; Japanese producers had by 1970 captured an overwhelming share of the U.S. audio market. The explanation appears to be

[4] I Berger, "Power Plays," *Saturday Review*, Jan, 6, 1976, p. 4(I

[5] "1972 HI-F' I Preview Directory," *Audio*, September 1971.

[6] Ibid.

simple: the market for separate amplifiers of all sizes was not very large, and within it, the market for the very largest amplifiers, with their high price tags, was even smaller—less than 10 percent.[7] The Japanese approach had been to concentrate their product development and marketing efforts on the largest selling stereo components, such as integrated tuner-receivers. Japanese firms like Akai, Hitachi, Kenwood, Nikko, Pioneer, Panasonic, and Sansui also offered separate amplifiers in the more popular power ranges. Many of these companies were large and diversified. Panasonic, for example, is a brand name of the Matsushita conglomerate, whose export sales to the United States in 1971 totaled $358 million. Pioneer had 1970 U.S. sales of $126 million, and was already one of the largest high-fidelity equipment producers in the world.

These firms relied on their ability to sell equipment perceived to be of good quality at low prices. Their strategy had been to concentrate almost exclusively on mass-market products, leaving the expensive, high-end components to smaller American firms. Phase Linear thus faced little competition from the major Japanese electronics firms in its early years—primarily because of the relative smallness of the market for super-power amplifiers. But even though Phase Linear achieved its initial success by appealing to audiophiles—and while doing so acquired a reputation for high quality—the company soon began selling to a wider range of buyers, largely because of its modest prices.

Distribution.—Most audio equipment manufacturers sell through networks of franchised dealers served by regional sales representatives. Dealers generally take delivery from the factory, although Pioneer and some of the other large firms maintain regional warehouses. The greatest portion of retail sales are made through audio specialty stores—high-volume, low-margin outlets emphasizing the heavily advertised, low-priced Japanese brands. A second type of retailer, the "audio salon, " tends to be individually owned, and to specialize in more expensive products. In addition to the prestige lines of the mass-market firms, these stores sell high-end equipment made by smaller and less well-known companies. Other major outlets include: mail order houses; discount and department stores; appliance, radio, and TV dealers; and catalog showrooms. Generally, these limit themselves to the more moderately priced and popular components.

7 Interview with Don Prewett, Phase 1,1 near Corp

Product Development

The super-power amplifier for home stereo systems was largely the brainchild of Phase Linear's founder, Robert Carver. Very high power as a route to better sound quality at all listening levels was a novel idea when Carver began experimenting in his home workshop, He built a series of amplifiers whose power capability surpassed anything on the market. The tests he ran backed up his insights; music sounded better to him played through the prototypes. Measurements of audio distortion supported his subjective judgments.

Convinced of the virtues of a stereo amplifier with a wattage rating more than double anything then available, Carver set out to create a design suited for commercial production. Most of this work he did himself, While Carver enlisted the aid of several Motorola engineers to solve the transistor voltage breakdown problem, the ideas were basically his.[8]

Phase Linear placed a premium on technology in those early days. Carver, highly regarded in the audio industry as a gifted designer, wanted to build an amplifier of unprecedented power, but he also wanted to build one that was affordable, This second objective, more than anything else, called for the creative use of technology in order to reduce production costs—the simplest possible design that would deliver very high power levels,

Carver did not have the financial resources to do much marketing research, but his experience told him that a low-priced, high-power amplifier would sell. After showing prototypes built in his home workshop to dealers, and being assured that they would carry the product, he decided to go into limited production. Manufacturing began in an old Safeway store leased for the purpose.

Marketing

At first, Phase Linear took a rather ad hoc approach to distribution and marketing. As word of the Phase Linear 700 spread, the company accepted direct orders from anyone—individuals, as well as dealers large and small. In 1971, phase Linear hired a marketing manager who set up a system of company sales representatives, but the firm still found itself with a growing backlog of orders from an unwieldy assortment of some 600 buyers.[9] Two years later, a new marketing manager took over—Don Prewett, a recent MBA graduate. Prewett began setting up a new distribution system,

8 "A 700 Watt Amplifer Design, " op. cit
9 Prewett, op. cit.

It took 2 years to reorganize Phase Linear's system of dealers and sales representatives. Prewett found representatives with overlapping territories and Phase Linear products stocked by competing stores. The firm's managers decided that Phase Linear products should be sold primarily through large chains and retailers of stereo equipment, which at that time were growing at a phenomenal rate, while avoiding small, specialized outlets. Two of the highest volume stereo chains in the country became major outlets for Phase Linear. With the demand for stereo equipment exploding in the early 1970's, these retailers were opening many new stores, By 1980, the company was selling its products through 16 sales representatives to 275 dealers operating about twice that number of retail outlets. Dealers and designated repair shops handled service in the field.

Phase Linear's strategy was to dominate its chosen market niche and expand from there, The 700 faced no real competition for more than 3 years, As it became apparent that the first part of this strategy would be successful, the company quickly began to extend its product line, In January 1972, it came out with the Phase Linear 400, which offered 200 watts per channel, This amplifier proved even more popular than the 700. By 1974, two to three times as many 400s were being sold as 700s, and the company's annual sales had reached $3.5 million.

Thanks to imaginatively simple design, production costs were low; because of the lack of competition, the Phase Linear 700 could be priced to yield a healthy profit. As a result, the firm was able to generate virtually all the funds needed for expansion from internal sources.

The Industry Reaction

Phase Linear's entry into the high-fidelity industry was inconspicuous. At the time of its incorporation in early 1971, the company counted only a few employees. Most of the industry regarded its product as an oddity with limited appeal.

Japanese firms, which constituted the dominant force in the audio industry worldwide, had overlooked the potential of extremely high-power amplifiers, which did not seem to fit their export-oriented approach. Efficient production technology and effective advertising, sales, and distribution enabled them to drive their American competitors out of the market for mainstream products like stereo tuner-receivers. But the Japanese manufacturers did not regard the stereo separates market as big enough to deserve much attention. Firms such as Kenwood, Sansui, and Pioneer maintained separate stereo component lines, but mostly for the sake of product mix and the lustre that high-end components added to their image.

As a result, competitive response to Phase Linear's products was slow in taking shape. Only in 1975, after the company had already secured the largest market share of any entrant in the market for separate amplifiers—15 to 17 percent—did several firms, both American and foreign, introduce super-power amplifiers of their own. For the most part, Phase Linear's U.S. competition came from small and relatively new companies. One of these, the Great American Sound Co., came out with a model called the Ampzilla aimed at the heart of Phase Linear's market—the 20- to 35-year-old male hi-fi hobbyist. Bose Co., which had been primarily a manufacturer of speakers, also introduced a super-power amplifier. One of the largest firms to enter at this time was Marantz, mentioned earlier. These companies constituted the first wave of competition. A second wave came as the huge Japanese manufacturers, including Mitsubishi and Yamaha, finally began making super-power amplifiers.

The response of Pioneer Corp., the sales leader in the industry, was the most belated—but most significant by far for Phase Linear. In 1978, U.S. Pioneer, a wholly owned subsidiary of Pioneer-Japan, bought Phase Linear. Just prior to the acquisition, Carver had sold his stock interest back to the corporation. At this point, U.S. Pioneer purchased the company from the remaining stockholders—Carver's ex-wife, the SBIC, and his former partner—for a price reported to be in the middle seven-figure range,

How did this change of ownership affect Phase Linear? While leaving the company's management team intact, Pioneer placed at Phase Linear's disposal a wide range of new resources. The company now had ample financing for product development efforts, and new sources of technology. Phase Linear's marketing capability was strengthened because it could use the parent company's extensive U.S. retail network. Pioneer also became a supplier of component parts for Phase Linear's products.

What was Pioneer's motive in purchasing Phase Linear? The major reason was probably a desire to strengthen its position in a rapidly growing market segment. Partly because of their successful strategy of dominating the mass market, many of the Japanese brands lacked the quality image necessary for success at the upper end. The best evidence for the thesis that Pioneer acquired Phase Linear primarily for its prestige value is the succession of new stereo components introduced under the Phase Linear name. Within 2 years of the acquisition, "Phase Linear" turntables and tuners were being exported from Japan to the United States. These products were developed by Pioneer design engineers and manufactured at Pioneer facilities. Except for their high price tags, they did not differ greatly from comparable Pioneer products.[10] Rather than any significant transfers of technology to or from the United States, the effects of the takeover seem to have been restricted to marketing and financial matters.

In recent years, Phase Linear has fared well internationally, with 30 percent of its 1979 sales coming from exports, two-thirds of these to Europe. But Japan is one major market that Phase Linear, along with almost all other U.S.-based audio manufacturers, has not been able to crack. Only two American companies—McIntosh and JBL, the latter a manufacturer of speakers—have established distribution channels in Japan. Their entries took place shortly after the end of the war. Since then, no major American manufacturers of consumer electronics have been able to sell their products within Japan in any volume. This inability stems at least in part from distribution problems. The task is not impossible, but costs for deciphering and meeting the many product regulations, as well as establishing marketing channels, are great. Even so, the distribution of electronic products and household appliances in Japan is less complex than for goods such as food or kitchenware. A major reason is the emergence of a few large manufacturers of consumer products and household appliances—e.g., Matsushita—which have taken the initiative in organizing simpler marketing channels, Still, over 80,000 retailers, more than three-quarters quite small, handle consumer electronic products.

Phase Linear executives had their eye on the Japanese market for some time prior to the 1978 acquisition by Pioneer, but report that Pioneer's policy has been to refrain from encouraging efforts by Phase Linear to export back to Japan. In particular, Pioneer apparently has no intention of making its domestic marketing channels available to its American subsidiary. This might reflect: 1) simple exclusion; 2) a decision that it would be too costly to undertake a marketing program in Japan; or 3) a market-dividing strategy whereby Pioneer decided to promote Phase Linear only in the United States and Europe.

[10] Interviews with stereo dealers.

Conclusion

Within the high-fidelity industry, qualitative differences between products of similar price tend to be small. Industry executives generally believe that the successful firms are those that market most effectively. Phase Linear was typical; its rapid rise to a position of leadership in one sector of the industry was largely due to effective marketing—designing and building a product that others had overlooked but that consumers were ready to purchase. Robert Carver began to pursue his ideas based on intuition about the market. At the time, the notion that real demand could exist for a super-power amplifier would probably not have gotten much of a hearing in a large, established company.

Technology played a crucial role in the second stage, the actual development of the product, where Carver's sense of design led to a simple, low-cost amplifier. Phase Linear's critics sometimes remarked that they were "designed to the bone, " meaning that they gave maximum power while offering little in the way of backup or protective circuitry. But it was apparently just this quality of brute power that younger buyers of stereo equipment wanted. Nonetheless, the company also recognized that demand for a 700-watt amplifier would be limited, and quickly moved to broaden their offerings.

Robert Carver later started another company; in 1982, Carver Corp. began advertising a power amplifier featuring "750 Watts/chan. Dynamic Headroom for just $799."

Semiconductors: The 4K Dynamic MOS RAM

The Product

Electronic data processing, at one time solely a matter of computers, has spread to a wide range of products: industrial controllers, automated machine tools, "smart" terminals, calculators, even household appliances. These systems need memory—the ability to store and retrieve information (see ch. 3). Random access memories (RAMs] can retrieve or rewrite digital data stored in an arbitrary location on command. Most integrated circuit memory is of the random access type. Both major transistor technologies are used in semiconductor memories—bipolar and MOS (metal oxide semiconductor, ch. 3), with MOS now the largest seller by far.

MOS RAMs can either be static or dynamic. Static RAMs hold their contents indefinitely, provided they are supplied with power. Dynamic RAMs rely on capacitance for storage; they must be "refreshed" every few milliseconds. Static RAMs require more complex memory cells than dynamic RAMs, and are thus not as dense, taking up more area on the chip and costing more.

In 1974, when the 4K dynamic RAM—which can store 4,096 bits of information—was introduced, a new generation of memory circuits was appearing about every 30 months. Each design generation had been four times larger than the previous one, the sequence being 256 bits, 1K, 4K, then 16K, and—in the early 1980's—64K. By 1983, 256K RAMS were in pilot production. One explanation for the fourfold density increment is that, while technological *capability* in terms of circuit density roughly doubled each year, design costs were high enough so that, if new designs came out every 12 to 15 months, they would not generate enough cumulative sales to be profitable. By the end of the 1970's, the intervals between RAM generations had lengthened to several years.

The newly introduced 4K dynamic RAMs were hailed in mid-1974 as far outdoing 1K types as the cheapest way to satisfy user needs, Despite spotty availability during that year, they were quickly designed into microcomputers, minicomputers, and peripherals; manufacturers of mainframes waited for price decreases and assurances of product reliability before switching from 1 K to 4K chips.

The Industry Setting

While some captive semiconductor manufacturers—notably IBM—have designed and built their own RAMs for internal use, this case study treats the competition for sales in the merchant market. Development of 4K chips for merchant sales began in the early 1970's, with samples available by late 1973. As the 4K RAM moved into volume production, the semiconductor industry entered the most severe downturn in its history, the result of a general recession in the U.S. economy beginning in 1974. Semiconductor firms furloughed 50,000 employees, and idled $750 million in production capacity.[11]

As the 4K chip emerged and economic recovery began, 1K RAM sales declined, The 4K RAMs accounted for only $14 million in sales during 1974, but $45 million the next year. By 1976 1K sales had fallen to $42 million, while 4K sales soared to $161 million.[12]

Intel Corp. 's 4K RAM design was first onto the market—via a licensee—but the competition quickly became intense, complicated by production problems at several firms, including the industry's largest manufacturer, Texas Instruments (TI). Only at the end of 1975 had firms such as Intel, TI, and Mostek ironed out most of their processing difficulties; while earlier projections had been for shipments of 10 million chips during the year, actual output was perhaps half this, The 4K RAM posed the greatest difficulties the industry had faced up to that time in moving a product into volume production; indeed, before the 4K RAM reached high volumes, 16K RAMs had been announced.

It took several years for an industry standard 4K RAM configuration to emerge. Three chip designs were vying for dominance, with the situation in considerable flux:[13]

> Intel/TI's 22-pin package, announced by Intel and then modified by TI, uses TTL voltage levels for all address, data-in, and data-out lines; it requires only one high-voltage clock level but needs three power supplies.
>
> Motorola/AMI's [American Microsystems, Inc.] 22-pin package differs in having an extra reset pin, which must be energized when power is first applied.
>
> Mostek's 16-pin package takes up less board space than the other two, at the cost of some added system complexity in clocking and interface logic, since the device must be multiplexed; it is also TTL-compatible at all inputs, including the clock input.

By the end of 1976, sales of 16-pin designs were increasing at the expense of 22-pin devices. The 22-pin part was larger; the extra pins also led to greater assembly cost. A second focus of technological competition was access time—the time, on average, to retrieve a bit of information from the memory. Access time for memory chips is normally measured in nanoseconds, 1 nanosecond (ns) being 10^{-9} seconds. For RAMs, an access time of 100 ns is considered fast; 500 ns is slow.

The Competitors

Capital requirements for manufacturing 4K RAMs were not, in the mid-1970's, a significant barrier to entry. Many of the competing firms had

[11] "New Leaders in Semiconductors," *Business Week*, Mar 1, 197b, p 40

[12] *Dataquest*, Oct. 7, 1977, pp. 18.6-9.

[13] L. Altman, "Semiconductor Random-Access Memories," *Electronics*, June 13, 1974, p. 109.

begun operations only a few years earlier, and were still relatively small.

Microsystems International Ltd.—The first company to bring a 4,096-bit RAM to market—in late 1972—was Microsystems International of Ottawa, Canada, a licensee of Intel. The 22-pin, 3-transistor memory cell chip was based on proprietary process technology, with the company benefiting from earlier experience as a licensee for Intel's 1K RAMs. Although first with a working part, Microsystems International never became a major factor in 4K RAM sales.

Intel.—Intel's 4K chip followed an immensely successful 1 K product—with the possible exception of IBM's proprietary 1K design, the most widely used semiconductor memory circuit up to that time. Judging that the product lifetime for a 2K RAM in volume production would probably be no more than 6 or 8 months, Intel jumped to a 4K chip, introducing-in the summer of 1973—a slow (600 ns access time) 4K device designed for small systems. The company planned to introduce a high-speed version later in the year; both were to have a 22-pin, single-transistor memory cell design. The higher speed chip, with maximum access time of 150 ns, would be better suited for large computers and was projected to take over most of Intel's 4K production during the first half of 1975. Intel hoped to capture as much as half the potential market,

Meanwhile, customer desire for greater circuit board density was prompting movement away from the 22-pin package, At the end of 1974, Intel announced plans to introduce its own 16-pin device. The company thereafter continued to build both 22- and 16-pin RAMs,

Mostek.—In September 1973, Mostek was sampling an innovative 16-pin RAM, one in which some of the pins served two functions (called multiplexing). The chip enjoyed a two-to-one density advantage over the competition. Eventually, after a redesign reduced the size even further, it became the de facto industry standard. However, Mostek, along with other chipmakers, suffered through yield and quality problems which cut into its ability to capture early market share.

Despite the pioneering features of its 16-pin design, the firm—in common with the rest of the industry–did not rely on patents to protect its technology. Mostek's 1977 Common Stock Prospectus stated ". . . the Company believes that success in the semiconductor industry is not dependent upon patent protection but is dependent upon engineering and production skills and marketing ability. It does not anticipate that the grant of any patent application will significantly improve its competitive position. "

National Semiconductor.—National developed both one- and three-transistor cell designs of its own. By mid-1975 it was marketing 22- and 18-pin chips—the 22-pin part faster than, but compatible with, that of TI. National's strategy of seeking faster access times is part of the explanation for its decision not to build a 16-pin device; National's engineers felt, incorrectly as it turned out, that the Mostek approach did not lend itself to speed improvements that would prove great enough. The 18-pin choice allowed good board density and high speed without requiring the multiplexing circuitry of 16-pin packages. Two other firms quickly lined up as alternate sources for National's 18-pin part.

Texas Instruments.—TI was the first to drop its 4K RAM price below the cost to purchase four 1K chips. By September 1974, TI was producing more 4Ks than anyone else, having solved its earlier yield problems. At the close of the year, TI added an 18-pin package to its existing 22-pin 4K catalog; both the 18-pin and the new 22-pin part offered access times of 200 ns. TIs' second source for its 4K RAMs was Advanced Micro Devices (see below).

Other U.S. Entrants.—Fairchild became Mostek's second source, offering a pin-compatible version of Mostek's unit while also producing another design, with faster access times, based on the proprietary Fairchild Isoplanar processing technology. Meanwhile, American Microsystems, Inc. (AMI) and Motorola developed their 4K RAMs jointly, sharing masks and processing technology. AMI was particularly confident of its product—' 'even for the chronically confident semiconductor industry''—and expected its entry to become the industry standard; its speed and power characteristics, single clock design, pin configuration, and second-source at Motorola all seemed to the company to justify this belief.[14] AMI's partner, Motorola, was relying on this new 4K RAM to bring volume MOS sales to its semiconductor division, "after a couple of false starts with, early memory products."[15] Still, Motorola also sought other alternate sourcing arrangements.

Japanese Firms.–-Semiconductor manufacturers in Japan were developing their own 4K RAMs over the same time period. Nippon Electric Co. designed a 4K RAM described as an improved and enlarged version of the company's three-transistor cell, 1K part.[16] Hitachi hoped to have a 300 ns chip on the

[14] H Wolff, ''4 ,096-Bit RA MS Are on the Doorstep,'' *Electronics*, A pr 12, 1973, p. 76.

[15] H Wolff "Customers Sweat out 4,096-Bit RA MS," *Electronics*, Mar 21, 1974, p. 70

[16] ''4,096-Bit RAMs Are on the Doorstep,'' op cit

market by the end of 1973. Fujitsu's 4K RAMs used three-transistor cells, but one-transistor production versions were anticipated. Toshiba was also developing a 4K design.

These development efforts attracted little attention in the United States. Shipments of 4K RAMs from Japan did not begin to enter the U.S. market until 1977, and then only in small quantities. If Japanese competition appeared to be no more than a m inor t hreat, European firms posed even less of one-in part because most had neglected MOS technology, continuing to concentrate on bipolar. In 1976, U. S. firms had 90 percent of the world market for MOS devices of all types, with the Japanese holding most of the rest-largely as a result of sales at home.

Initial Japanese entry into the U. S. market was based on a combination of low prices and high quality, with special emphasis given the latter (Chs. 5 and 6). Although the Japanese were a minor factor i n the case of the 4K RAM, they persisted in this strategy with the 16K RAM and other semiconductor products.

The Market

Demand.—As table C-1 shows, fewer than a million 4K RAMs--at $15 to $20 each--were sold in 1974. Volume increased as prices broke the $10 barrier-dropping to $6 late in 1975—and mainframe computer manufacturers began to buy in large quantities. Sales peaked in 1978, before 16K RAMs took over.

The companies involved grew rapidly as 4K RAM volumes jumped, Intel's sales in 1970 totaled only $4,2 million; by 1974 they were $134.5 million, and by 1979 had reached $663 million, This was not all due to the 4K RAM, but that device played a major role.

Distribution.—Within the United States, most semiconductor firms sell directly to large customers as well as through independent distributors. During the mid-1970's, many of the firms producing 4K RAMs were rather small, with little marketing experience. However, a well-developed network of industrial distributors such as Arrow Electronics and Hamilton / Avnet served the many smaller customers for memory products.

Table C-1 .—Worldwide Sales of 4K Dynamic MOS RAMs

Year	Sales (millions of units)
1974	0.7
1975	5.0
1976.	28,0
1977	57,1
1978,	76,5
1979.	69.2
1980	31.2
1981	13.0

SOURCE Dataquest

Product Development

Top managers in semiconductor firms devote a great deal of attention to product and process development—the two go together—because of the rapidly evolving technology, Many industry executives have technical backgrounds,

Planning.—At Intel, product planning committees are organized for each of the firm's "strategic business segments. " The committees—e.g., that for RAMs—operate with a 5-year time frame. Planning responsibilities may take a third of a committee member's working hours. Intel's approach has been to look for high-growth products where the company's technology can provide an advantage. proposals emerging from the planning process are presented to an executive group that includes the chairman and vice-chairman of the board, the president, and the vice presidents.

Texas Instruments—another technology leader--emphasizes project-oriented teams for planning future activities, while a more conventional operating hierarchy looks after current operations.

Not all firms in the industry try to be innovators. Instead, managements may opt to become alternate sources for products introduced by others. This strategy is sometimes dictated by costs—since the extensive research and development (R& D) necessary to come up with a proprietary design may seem too risky, particularly for a company without a position of technical leadership. It does require the ability to duplicate (and perhaps improve on) the device in question, and get i n to production quickly.

In the case of the 4K RAM, American entrants followed one of two approaches to R&D. In the first group were firms such as Intel and Mostek, which attempted to take the lead, hoping that their designs would become de facto industry standards. In the second were companies like Advanced Micro Devices, that aimed at becoming alternate suppliers with a competitive advantage in attributes such as quality or performance. Technical leadership in the semiconductor industry requires two kinds of scarce resources: money and skilled engineers. The choice of strategies depended on these, but even a second-source supplier needs clever designers —

and still more, competent process engineers. During the 1960's and 1970's, successful U.S. merchant firms were sometimes built around the abilities of three or four inventive circuit designers. Even so, the R&D emphasis in many firms during development of the 4K RAM was heavily on process technology. The case of Advanced Micro Devices (AMD) illustrates the point.

The Example of Advanced Micro Devices.—AMD was founded in 1969 with an initial capital investment of $1.5 million, Research, design, and development activities began immediately; by the end of the first year half a million dollars had been spent, although sales had not begun. R&D played only a limited role in the strategy adopted by the company. The president and chairman of the board —W. J. Sanders, III—while an engineer, had resigned a position in marketing at Fairchild to start AMD. Sanders chose to emphasize second-sourcing of chips developed by larger firms, Not only did AMD have limited funds for developing new products, but initially the company had no proprietary technology.

Product design and development throughout the industry was almost exclusively a technical activity during these years, Marketing research was insignificant by comparison. Neither Intel nor AMD had internal marketing research staffs. One reason was a pervasive feeling that production capacity would limit total sales over the foreseeable future.

During its first few years of operation, AMD followed a strategy of introducing devices that could be put into production quickly to serve existing markets; R&D spending remained low until 1974, when it reached about $1.5 million. The company tried to concentrate on high-volume chips—for example, targeting customers who might be able to grow rapidly in their own industries, which in turn would permit AMD to expand more rapidly than its competitors, At first, the firm concentrated its sales efforts on 25 to 30 customers worldwide. In the late 1970's, AMD began to modify its approach, pursuing new products of its own,

The choice of integrated circuits to second-source was critical for AMD. To fit the company's product development strategy, a proposed new integrated circuit would: 1) be marketable in high volume at a price attractive to AMD's customers, implying; 2) that it would be complex enough to be a cost-effective substitute for existing devices, but not; 3) so complex that it became, on the one hand, difficult to make, or, on the other, so specialized as to limit its market. The essential links are between design engineers—those at the semiconductor firm and those at the customer—rather than between sales staff and purchasing department.

The three fundamental steps in producing integrated circuits—wafer fabrication, assembly, and testing—are now all essentially mass production processes. During the peak period of 4K RAM production, however, assembly and testing were both quite labor-intensive. Because of this, AMD—like its counterparts in the U.S. industry—had established offshore plants in low-wage countries. AMD's offshore facilities were in Manila and in Penang, Malaysia.

AMD's approach to the 4K RAM market typifies its strategy during the mid-1970's. The firm produced two 4K chips—one an 18-pin design with two power supply voltages, the other a 22-pin part requiring three voltages. Both were interchangeable with 4K RAMs manufactured by TI, but AMD made a number of design changes aimed at reducing power consumption, improving noise immunity, and meeting military standards. The last has been a centerpiece of AMD's marketing approach; by advertising that all its chips met military specifications, the firm sought to establish an image of high quality and high reliability, AMD's emphasis on making modest improvements in the products they chose to manufacture, adhering to high quality standards, and concentrating on standard devices foreshadowed the Japanese strategy of a few years later.

Demand for AMD's 4K RAMs came mostly from computer companies—about 10 in number—along with another 150 firms manufacturing systems and equipment ranging from typesetters to computer peripherals, and including a half-dozen telecommunications accounts as well as 10 or 12 military contractors. Each customer was, potentially, a high-volume purchaser. A mainframe computer with 8 megabytes of memory, for instance, needed 18,000 to 20,000 4K RAMs,

Pricing and Profits

As part of its overall strategy, AMD attempted to hold its prices somewhat above those of the competition by stressing quality. Prices for semiconductor products tend to be high at first, declining rapidly as production volumes and the number of entrants grow. Manufacturers sometimes set prices in anticipation of future cost reductions. Eventually, product obsolescence puts still more downward pressure on prices. At the time the 4K RAM was coming onto the market, the semiconductor industry was in a deep recession, leading to even more price cutting than normal.

Intel—one of the acknowledged technical leaders —also charged premium prices, but on the basis of offering the most up-to-date products; the company continues to pursue a strategy of building unique circuits when possible, thus maintaining healthy profit margins. Intel has, in many years, been among the most profitable companies in the industry—table C-2. The table lists profit levels for a number of U.S. merchant firms in 1978, the peak sales year for 4K RAMs and a generally good one for the industry; profitability ran somewhat ahead of that for U.S. industry as a whole, represented by the Fortune 500 average.

The 4K RAM Lifecycle

Before Intel's pioneering 1K RAM entered the market, semiconductor firms often simply copied each other's products. Customer demands for alternate sourcing-more than one supplier for a given part—provided an easy avenue into the market for a new company. Mostek's Executive Vice President, Berry Cash, remarked: "Everyone used to copy everyone else. About the only thing you could do when you got something good was run like hell and work on new products to obsolete it."[17]

This pattern changed, partly as a result of experience with the 1 K RAM. A number of firms tried but failed to duplicate Intel's chip; after 3 years only two or three other companies had learned to build it. As a consequence, companies began to negotiate formal alternate sourcing agreements for the next generation 4K RAM. Through these agreements, firms could acquire design rights—and sometimes lithographic masks. Thus, as pointed out earlier, Fairchild negotiated a second-source agreement with Mostek, while Motorola and American Microsystems worked jointly on 4K RAM development.

During the early years of the 4K RAM product cycle—1973-76—Intel enjoyed a major share of sales, but in the end, most observers rated Mostek the overall "winner" of the 4K RAM competition. Many other entrants benefited in terms of profits and demonstrated viability in the rapidly growing memory market. Mostek's success was due not only to customer acceptance of its 16-pin design, but also to the head start it got when TIs' 22-pin device encountered production problems.

The situation in 1977, the year before output peaked, is illustrated in table C-3. While Mostek sold the most of any one design, TIs' total 4K RAM sales—spread over three designs—were slightly greater. There were really no losers, especially since manufacturing capacity constrained sales. Nonetheless, Mostek's 16-pin RAM found the greatest eventual acceptance in the marketplace; 1977—the year covered by the table—marked the sales peak for 22-pin units, while the 16-pin alternative did not peak until 1979. The world market share of 4K RAMs for Japanese firms was 18 percent in 1977, with NEC the clear leader. The Japanese were splitting their efforts between 16- and 22-pin designs.

Table C-4 gives market shares from 1977 to 1981. For the first years, AMD's second-source strategy led to an increasing proportion of a declining market, while Intel's share declined in part because it began moving into new products. The market share of Japanese firms actually fell over this period. By 1980, several manufacturers had begun to abandon the 4K RAM market.

17" Bourn Times Again for Semiconductors," *Business Week*, Apr 20, 1974, p 66

Table C-2.—Profit Levels for U.S. Semiconductor Firms, 1978

	After-tax earnings	
	As percent of sales	As percent of equity
Advanced Micro Devices	7.1 0/0	17.60/o
Fairchild Camera and Instrument	4.6	12.0
Intel	11.0	21.6
Mostek	7.1	15.8
Motorola	5.6	16.6
National Semiconductor . .	4.6	17.1
Texas Instruments	5.5	17.6
Unweighed average	6.50/o	16.50/o
Average for Fortune 500 industrial firms . .	4,80/o	14.3"/0

SOURCE Annual reports

Conclusion

The 4K RAM reached its unit sales peak in 1978 (table C-l). Dollar volume had been greater the year before—a common phenomenon in the industry. While volumes have since tapered off, 4K RAMs will continue to be widely marketed at least through the mid-1980's. Where a dozen companies made the devices in 1980, the number has since been cut perhaps in half—those who can still make a reasonable margin on sales remaining. The lifecycle of the 4K RAM proved somewhat longer than that for 1K chips, illustrating a trend toward lengthening product cycles for RAMs that is expected to continue. One factor in the longer lifecycle was strong price competition; as 4K prices fell, mass acceptance of the next-generation 16K RAM was delayed. Only when 16K prices came down to the point where one

Table C-3.—Estimated Worldwide Sales of 4K Dynamic MOS RAMs, 1977

	Shipments (millions of units)			
	16-pin	18-pin	22-pin	Total
United States:				
Advanced Micro Devices	—	0.55	1.84	2.39
Fairchild	2.08	—	—	2.08
Intel	2.0	—	8.4	10.4
Intersil	0.5	—	0.4	0.9
Mostek	11.8	—	—	11.8
Motorola	1.55	—	1.19	2.74
National	0.38	—	3.3	3.68
Signetics	0.54	—	0.33	0.87
Texas Instruments	0.9	5.9	5.6	12.4
U.S. total	19.8 (820/o)	6.45 (96%)	21.1 (80°/0)	47.2 (830/o)
Japan:				
Fujitsu	1.8		1.1	2.9
Hitachi	0.45		0,46	0.91
Nippon Electric Co, (N EC).	2.15	0.25	3.7	6.1
Japan total	4.4 (18%)	0.25 (4°/0)	5.26 (20°/0)	9.91 (17%)
World total	24.2	6.7	26.4	57.1

SOURCE Dataquest

Table C-4.—World Market Shares of 4K Dynamic MOS RAMs

	Share of unit sales				
	1977	1978	1979	1980	1981
United States:					
Advanced Micro Devices	4.1 %	8.6 "/0	14.60/o	9.40/0	12.7 0/0
Fairchild	3.6	1.2	—	—	–
Intel	18.2	14.4	8.7	3.2	—
Intersil	1.6	0.5	1.4	3.9	1.1
Mostek	20.7	22.2	20.1	22.8	17.3
Motorola	4.8	7.4	9.2	16.2	24.9
National	6.4	7.3	11.3	14.6	16.1
Signetics	1.5	1,5	0.7	—	—
Texas Instruments	21.7	21.8	15.3	2.6	—
U. S. total	82.6°/0	84.90/,	81.3%	72.70/,	72.1%
Japan:					
Fujitsu .,	5.1%	2.50/,	1.1 %	2.1%	1.5%
Hitachi	1.6	2.3	1.2	0.6	–
Nippon Electric Co.	10.7	8.0	7.9	4,7	2.5
Japan total	17.4°/0	12,80/o	10.2 "/0	7.4 "/0	4.0 "/0
Europe:					
ITT.	–	2.0%	7.4%	16.0%	18.9%
SGS-Ates	—	0.4	1.1	3.9	5.1
		2.4"/,	8.5%	19.9%	24.0°A

SOURCES **1977**—table C-3.
1978-1981—Dataquest

chip cost about the same as four 4K devices did the new generation parts begin to take over. Similar forces were at work during the early 1980's as 64K RAMs entered the marketplace.

Computers: A Machine for Smaller Businesses

The Product

Before 1970, the computer industry was dominated by a few relatively large manufacturers—with IBM holding by far the greatest market share. As the decade progressed, advances in hardware created numerous opportunities for newer firms to sell small computers in markets as yet untapped by established mainframe-oriented companies. The new entrants at first aimed their minicomputers at original equipment manufacturers (OEMs) and at sophisticated customers who could put small processors to work in science and engineering. Between the minicomputer market and that for large, general purpose mainframes lay a vast pool of potential customers—many of them small businesses—largely unfamiliar with the esoterica of computer hardware and software, and without the capability to plan their own data processing installations. Companies from both the mainframe and minicomputer portions of the industry began to design small business computers (SBCs) to attract such customers.

Small business systems range in price from about $5,000 to perhaps $100,000. Typical installations include a central processing unit, one or more terminals for input, disk storage, and a serial or line printer for hard copy output. By the late 1970's, 80 to 90 suppliers were marketing nearly 300 different SBC systems.[18] Among these, the IBM System/32—the focus of this case—fell near the middle in cost and features. When first introduced, the System/32 could be leased for $770 to $1,085 per month, or purchased for $33,100 to $40,800. It had been designed for businesses with sales in the range of $1 million to $10 million, and as many as 200 or 300 employees. The complete system—consisting of the central processing unit, up to 32 kilobytes of main memory, a keyboard, display, printer, a single floppy disk drive, and a nonremovable hard disk for mass storage—was housed in a desk-sized enclosure. Software was unbundled, with everything but the operating system sold separately. In 1978, the software available included three programing languages and a series of industry-specific applications packages.

Hardware.—Thirty-two models of the System/3a were available, differing mostly in the capacity of the hard disk—3.2 to 13.75 megabytes—and printer configuration.[19] Printer options included a serial printer with speeds ranging from 40 to 80 characters per second, and line printers of 50 to 155 lines per minute, The basic machine came with 16 kilobytes of memory; model changes could be made in the field.

The System/32 could be operated in batch or interactive modes and also function as a smart terminal or a satellite processor linked to other computers. For example, a System/32 can easily be set up to communicate with: another System/32; an ink-jet document printer; an IBM Office System 6/430, 6/440, or 6/450; an IBM Mag Card II typewriter; IBM Systems /3, /7, /360, or /370; some of the equipment in a 3740 Data Entry System; or a 5230 Model 2 Data Collection System.

Software.—IBM supported the System/32 by regularly offering new software. The three programming languages available were: Report Program Generator II (RPG II), a commercially oriented language; COBOL; and FORTRAN IV. A utility program aided in file preparation and management; other software supported the communicant ions features mentioned above—e.g., use of the System/32 as a remote work station for a 370 series mainframe. Other miscellaneous software included: word processing; form letters; a library of mathematics subroutines; statistics; critical path analysis; and a manufacturing management package for scheduling purchases, fabrication, and shipments.

Much more software was made available through the 14 Industry Application Programs (IAPs) supplied on IBM-owned floppy disks and written in RPG II; these could be customized still further if necessary. The 1+1 IAPs handled tasks associated with: accounting firms; medical groups; bulk mailing; construction; hospitals; manufacturing; distribution; law firms; lumber dealers; food distributors; student administration; motor freight; financial institutions; and retailing. Typical IAP functions are accounting, analysis or control of cost/time/i riven - tory/sales, management of files and records, and planning and scheduling.

Upward comparability was one of IBM's design goals. System/32 purchasers had two possible growth paths: into a System/3 Model 8, 12, or 15;

[18] *Datapro Feature Report: All About Small Business-; omputers* (Delran, N J Datapro Research Corp , September 1978), p 70C-010-30a

[19] *Datapro Reportson Min icomputers IBM System/32* (Delran, N.]. Datapro Researc h Corp , January 1978), pM 11-491-601

or into a System / 34. With minor modifications RPG II programs from a System / 32 could be run on a System / 3 or vice versa; this also meant that System / 3 users could move into 32s or add 32s to their networks. For those wanting to move into a System / 34, the System / 32 RPG programs were source-compatible with the System / 34, allowing IAPs to run without change.

Support by the manufacturer—not only new software packages, but also hardware updates and servicing—are important to most SBC customers. Those who rented the System / 32 could get service 24 hours a day, 7 days a week. Purchasers had service available 9 hours per day, 5 days per week under the Minimum Monthly Maintenance Charge, or could buy 24-hour service for an additional fee. IBM also emphasized ease of use—the minimal training needed to run IAPs, indeed to operate the entire system.

The Market

That the SBC market offered enormous growth potential was a truism of the early 1970's. The pool of prospective customers for an SBC costing less than $1,000 per month included as many as half a million small organizations—virtually none of which had prior electronic data processing experience. Besides the sheer numbers involved, this market was important for another reason, Computer customers exhibit high loyalty to the firm from whom they buy their initial system. By capturing first-time purchasers, a supplier gains a big future advantage. Computer manufacturers who chose not to compete vigorously in the SBC market ran a real risk of seeing their future market share and competitive position eroded. Adding to the potential market were expanding applications in distributed data processing, where many SBC models could be used as remote job entry stations.

These markets brought a pair of requirements for a competitive SBC. First, it would have to be simple—user-friendly—so that a customer with little or no data processing background could learn to operate it quickly. The second requirement was compatibility with other machines in a networking or distributed processing environment. Upward—and for larger SBCs, downward—compatibility was an important selling point, so that customers could expand or upgrade their installations.

The established mainframe computer manufacturers had, at least initially, advantages in all these areas. Their nationwide sales and service staffs were accustomed to dealing with customers having business applications, rather than the OEMs and technically trained users who bought minicomputers. They also had considerable software experience; mainframes were ordinarily marketed with extensive software support compared to the minicomputers of that era. Moreover, a mainframe manufacturer could design an SBC compatible with other parts of its product line; existing customers then comprised a readymade market base. As a final—and very important—weapon, the large, established firms had brand recognition. Not only IBM, but companies like Burroughs, NCR, and Univac were familiar names. Many new purchasers, bewildered by competing claims and fearful of the pitfalls involved in purchasing a computer, automatically turned to one of these companies. A decade later, IBM reaped similar benefits when it entered the personal computer market. Despite these putative advantages, most of the established mainframe manufacturers had a good deal of trouble adjusting to the competition for SBC sales.

Minicomputer firms—for many of whom SBCs were upward rather than downward extensions of their product lines—faced serious handicaps in comparison. Unlike the mainframe companies, minicomputer suppliers such as Digital Equipment Corp. (DEC) had little experience selling to end-users. OEMs or engineering organizations did not need extensive support; minicomputer firms had neither large service networks nor large marketing staffs. They competed most heavily on hardware features and price. Software was less critical; most users could write their own. Minicomputer customers who needed software or other support frequently bought from "systems houses" or other middlemen, Systems houses purchased hardware in bulk, supplying customized software and assembling a system to meet customer requirements. Not restricted to any one manufacturer, they could put together processors, terminals, storage units, and other peripherals from a variety of sources to customize a given installation. By taking advantage of the lower hardware prices it could command, a systems house might be able to supply an entire installation, including software, for less than the hardware cost to a single-unit purchaser. Qantel and Basic Four both had considerable success as systems houses before entering the SBC market with equipment of their own designs.

Minicomputer makers also experimented with other marketing channels aimed at small end-users. An example is the "software representative" created by Datapoint to locate potential customers. The sale was between Datapoint and the end-user, with the representative getting a commission and afterwards supplying software and other services independently.

Development of the System/32

IBM had been slow compared to Burroughs and NCR in exploiting the SBC market. Prior to the introduction of the System/32 in January 1975, IBM's only offering was the System/3. Originally priced at the very top of the SBC range—although later models cost much less—the System/3, which reached the market in 1970, had gone on to sell more units than any other computer in IBM's history; by 1975, over 30,000 had been purchased worldwide. The success of the System/3 was a major reason for IBM's decision to expand its line of SBC machines into the lower price ranges.

In many respects, the System/32 was a direct descendent of the System/3 Model 6. The central processing units of the two were quite similar, and many of the software products offered for the System/32 were adaptations of those developed for the System/3 Model 6. Changes included faster printers, simplified operation, and improved applications programs. With the System/3 Model 6, only limited applications software had been available, and those wishing to write their own programs had to master a complicated operating system.

Development of the System/32—hardware, software, and the market studies leading up to these—was the job of IBM's General Systems Division (GSD). The GSD emerged from a major corporate reorganization in 1972 that split the former Data Processing Group into three divisions. With this reorganization, the GSD was given development and manufacturing responsibility for the System/3 and related peripherals. Responsibility for all small business applications within IBM followed in 1974, at which time the GSD was given its own marketing arm.

By the next year, the GSD marketing and sales force had grown to some 4,500 sales representatives working out of 67 sales offices, plus nearly 3,000 field engineers. The System/32 entered the market accompanied by an extensive advertising campaign, along with exhibits at trade shows, direct mail, and in-person sales calls. These promotional efforts were tailored to potential customers with little or no computing experience, Initial sales of the System/32, which was made in Rochester, Minnesota and Virmercate, Italy—with components and subassemblies coming from other IBM facilities—exceeded the company's projections.

The System/32 offered a price-performance combination not available in other IBM systems. Heavy demand during the first year led to extended delivery dates. The reason for this success was not any technological advantage with respect to the competition, but IBM's accurate perception of the needs and concerns of the SBC market. Indeed, from a hardware perspective the System/32 was a rather limited machine. Instead of being designed for multiprogramming, it was restricted to executing one program at a time. It had less disk storage than a number of other SBC systems. Furthermore, because the disks were hard and nonremovable, only on-line storage was available. The technology utilized in the System/32 did reflect the state of the art in using MOS integrated circuits in both memory and processor.

Probably the most innovative aspect of the System/32 was its software. While IBM had been accustomed to writing customized software for mainframe purchasers, such an approach was not practical given the large number of SBC customers. Hence the Industry Application Programs, aimed at meeting perhaps three-quarters of user needs. The remainder could be supplied by IBM or an independent vendor at extra cost. The IAP concept was not unique, but the design, distribution, and support for these programs was a major undertaking, Unbundling the software was another new departure; IBM had traditionally supplied hardware and software together at a single package price. IAPs, in contrast, were sold for an initial one-time payment plus a monthly support fee. The Wholesale Food Distribution IAP, for example, carried an initial charge of $3,120, plus $147 per month for support. By emphasizing reliable hardware, minimal maintenance, and off-the-shelf software, IBM was able to continue its "hand-holding" approach to marketing while supplying large numbers of machines.

The Competitive Response

Burroughs and NCR were the two companies most affected by IBM's entrance into the SBC market. While both offered broad product lines, SBCs had come to represent a significant share of their total revenues. Both had seen the importance of SBCs early, and sought to utilize their sales and marketing organizations—which were much more extensive than those of the minicomputer suppliers—to establish themselves in this part of the market.

Burroughs, then the dominant force in SBCs, had formed two special marketing groups–the "general accounts force, " and the "selected accounts force''—to handle smaller machines. The general accounts force sold exclusively to small firms, while the selected accounts force devoted its efforts to large organizations with requirements that could

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be served by small computers. Thus Burroughs explicitly recognized the dual nature of the SBC: stand-alone for the small enterprise, distributed processing for larger customers.

Burroughs had originally entered the lower end of the SBC market in 1973 with the first of its B700 series, selling more than 2,000 in the first 3½ years. When the System/32 was introduced, Burroughs responded immediately—doubling the main memory of the B700 and bringing out six new models. In April 1976, Burroughs announced the B80, which was—unlike IBM's System/32—capable of multiprograming and multiple terminal support. This machine was well received initially, but suffered from severe software problems; it was soon replaced by the B90. Burroughs' share of the SBC market began to slip, a considerable concern to a company that, as early as 1973, got 30 percent of its revenues from the low end of its product line.[20]

NCR also made an early entry into the SBC market, In 1972 it had introduced the NCR 322, a minicomputer priced in the $15,000 range, followed by the Century 8200, the first of a series of SBCs. These two models represented the first results of a thoroughgoing and painful reorganization at NCR, a company that few observers at the time believed could survive. NCR was seen as tradition-bound, still producing electromechanical products that could not compete with electronic equipment. Then, under a new president in the early 1970's, NCR invested nearly $300 million in product development, one thrust being interactive systems designed specifically for business applications.[21] A turnaround followed, as the company went from a loss of $60 million in 1972 to earnings of $72 million in 1975.

The new commitment to electronic products also brought changes to NCR's marketing organization. The old system of branch offices was dismantled, to be replaced by a "vocational sales" organization. Under the earlier system, each salesperson had been responsible for a group of products: sometimes two NCR representatives found themselves competing for the same sale, Under the new arrangement, salesmen were responsible for selling to one of four vocational groups: retail stores; financial organizations; commercial-industrial enterprises; and a residual group consisting of medical, educational, and government organizations. In addition, the entire field engineering force—some *7,000* people—was retrained to service the new electronically based product line.[22]

Sperry Univac was the last of the major mainframe manufacturers to move into the SBC market, introducing the BC/7 in 1977—a machine featuring multiple terminal concurrent data entry capability, a great deal of available storage, and removable disks–none of which were available on the System/32. Sperry Univac had created fully staffed marketing organizations in 18 cities, with plans for further expansion, just for the BC/7.[23] A further indication of their commitment to the SBC market was the acquisition of Varian Data Machines, a major manufacturer of minicomputer products. Nonetheless, the BC/7 family suffered from applications software that did not compare favorably with the competition, and could capture but 2 percent of the SBC market.

Among the minicomputer firms, DEC was and still is the largest and most successful. The company, which had developed the first commercially successful mini—the PDP-8—probably had the most to lose in competing for SBC sales. DEC had established itself by mass-producing "black boxes" sold primarily to OEMs. In the 1970's, this market was coming under increasing pressure from other companies, including those making microcomputers, and DEC realized its greatest growth prospects lay in small business and other end-user markets.

When the System/32 was introduced, DEC was the first to respond, countering—only 10 days after IBM's announcement—with the Datasystem 310, which played to DEC's own strengths. It was slower, with less memory than the System/32, but cost a third less. DEC retained its established marketing practices, selling networked systems directly while relying on independent distributors for simple turnkey sales. These distributors bought hardware at a discount, added software, and then sold the systems at approximately the same price DEC would have charged for the hardware alone. After purchase, DEC provided hardware maintenance, with the distributors responsible for software.

Another minicomputer manufacturer, Wang Laboratories, also responded quickly, releasing a series of computers—the WCS series—that proved quite successful.[24] Like other minicomputer manufacturers, Wang stressed its low prices and proven

[20] "The Burroughs Syndrome," *Business Week*, Nov. 12, 1979, p. 80.

[21] "NCR Transition Nearly Complete: Company Targets Three Markets, " *Computerworld*, May 24, 1976, p. 35.

[22] "NCR's New Strategy Puts It in Computers to Stay, " *Business Week*, Sept. 26, 1977, p. 104.

[23] "Sperry Sets Computer for Small Business, " *Advertising Age*, Apr. *25, 1977*, p. *46.*

[24] *Auerbach Computer Technology Reports: Wang Laboratories*, Auerbach Publishers No. 140.6856.150, 1977, p. 2.

hardware. However, the company realized that price competitiveness alone would not assure success, and moved to establish a dealership and service network to provide the services that SBC customers expected. One function of Wang's new distribution system was to provide applications software, including customized programs.

Conclusion

When IBM moved into the SBC market, other firms rapidly cut prices on existing models and sought to upgrade and expand their product lines. More companies entered the fray, perhaps feeling that IBM's entry had legitimatized the SBC. Buyers could choose from more sophisticated systems at lower prices. *Business Week* estimated that, by 1975, IBM had captured about 28 percent of SBC sales, with Burroughs around 12 percent and NCR just under 5 percent. IBM's share of this market continued to climb; by 1978 it was put at 37 percent, with Burroughs and NCR together still accounting for less than 20 percent.[25]

[25] "The Burroughs Syndrome," op cit

By 1980, the System/32 in its basic configuration sold for $23,490—a reduction of $10,000 compared to the original price 5 years earlier. While the System/32 was more successful at the outset than anticipated, sales declined rapidly once its successor, the System/34 was introduced. The System/34 could handle multiple work-stations; it offered more processing power, multiple programing capabilities, and more storage. Selling in the same price range, the System/34 continued the trend toward greater performance/cost ratios.

Beyond its brand recognition and "safe" image, IBM's immediate success with the System/32 came from its decision to stress applications—an obvious strategy, but one that IBM executed better than the competition. The technology in the System/32 was not much different from its predecessor. In the SBC market, technical wizardry counted for little compared to cost and convenience.