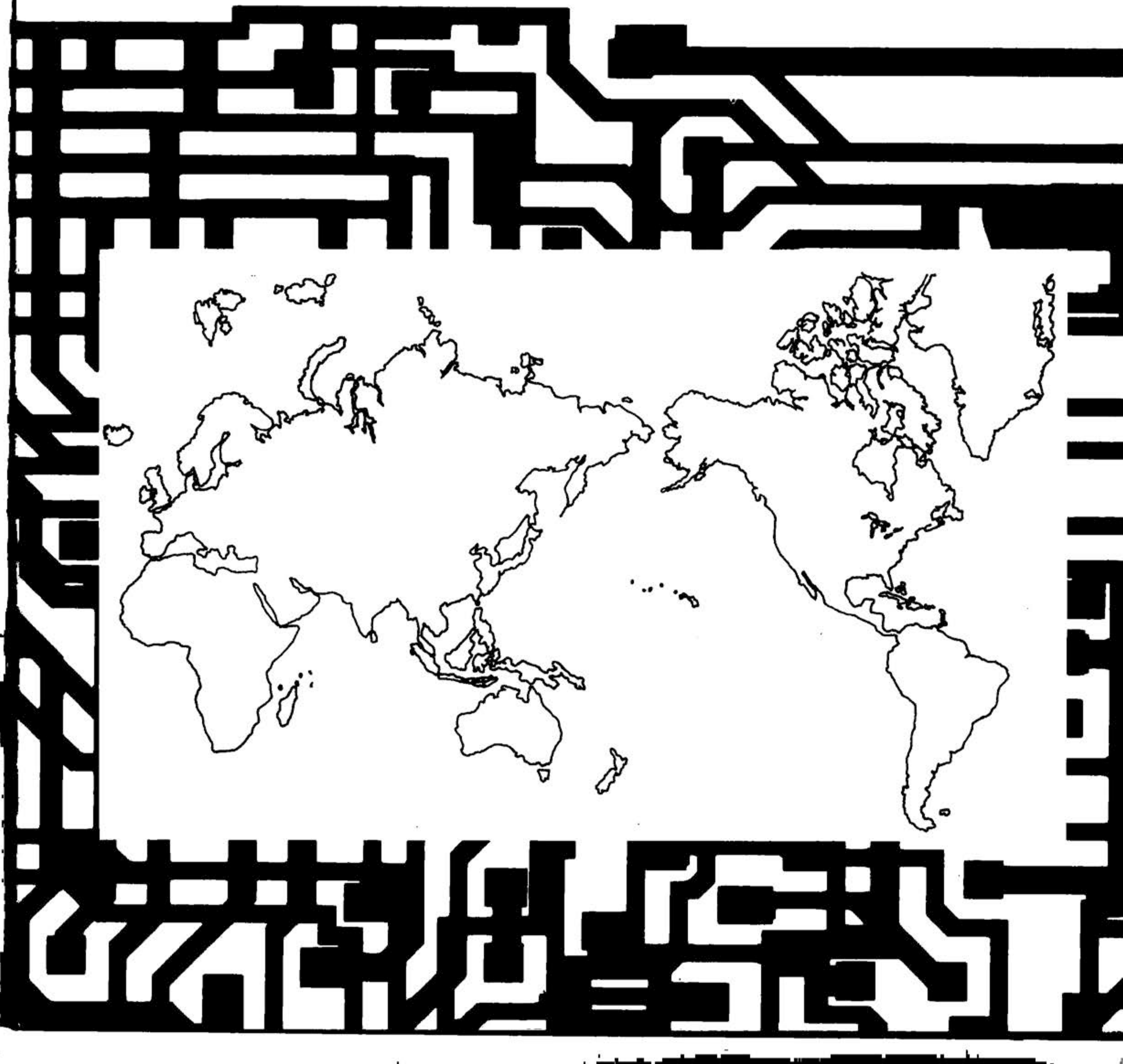
Delicate Bonds: The Global Semiconductor Industry

A Special Issue of Pacific Research



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Editor
Lenny Siegel
Production
John Markoff

Delicate Bonds: The Global Semiconductor Industry

by Lenny Siegel

This special issue of **Pacific Research** is being published as part of the Pacific Studies Center's Global Electronics Information Project. The purpose of this project is to circulate critical and and analytical information about the semiconductor industry, material which seldom breaks through the barrage of press release journalism in the U.S. mass media.

PSC also publishes the monthly "Global Electronics Information Newsletter," a brief summary of current events in the global semiconductor industry. In addition to regularly updating information from this pamphlet, the newsletter is designed to help create a network of researchers, activists, and groups interested in the evolution of the solid-state electronics industry. We welcome requests for information, research notes, and theoretical hypotheses, as well as names of possible subscribers. The current one-year rate is $5 (US$6.25 Canada, $10 foreign airmail).

Pacific Research, the journal of the Pacific Studies Center, is published quarterly (we're behind schedule now). It consists of original articles on the political economy of Asia and the Pacific, multinational corporations, and U.S. foreign and military policy. Recent issues have covered East-West Trade controls, export industries in the Philippines, and the cultural impact of electronics production on Southeast Asian women. See the inside back cover of this special issue for a complete listing of back issues, all of which still can be purchased.

Upcoming **Pacific Research** issues will report on Mattel Toy Company's overseas operations; Japan-U.S. semiconductor competition; and nuclear power in South Korea. PSC welcomes outside submissions for publication, but cannot promise payment.

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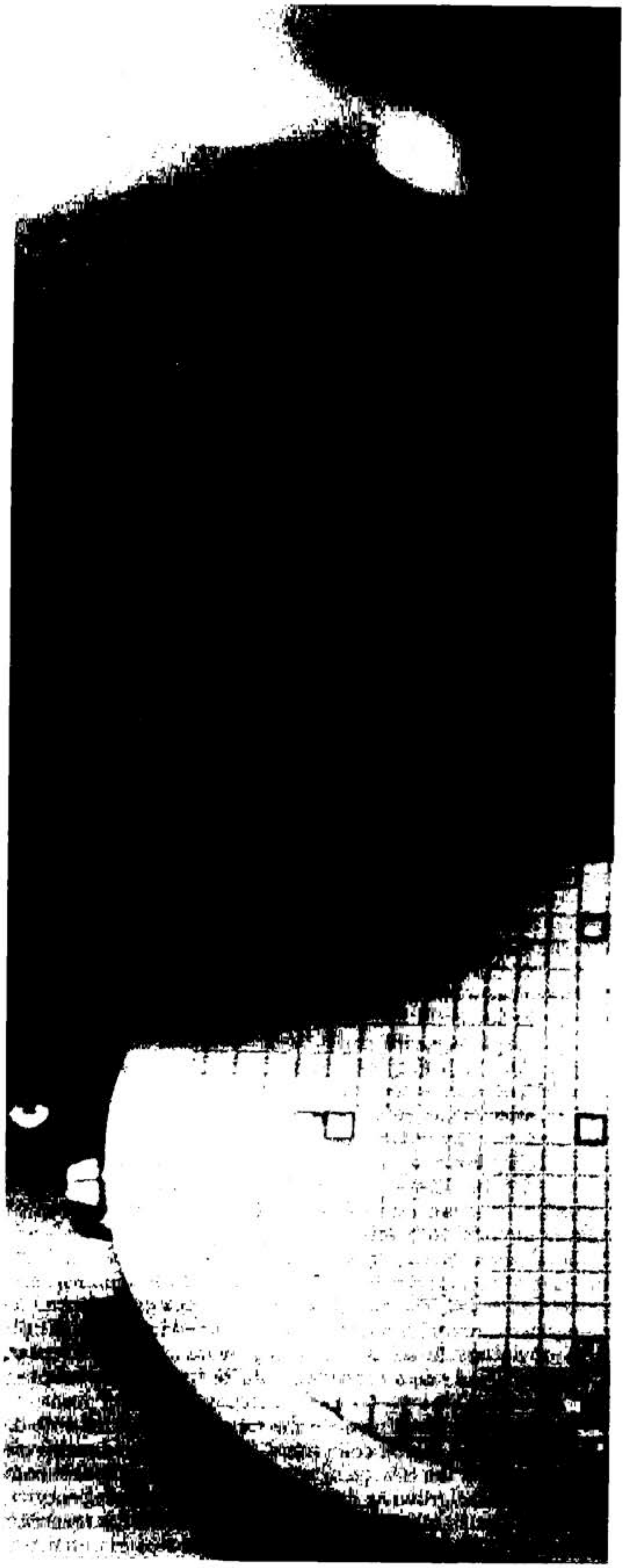

Courtesy of Intel

Introduction

The semiconductor industry — the production of small, solid-state electronic components — has achieved such fantastic technological advances in recent years that some observers have called the applications of integrated circuitry a "second industrial revolution." In particular, unions in Europe have warned of a dramatic shift in global employment patterns rivaling the rise of organized manufacturing two centuries ago.

However, in an ironic sense, the production of the solid-state components themselves, in the U.S. and Eastern Asia, today resembles 18th century manufacturing. Factory women in Asia, fresh from the countryside, live in crowded dormitories and assemble electronic circuits for pennies an hour. Unions are scarce. Workers in both Asia and the U.S. have little to say about their working conditions.

Considered for years to be a "clean," light industry, semiconductor production is finally being recognized as a dangerous user of toxic chemicals. Workers are regularly exposed to acids, solvents, and metallic fumes; fire hazards are significant; plants frequently release dangerous pollutants. In addition, assembly workers risk eye damage and severe job stress.

Yet the semiconductor industry is in the vanguard of the *globalization* of capitalism — in markets, production, and ownership. From its early growth in the 1960's, the semiconductor market has been international, although the U.S. government has deliberately restricted the flow of semiconductor products and technology to the Socialist Bloc.

For most products, the industry maintains a unique international assembly line, heavily dependent on decisions at company headquarters in the U.S. and other rich nations. Design and capital-intensive processing take place in the U.S., Japan, and to some extent, Europe. Labor-intensive assembly — the bonding of microscopic gold threads to semiconductor chips — is done primarily in less-developed Asia. And final product testing is usually conducted in the wealthy countries, although there is some testing of older, simpler product lines in industrializing countries such as Singapore and Hong Kong. Even within Asia, semiconductor firms have created a division of labor, establishing unskilled, labor-intensive "jelly bean" — or simple integrated circuits — assembly facilities in low-wage areas such as the Philippines and Indonesia.

From the mid-1970's, large multinational corporations, from Europe as well as the U.S., have taken control of most of the independent U.S. semiconductor producers. While in its infancy, the industry thrived on innovation; now investment capital is the number one need. For this reason, it is likely that the industry will continue to consolidate under international ownership.

Spokesmen for U.S.-based semiconductor companies have, since the late 1970's warned that the growing competitiveness of Japanese components makers could severely damage the U.S. industry. However, these entrepreneurs seem more worried about their own financial position than the welfare of their workers. Only when seeking government help are they "American."

In fact, U.S.-based electronics companies rely heavily on the exploitation of Asian women to maintain their profits. Governments which choose the U.S.-backed route of "export-led industrialization" must essentially promise a cheap, docile labor force. Asian human rights violations, officially deplored by the U.S. government and some of the companies, are the logical consequence of that promise, and U.S. policies have — despite recent rhetoric — consistently supported such repression.

Unions, human rights and religious organizations, women's groups, and even environmentalists are beginning to realize the dangers to human welfare posed by the semiconductor industry in its present form. As long as management dominates the flow of information about the industry, however, workers will see their problems isolated, or adopt nationalistic positions hostile to sister workers in other locations.

We, at the Pacific Studies Center's Global Electronics Information Project, believe, however, that the advanced global structure of the semiconductor industry has created the potential for international cooperation. Workers and their allies in the U.S., for instance, can serve themselves and their Asian sisters by forcing changes in U.S. Asian policy. As the industry matures in the U.S., it will invariably unionize. American unions can cooperate with labor organizations in Asia and Europe, but only if they understand the "delicate" bonds that link them together.

The Rise Of The Silicon Chip

The invention of the germanium transistor, the first solid-state electronic valve, culminated years of scientific study propelled by the needs of both government and private industry. First, at AT&T's Bell Laboratories, "the idea of using some kind of electronic switch other than the vacuum tube to replace the telephone system's mechanical switches surfaced . . . in 1936."[1] Bell gathered a research team to conduct theoretical and experimental research in solid-state physics, however, it diverted its attention to submarine-detecting radar during World War II. Second, during the war the U.S. military sponsored some semiconductor research labs, some of which made important theoretical advances, in the search for a smaller, energy-efficient device to replace the vacuum tube in radar applications.

Following the war, most of the military-backed semiconductor labs closed down, but Bell re-established its research program under the leadership of physicist William Shockley. Shockley shares the credit for the invention of the transistor with John Bardeen and Walter Brattain, the two Bell researchers who first demonstrated a working transistor in December, 1947.

Bell widely publicized its invention and the supporting technology. By 1952 26 domestic and 9 foreign electronics companies had obtained licenses.[2] But early production of the expensive devices would have grown at a snail's pace had it not been for the interest of the U.S. military. The military sponsored semiconductor research in corporate and academic laboratories, but its major contribution was as a customer. In the first five years during which the transistor was available commercially, the Pentagon, particularly the Army Signal Corps, ordered millions of dollars of the new devices, enabling the development of mass production techniques.

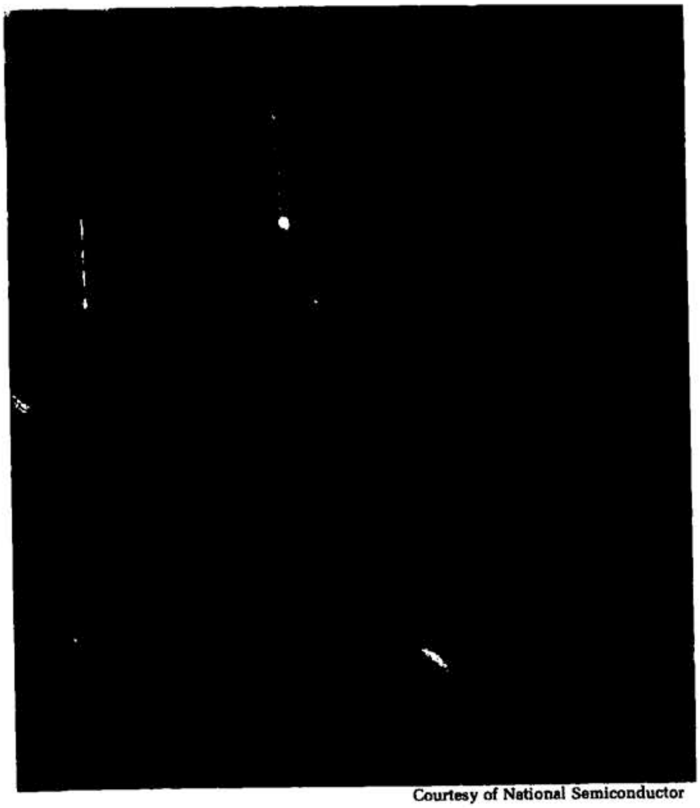
In 1954, a group headed by Bell alumnus Gordon Teal, at Texas Instruments, invented the first silicon transistor, which could handle much larger currents and wider temperature ranges than the earlier, Germanium versions. To this day, most semiconductor devices are built from silicon, fortunately one of the most common elements on the earth's surface — in silicon dioxide (sand or quartz).

Among the semiconductor industry's many innovations of the late 1950's, the development of the *planar* process, by Jean Hoerni at Fairchild Semiconductor, proved critical. Hoerni's process replaced wire connectors, which to that time were used to link the electrical regions of transistors, with metallic lines diffused into the silicon itself.

The next major step in semiconductor research was the development, from 1959 to 1961, of the integrated circuit, a silicon chip incorporating the properties of two or more transistors. The first IC's were produced, nearly simultaneously, at Texas Instruments and Fairchild, by teams heads by Jack St. Clair Kilby and Robert Noyce, respectively.

Once again the U.S. government played a major role in the move toward mass production. In 1961 the Minuteman missile system awarded TI a sizable contract to design and produce integrated circuits, and it eventually ordered hundreds of millions of dollars in solid-state components. Fairchild, meanwhile, received major orders from the burgeoning space program.

The development of semiconductors also coincided with the development of digital computers. Compact, inexpensive circuitry enabled the design of smaller, but more capable computers, and the growing demand for data processing services provided the semiconductor industry with a huge market to support its technological advances.



Courtesy of National Semiconductor

Revolutionary advances in product, production and applications technologies have now injected semiconductors into every sector of the U.S. economy. The largest market segment still is data processing, including calculators, minicomputers, and graphics terminals, as well as powerful "mainframe" computers. Today it seems that integrated circuits are used in almost everything, including communications equipment, home appliances, industrial processing equipment, automobiles, watches, games, and medical instruments.

Though the U.S. military remains an important consumer of semiconductors, its market share has dropped markedly. Through 1965 the Pentagon held a 70 percent share of the integrated circuit market, but by 1978 that had fallen to 7 percent.[3] Electronics technology is perhaps the most important factor in U.S. military superiority, but the dramatic growth of the civilian semiconductor sector has left the Pentagon behind. For this reason, the Advanced Research Projects Agency has established a program to develop "Very High Speed Integrated Circuits" (VHSIC). ARPA hopes to influence the development of new circuitry, by providing more than $200 million in research contracts and by teaming semiconductor houses such as Fiarchild and National Semiconductor, with major military systems manufacturers such as Raytheon and Westinghouse.[4]

In 1979 the semiconductor industry achieved worldwide sales of about $13 billion,[5] primarily in the U.S., Japan, and Western Europe. Financial statistics grossly understate the growth of the industry however, since the cost per electronic function has fallen by a factor of 100,000 in less than two decades. The cost per memory bit, $50 in the mid-1960's, dropped to less than $.0005 in the 16,000-bit random access memories (16K RAM's) of the late 1970's.[6] This continuing reduction in cost has been the driving force behind the rise of the semiconductor market.

Corporate Structure

Though the transistor was introduced by AT&T — the world's largest corporation (by assets) and synonymous with monopoly — the semiconductor industry has been anything but monopolistic. In fact, its corporate history has rivaled its technological history for its dynamism.

From the announcement of the invention of the transistor in 1948, Bell Labs actively sought to distribute its technology to other electronics companies, licensing patents widely and holding seminars to brief scientists from other organizations. (In fact, the company made the technology available to hearing aid manufacturers free of charge, in honor of Alexander Graham Bell's work.) *Electronics* suggests that AT&T wished the speed the development of solid-state circuitry, for use in the phone system. That is, Bell was more interested in semiconductors as a consumer, not as a producer.

But John Tilton, a Brookings institute Scholar, cites another factor. In 1949 the Justice Department initiated an anti-trust suit against AT&T, to separate Western Electric (the manufacturing subsidiary under which Bell Labs was organized) from the operating branches of the Bell System. The settlement, in 1956, directed Bell to license all existing patents to domestic firms royalty free, and to make all further discoveries available for licensing at reasonable rates.

Whatever the primary cause, Bell Labs set a precedent which was followed by Texas Instruments and Fairchild. In fact, at least until 1971 it was true that Fairchild "actively seeks licensees for its basic planar patents including extensive technical assistance, but charges royalty rates as high as 6 percent on product sales."[8] Today most semiconductor companies still make a practice of licensing technology to their competitors. And it is standard industry practice to develop "cross-licensing" technology exchanges.

With the basic technology readily available, many companies moved into semiconductor production. Some — the *captive* producers such as Western Electric, IBM, and other computer companies, a number of military contractors and, more recently, General Motors, have produced primarily to supply components for their own equipment and systems. Others — the *merchant* producers — have produced primarily for the open market. The distinction between these two segments is blurring today, however, as many of the semiconductor specialists are beginning to produce end use equipment.

The early merchant market, supplying transistors and diodes to replace vacuum tubes, was dominated by vacuum tube makers such as RCA, General Electric, and Sylvania. The production technology was simple, and existing marketing structures sufficed.

However, as the industry developed, few electrical equipment manufacturers could keep up. Used to operating in more established markets, these companies were unwilling to cut prices during periods of high demand. The new semiconductor firms, however, reduced charges to enlarge their long-term market shares.

More important, established manufacturers were unwilling to offer young scientists and engineers either the pay or authority that they sought. Because expertise, rather than raw materials, capital, or energy was the number one requirement for the industry, dissatisfied professionals could — and did — strike out on their own.

Silicon Valley

William Shockley had little difficulty attracting backing — from Beckman Instruments — when he founded Shockley Semiconductor, in his native Palo Alto, upon leaving Bell Labs in 1954. Shockley not only carried with him his own scientific experience, but he was able to attract a group of young engineers and scientists to the warm climes of the Santa Clara Valley.

Shockley, however, was unable to lead his team. In 1957 eight of his young assistants — including Noyce and Hoerni — quit the company to form, with the backing of Fairchild Camera and Instruments, Fairchild Semiconductor. Although Fairchild soon became one of the top merchant semiconductor houses and introduced a number of key technological advances, its Eastern management was unable to satisfy the innovators. In clusters of two and threes, a large number of Fairchild's researchers and executives, including the eight founders, quit to found or re-organize other semiconductor firms in the area. The first group formed Rheem Semiconductor (Raytheon) in 1959, and two other groups, one including Hoerni, formed Signetics and Amelco (now Teledyne Semiconductor) in 1961. In 1967 Fairchild Semiconductor general manager Charles Sporck left to rebuild a merger of Molectro (another Fairchild spin-off) into National Semiconductor as a major competitor. In 1968 Robert Noyce and Gordon Moore, another Fairchild founder, quit to form Intel. And the following year, market manager Jerry Sanders took seven other Fairchild employees with him to form Advanced Micro Devices. In 1971, 21 of the 23 semiconductor firms in the Bay Area could trace their ancestry to Fairchild.[9]

The Santa Clara Valley proved a warm breeding ground for semiconductor companies, as well as other high technology ventures.

Fairchild was not the only source of semiconductor talent. Semiconductor firms recruited managers and engineers from established electronics firms, competing semiconductor firms, and straight from graduate school, where military-sponsored programs continued to train young researchers in state-of-the-art technology. In 1968 Sherman Fairchild, founder and chairman of Fairchild Camera, offered an impressive financial package to Lester Hogan, head of Motorola Semiconductor, to recruit him as Fairchild company president. And in 1969, in Texas, a group of Texas Instruments employees overcame their employer's reputation for staff loyalty to form Mostek.

The Santa Clara Valley proved a fertile breeding ground for semiconductor companies, as well as other high technology ventures. Stanford University, by carrying out millions of dollars in electronics research for the Pentagon, creating the Stanford Research Institute, and leasing Stanford land to high technology companies, had consciously created a "community of technical scholars." University training, research, and consulting provided companies with important expertise, and Stanford-backed companies such as Hewlett-Packard, Varian, Applied Technology, and Lockheed Missiles and Space Company provided either instruments or markets for the semiconductor ventures. Furthermore, the comfortable climate and suburban lifestyle proved rewarding to the industry's innovators.[10]

Shockley Transistor, Fairchild Semiconductor, and Rheem Semiconductor were all financed by existing electrical equipment manufacturers. As the pattern of industrial innovation emerged, however, entrepreneurs sought the backing of "venure" capitalists, private investors hoping to make huge profits by providing funds at an early, risky stage. Arthur Rock, perhaps the best known Silicon Valley venture capitalist — quickly raised $2.5 million to help start Intel. Another group, Institutional Venture Associates, has invested a reported $18 million in 21 high technology companies since 1974. By 1980 that investment had grown to $110 million.[11]

By the early 1970's, such a concentration of semiconductor research and production had developed that the area became know as "Silicon Valley." As the concentration of semiconductor and other high technology firms grew, small entrepreneurs and major multinational corporations were attracted to the valley. Literally hundreds of electronics, chemical, and consulting firms developed to supply materials, equipment, and services — from programming to specialized graphics — to semiconductor makers and users.

This environment remains an exceptional breeding ground for new high-technology venutres, despite the skyrocketing cost of living and resulting shortage of skilled and professional employees. In fact major electronics firms — such as Western Electric, Xerox, and Northern Telecom — have established research arms on the Peninsula in recent years to take advantage of the area's scientific resources. Today, more than 150,000 people work in the area's electronics industry. About 40,000 work in the valley's 15 largest semiconductor firms.[12]

A Competitive Industry

By 1972 there were 96 U.S. companies producing semiconductors and at least 217 more producing semiconductor parts. More than half of the former were specialized semiconductor houses; 37 were branches of "conglomerates;" and 9 were captive producers.[13] Of the top nine merchant suppliers of integrated circuits in 1975, only three were diversified electronics firms.[14]

Easy entry into the marketplace guaranteed that semiconductor production would be a competitive industry. To obtain a market share for each new generation of integrated circuits, companies priced circuits below their initial production costs. In most cases this paid off, for production costs per circuit declined with experience, new technologies, and greater economies of scale. In a beneficial circle, lower production costs enabled lower prices, which promoted greater sales, which enabled even lower production costs through mass production.

Thus, at a time when most U.S. manufacturing industries observed monopolisitic pricing behavior — not using price competition to increase market shares — the semiconductor industry aggressively pursued the classical patterns of competitive capitalism. However, firms that gambled on the wrong product fared poorly, for they could not recoup the losses associated with design and early production runs.

Most semiconductor firms have thrived during periods of economic expansion, but many absorbed major losses during the recessions of 1970 and 1974-75. Semiconductor executives planned their expansion and built up inventories in expectation of continuously expanding markets.

Although they could, and did, cut back their workforces, they found themselves stuck with substantial fixed costs and inventory surpluses.

Top Nine Merchant I.C. Houses in 1975

		(Headquarters)
1. Texas Instrunents	Diversified Elec.	Dallas
2. National Semiconductor	Predom. Semi.	Silicon Valley
3. Fairchild	Predom. Semi.	Silicon Valley
4. Motorola	Diversified Elec.	Phoenix
5. Intel	Predom. Semi	Silicon Valley
6. Signetics	Predom. Semi.	Silicon Valley
7. American Microsystems	Predom. Semi.	Silicon Valley
8. RCA	Diversified Elec.	Somerville, New Jersey
9. Mostek	Predom. Semi.	Carolltown, Texas

Ironically, in the late 1970's many firms "overprepared" for the recession of 1980. The broadening applications of integrated circuits and computers have thus far kept demand for semiconductors relatively hgih. U.S. semiconductor firms which expanded production cautiously could not keep up with demand, particularly for memory circuits. Japanese producers, working in another economic cycle and with different financial priorities, took advantage of the shortage to establish a major share of the world market. In some recent cases American semi houses — National, for instance — have actually ordered 16-K Random Access Memories (RAM) from Japanese suppliers to supply their own equipment factories.[15]

Consolidation

As the semiconductor industry matures, it is being reintegrated into the electronics industry. New entries are rare, and one by one the semiconductor specialists are being bought out by U.S. and foreign-based multinational corporations.

Vacuum tube makers that pioneered transistor production, but essentially dropped out of the merchant semiconductor business — GE, Sylvania, and Westinghouse — have all purchased integrated circuit operations.

As semiconductor producers have squeezed more and more functions onto each chip, the capital needs of the industry have risen. While it cost Monolithic Memories only $2.5 million to begin production as recently as 1969,[16] a new company today would require from $20 million to $50 million. Thus, while entrepreneurs continue to form new electronics and high technology service firms in Silicon Valley, few have established new semiconductor makers — that is, companies that fabricate wafers — since 1973. One notable exception has been Zilog, organized by two Intel alumni. Zilog has not had problems raising cash, however, since it capitalized entirely by Exxon.

The same growing capital requirements have influenced existing companies. In part because of competitive price behavior, in part because the industry's owners have found it necessary to share revenues with professional employees in the form of high salaries and other benefits, semiconductor specialists have been unable to finance expansion from their own cash flow. Companies are often reluctant to take long-term loans from banks, because the payments remain fixed even during slow sales periods. Several ventures had difficulty meeting debt commitments during the recession of 1974-5.[17]

Most independent semiconductor firms, therefore, have sought financing through merger with other, larger firms. Of the six leading independent firms marketing indtegrated circuits in 1975, four have been bought out.[18]

Buyers of smaller semiconductor firms have included Nippon Electric of Japan(Electronic Arrays), Siemens of Germany(Litronix and 20 percent of Advanced Micro Devices), General Electric(Intersil), and Honeywell(Spectronics and Synertek).

Most of the corporations that have bought out or bought into U.S. semiconductor houses are either users of semiconductors or makers of semiconductors themselves. They invest for the long-term promise of profits, to enter a new market, or to develop captive production capacity. Particularly because so many of the buyers are foreign, many observers have suggested that investment is a cheap way for foreign firms to obtain technology not available in their home countries. This is partially true, but it is also true that major, successful electronics firms like Siemens, Philips, and Nippon Electric have much to offer to their U.S. subsidiaries.

Major Acquisitions

Corp.		Acquired By		
Signetics	1975	Philips (Netherlands)	100%	$49
American Microsystems	1978	Bosch (W. Germany)	25%	$14M
Mostek	1979	United Technologies (US)	100%	$349
Fairchild	1979	Schlumberger (France)	100%	$397

National and Intel, the two remaining major semiconductor independents, hope to withstand the consolidation trend by expanding themselves into the production of consumer poducts and data processing systems. Any major financial setback at either company, however, could drive it into the arms of an auto, instruments, or electronics company with the financial resources not only to finance expansion but to withstand periodic losses.

Workforce

Although the need for talented scientists and engineers has influenced the structure of the American semiconductor industry, the industry has much broader labor requirements. Many of the processes, particularly final assembly, are labor intensive. During the 1960's, roughly two-thirds of the semiconductor workforce was indirectly engaged in production, while nearly all the foreign employees of U.S. companies — which do more than two thirds of their assembly abroad — were and still are engaged in production.

As the industry matures, utilizing more capital intensive methods and requiring a larger design and marketing effort, the proportion of domestic production workers has declined. In June, 1980 98,300 employees, or 44 percent of the domestic semiconductor workforce of 221,500 were classified production workers.[19]

Within the production workforce, the need for technicians (skilled classifications) has grown with the introduction of more sophisticated equipment. Qualified technicians command high salaries; even inexperienced techs now make $1200 per month in Silicon Valley.[20]

Similarly, professional employees command high pay. Companies pay large premiums to hire experienced researchers from other companies, and many offer large bonuses to attract engineers and scientists from other parts of the U.S. and from Europe. Without such bonuses, new employees could not afford to live in Silicon Valley housing comparable to their old homes because of soaring housing costs.

The large bloc of workers, however, consists of semi-skilled production workers, who work in wafer fabrication, testing, and assembly. Because little or no experience or training is necessary, companies can hire employees away from other industries — such as retailing and agriculture — or from outside the workforce — housewives, recent high school graduates, etc. The semiconductor workforce is thus divided between affluent, highly educated employees and operatives who earn little more than the minimum wage. The current entry level pay for semi-skilled employees is about $3.75 to $4.00 per hour.

As competitive companies, semiconductor producers have a structural need to hold down costs. Because the shortage of skilled and professional workers prevents holding down payroll in those categories, the companies, individually and collecively, actively discourage any union organizing, which could bring higher pay for operatives. Some firms have developed sophisticated, paternalistic labor relations systems, while most crack down heavily on organizers and expend enormous resources to ensure that no union wins recognition. Industry associations frequently stage seminars led by union-busting specialists.[21]

In fact, the "need" to minimize wages and prevent unionization has been a primary factor in the plant siting decisions of American electronics companies. Though the U.S. electrical equipment industry has historically been centered in the Northeast, where unions have represented workers for decades, most merchant semiconductor firms have set up shop in the west: Silicon Valley, Texas, and Arizona.[22] It is no accident that the highest wages in semiconductors are in the Northeast. Nationwide only 27% of the semiconductor workforce is unionized; 96% of those are in the Northeast.[23]

Meanwhile the semiconductor economy of Silicon Valley has exceeded the area's resources. Companies are concerned about long-term power supplies. In some areas, limited sewage capacity is causing cities to restrict growth. But the major limitation is in the companies number one requirement — technical and professional labor. Silicon Valley has thousands of engineers, scientists, and technicians, but not enough to supply the needs of industry. Nor does it have the housing to absorb recruits from outside. Consequently, most of the large semiconductor companies from Silicon Valley are building their new production facilities outside Silicon Valley, but within the non-union West. New sites include New Mexico (Intel), Idaho (Zilog and American Microsystems), Oregon (Intel and Siltec) Utah (National and Signetics), and other parts of California (Synertek). None are closing their Silicon valley facilities, and they are keeping their primary R&D labs centered in the "community of technical scholars" spawned by Stanford University.

Most new firms in Silicon Valley, for instance, are actually backed by larger, established corporations. . .

Notes

1. *Electronics* Special Commemorative Issue, April 17, 1980, p. 216.
2. *ibid.*, p. 239
3. Leonard Weisberg, in *Industrial Technology* hearings, Senate Committee on Commerce, Science, and Transportation, October 30, 1978, pp. 74-75. For excellent documentation of the Department of Defense's early role in the development of the semiconducting integrated circuit see particularly John E. Tilton's *International Diffusion of Technology: The Case of Semiconductors* pp. 89-97 cited in footnote No. 7 below.
4. See *Military Electronics/Countermeasures*, April 1980, p. 28 or *Armed Forces Journal*, June, 1980, p. 36.
5. Robert Noyce, Intel Corporation, Statement before the Subcommittee on International Finance of the Committee on Banking, Housing, and Urban Affairs, United States Senate, January 15, 1980, p. 3. Other estimates are lower.
6. *Official Report of the Proceedings before the United States International Trade Commission, Investigation No. 332-102*, p. 17, cited in "Competitive Factors Influencing World Trade in Integrated Circuits, "USITC Publication 1013, November, 1979, p. 21.
7. *Electronics*, April 17, 1980, p. 236. John E. Tilton, *International Diffusion of Technology: The Case of Semiconductors*, Brookings Institute, 1971, pp. 76-77
8. Tilton, pp. 73, 77, 118.
9. The classic description of the Silicon Valley family tree, by Don Hoefler, appeared in *Electronic News in 1971 (January 11, January 18, January 25). Back issues of Electronic News* are hard to find, so it is fortunate that the Joint Economic Committee of the U.S. Congress reprinted the entire series (in a slightly garbled form) in *Technology and Economic Growth*, July 15-16, 1975. In addition, the Semiconductor Materials Institute, SEMI, has since published a chart entitled "Silicon Valley Genealogy."
10. See Gene Bylinsky, "California's Great Breeding Ground for Industry," *Fortune*, June, 1974; and "Silicon Valley: Paradise or Paradox?" Pacific Studies Center, 1977.
11. *Peninsula Times-Tribune*, September 4, 5, 1980.
12. Marcie Axelrad, "Profile of the Electronics Industry Workforce in the Santa Clara Valley," Project on Health and safety in Electronics, unpublished report, July, 1979.
13. U.S. Semiconductor Industry, U.S. Commerce Department Industry and Trade Administration, September, 1979, pp. 37-38. The Semiconductor Industry Association reported 36 captive and 63 merchant suppliers in 1978.
14. *Business Week*, March 1, 1976, p. 41.
15. *Business Week*, December 3, 1979, p. 85.
16. Zeev Drori, in *Industrial Technology*, p. 45.

17. "Competitive Factors," p. 34.
18. "Can Semiconductors Survive Big Business," *Business Week*, December 3, 1979, pp. 66 ff.
19. *Employment and Earnings*, U.S. Department of Labor Bureau of Labor Standards.
20. Michael L. Trautman, "The Semiconductor Labor Market in Silicon Valley: Production Wages and Related Issues," unpublished, March 7, 1980, exhibit C, based on interviews.
21. See Chris Paine, "Union-Busting Feast at Country Club," *Grapevine*, May, 1977, and Beth Nissen, "At Texas Instruments, If You're Pro-Union, Firm May Be Anti-You," *Wall Street Journal*, July 28, 1978, p. 1
22. Another, less important reason for the collection of semiconductor firms in the West was to be near existing aerospace contractors. If this were a major factor, however, more semiconductor firms would have operations in Southern California.
23. *Industry Wage Survey: Semiconductors, September, 1977*, U.S. Department of Labor Bureau of Labor Statistics Bulletin 2021, 1979, p. 5. Based on a survey of 88 firms.

Going Global

During the 1960's, prompted by the particular needs of production, the semiconductor industry established a unique form of international production, the integrated global assembly line. Midway in the process of manufacturing transistors or integrated circuits, the producers shipped the unfinished components abroad for assembly — bonding — and they then shipped the assembled chips back to the U.S. for testing. This global scheme, though much more complex today, still guides the industry.

With the rise of the transistor radio, American consumer electronics firms had set up assembly plants in the Far East, chiefly Hong Kong, to compete with the Japanese. The semiconductor pioneers, however, faced no substantial Japanese competition. Strong competition among U.S. producers sent leading manufacturers around the globe seeking lower assembly costs.

The pattern is familiar. Usually in response to a recruiting drive by a foreign government, or pleased with the performance of a local subcontractor, one or two manufacturers "dip their toes" in the investment "waters." If labor costs rose quickly, or if strikes hamstrung production, companies closed the plants. If conditions were lukewarm, the first few companies stayed — rapidly expanding markets allowed them to maintain production there and expand elsewhere — but others would not follow. And, if the initial companies succeeded profitably, competitors would rush to the scene.

Fairchild established the first "offshore" semiconductor assembly plant in Hong Kong, in 1962, and it "opened up" Korea in 1966. General instruments moved microelectronics assembly to Taiwan in 1964. When the Mexican government's Border Industrialization Program got into gear in 1967, Transitron and Motorola Semiconductor set up assembly facilities there.

During the 1960's companies concentrated their offshore semiconductor assembly in countries which were proving hospitable to the consumer electronics industry: Mexico, Hong Kong, Taiwan, and South Korea. By the end of the decade however, the semiconductor industry was growing much faster than home electronics production, and companies sought new sites. Since semiconductors were cheaper to ship than televisions and other electrical equipment, firms concentrated their labor-intensive assembly in the low-wage, though distant, Far East.

National Semiconductor led the flood of firms into Singapore in 1968, and into Malyasia in 1971. Though it was the first U.S. firm to assemble semiconductors in Thailand, in 1973, only one other U.S.-based firm followed suit, until 1980, when a third moved in.

Assembly subcontractors — independent companies that do assembly for manufacturers — began work in Indonesia and the Philippines in 1972, encouraging a few assemblers to establish operations in Indonesia, and eventually, in the latter half of the decade, unleashing a rush of firms into the Philippines.

A few firms have established plants in India, Mauritius, and Central America, but most semiconductor assembly growth is still in Southeast Asia.

As Japanese and European-based companies have entered the global semiconductor competition, they too have established assembly plants in low-wage areas, but in smaller numbers. A Commerce Department survey found only 17 offshore facilities operated by foreign semiconductor companies in less developed countries in 1973, compared to 89 operated in U.S. firms in 1974.[1]

Not only have the foreign companies shipped fewer components internationally, but the Japanese have chosen to automate a greater percentage of their assembly, keeping more of that stage of production at home. Ironically, Philips (Netherlands) picked up assembly plants in Korea and Thailand in 1975 when it acquired Signetics, while Nippon Electric took over a factory in Penang, Malaysia when it purchased Electronic Arrays in 1978.

In general, semiconductor industry is not a classical runaway industry, where firms — textiles and consumer electronics, for example — close plants in one location while opening new facilities in areas where labor is less costly. Domestic semiconductor employment has risen as fast, if not faster, than employment in the foreign subsidiaries of U.S. semiconductor firms. Nevertheless, the capital investment in factory buildings and equipment is so low for labor-intensive semiconductor assembly that runaways can be profitable.

In fact, there have been some plants closed in the U.S. Fairchild closed its Navajo reservation assembly plant, at Shiprock, New Mexico, in 1975,[2] and in the same year it moved a testing facility, employing about 700 workers from South Portland, Maine, to Singapore. From 1975 to 1977 the employees of at least three other major semiconductor firms, Motorola (1800 employees affected), GE (450), and Transitron (350), qualified for Federal "Adjustment Assistance." They were displaced by foreign production of their own companies.[3]

Semiconductor companies can also be "footloose" abroad, but thus far permanent plant shutdowns have been rare, and they are likely to remain so as long as the need for assemblers continues to expand. General Electric, which began assembling transistors in Ireland in 1963, shifted most of its semiconductor assembly to Singapore in 1970. Texas Instruments, though growing by leaps and bounds elsewhere, shut its Curacao (Netherlands Antilles) factory in the early 1970's following labor problems. A number of companies have shifted production from their Mexican border sites.

As the industry has developed, it has refined its international division of labor to cut costs even further. Several companies have established testing and warehousing facilities at selected Asian sites — primarily Singapore and Hong Kong. Fairchild, for instance, moved unskilled assembly operations from Singapore to Indonesia while establishing facilities in Singapore to test and warehouse components assembled in Indonesia, South Korea, Hong Kong, and now the Philippines. Fairchild now employs fewer, but more skilled and better paid, personnel in Singapore than it did in 1974.

As product and production technology change, so does the international division of labor. As U.S. companies switch over production to VLSI (Very Large Scale Integrated) circuits, which require complex, computerized testing, many testing operations are being moved back into the U.S.

CAPTIVE PRODUCERS

Many electronics firms or branches produce semiconductors solely for in-house use. These captive firms include instrument manufacturers such as Tektronix and Hewlett-Packard, communications equipment makers such as Zenith and Western Electric, military systems companies such as Boeing, Hughes, and Watkins Johnson, minicomputer producers such as Data General and Digital Equipment, and other major users of semiconductors, such a General Motors-Delco, Eastman Kodak, and Xerox. Some merchant firms, such as Texas Instruments and Rockwell, also "sell" a substantial portion of their product in-house.

It is difficult to collect data on in-house manufacturers, precisely because transactions are generally private. Usually, captive producers are insulated from the debates on trade and technology that bring merchant semiconductor executives before Congress frequently. And because semiconductor production is generally a small segment of the companies' overall operations, it is seldom written up in company annual reports.

Electronics did print some current data on the integrated circuit production of the six top U.S. manufacturers of mainframe computers, but unfortunately it neglected to mention any of their overseas assembly operations.

Though all major U.S. automakers now use microprocessors in all their cars, only General Motors has developed in-house production capability. Motorola, however, remains the primary supplier of semiconductors to GM, while GM's Delco Division — which reportedly has an assembly plant in Singapore — "second-sources" chips designed by Motorola.

Homework

Despite the cost savings abroad, semiconductor manufacturers have always maintained a share of bonding operations at their U.S. plants. Today an estimated 29% of assembly by U.S.-based firms is conducted within the U.S.[4] There are at least four reasons: First, companies prefer to conduct experimental operations — new products, new processes — near their home bases, where managers and engineers can easily oversee the work. Second, home operations are insulated, relatively, from international transportation strikes, wars, and civil unrest. No one wants to leave all his chips "in one basket," particularly if the basket is South Korea or the Philippines. Third, by Federal law certain military components must be assembled within the U.S.

Fourth, like the Japanese, some American producers are finally finding automated assembly to be cost effective. By utilizing its own technology — the microprocessor — the industry has developed production lines as efficient and flexible (important in a field where products and processes change so rapidly) as the "fast-fingered Malaysian." Furthermore, machines can provide a higher degree of accuracy and cleanliness, critical in maintaining the high yield ratios required for VLSI circuits.[5]

Market analyst Frost & Sullivan predicts that the trend toward automation will continue. It estimates that 39% of the semiconductor assembly by U.S.-based firms will be done in the U.S. by 1989.[6]

But automation does not mean that Asian assembly plants will be closed. For most products, it is still cost-effective to install automated bonders abroad, paying Asian workers extremely low wages. "Automated" equipment does not totally eliminate the need for operators, and the work does not require extensive training. Demand for advanced assembly equipment is growing so rapidly in Asia that Kulicke and Soffa, the leading maker of automatic bonders, more than doubled the size of its Hong Kong facilities in 1980.

Wafers Go International

As the demand for semiconductors grew, semiconductor firms established duplicate wafer fabrication facilities. As discussed in chapter two, these new domestic plants have helped companies avoid the congestion in Silicon Valley. Furthermore, as with assembly, no one wants to put all his wafers "in one basket." When National shut its Danbury, Connecticut plant, due to chemical leaks in 1978, and when volcanic ash forced Intel to suspend production at Aloha, Oregon in 1980, both firms could keep producing at other locations.

The demand for new wafer fabrication capacity has prompted several American semiconductor firms to go to Europe, where they can escape the 17% tariff on semiconductors by producing inside the European Community's tariff wall. The most popular areas are in the British Isles — Ireland and the United Kingdom — which provide investment incentives and some of the least expensive labor in Europe, as well as a labor force fluent in English. Among others, National Semiconductor and Motorola have wafer fabrication plants in Scotland, Siliconix in Wales, ITT Semiconductor near London, and Analog Devices and Mostek in Ireland. To avoid tariff costs, most of these facilities also assemble goods intended for Common Market distribution.

Recognizing that they have only a small piece of the wafer, national elites in several Asian countries have embarked on programs to establish their own wafer fabrication:

> In the past, Third World countries built steel mills to improve their economic status, but Mr. Saxton (Siltec executive) said, "Now these same countries want to build silicon wafer plants for the same reason they built steel mills."[7]

Unable to convince semiconductor houses to upgrade their plants to include wafer fabrication, the governments of South Korea and Taiwan, working with local capitalists, have brought in American consultants to establish wafer fabrication. Taiwan's Industrial Technology Research Institute, for example, hired RCA, which has substantial consumer electronics investments on the island, to provide equipment and training for wafer fabrication. Singapore has also encouraged upgrading; in 1980 a new local firm, Nanotek, announced plans to manufacture photolithography masks there.

These new plants may bring prestige and some additional technical training to Asian countries, but unfortunately they resemble the inefficient steel mills that already dot the underdeveloped world. None of these countries have the resources

The Silicon Revolution

Semiconductors, touted as the tool of a "second industrial revolution," actually incorporate revolutionary advances of three types: product technology, production technology, and applications technology.

1. *Product technology.*

The transistor replaced the vacuum tube, in most of its applications, because it was 1) smaller; 2) used less power; 3) was more reliable, and 4) within a few years of its invention, was less expensive. Integrated circuitry, in each of its new generations, has replaced earlier generations of semiconductors because producers continue to make advances in all four areas. There are physical and economic limits, but the industry's scientists and engineers continue tostretch them beyond predictable belief.

In the early 1970's, it appeared that it would be too difficult to adapt large scale integrated circuits to the multiplicity of applications demanded without losing the economic advantages of mass production. In 1973, however, Intel surmounted that problem with the first microprocessor, a programmable integrated circuit. That is a semiconductor that can be easily reprogrammed to carry out specific functions. Even early microprocessors contained more computing power than the original digital computers, for a tiny fraction of the cost, size, and power requirements.

Recently IBM announced that its engineers had placed the entire central processing unit (CPU) of one of its most advanced mainframe companies on a single chip.

Random access memories (RAM's) — computer storage devices — also demonstrate the increasing sophistication of semiconductor circuits. Since Mostek introduced the first 4,096-bit* (4K) RAM in 1973 most major semiconductor firms have been able to quadruple the capacity of their memory chips every two or three years. 64-K RAM's are being produced commercially now, and 256 RAM's are on the drawing board.

None of these advances, however, would have been possible without new production technologies.

2. *Production Technology*

Semiconductors work because microscopic impurities, deliberately introduced into pure silicon, create electric anomalies. When connected, those anomalies act as switches or amplifiers on electronic impulses introduced into the circuit. Accidental impurities — such as dust — can therefore interfere with wafer fabrication, the first major stage of production. Furthermore, the task of etching a photographic design, as complicated as a street map in a major city, onto a chip less than a tenth-of-an-inch square requires unbelievable precision. Design features, now normally 4 microns in width, may soon to reduced to less than 1 micron. Finally, the repeated handling of fragile wafers and miniature chips creates the possibility of damage. Since a damaged chip cannot be salvaged, mistakes toward the end of the production process can be particularly costly.

In overcoming these obstacles, the semiconductor industry and its suppliers have made significant technological advances. Producers of ingots outdo Ivory Soap by promising 99.9999999% pure silicon. Specialized equipment purifies the water used in wafer fabrication. Production workers wear surgical gowns and masks, to protect the wafers from contaminants. When Mt. St. Helens spread volcanic ash throughout the Pacific Northwest in 1980, Intel temporarily closed its Aloha, Oregon plant because the dust affected fabrication operations.

Semiconductor firms and independent suppliers are constantly seeking ways to increase production, reduce defects, and reduce costs. Silicon Valley abounds with independent firms and branches of larger corporations that specialize in semiconductor equipment, from computer-assisted design through final testing.

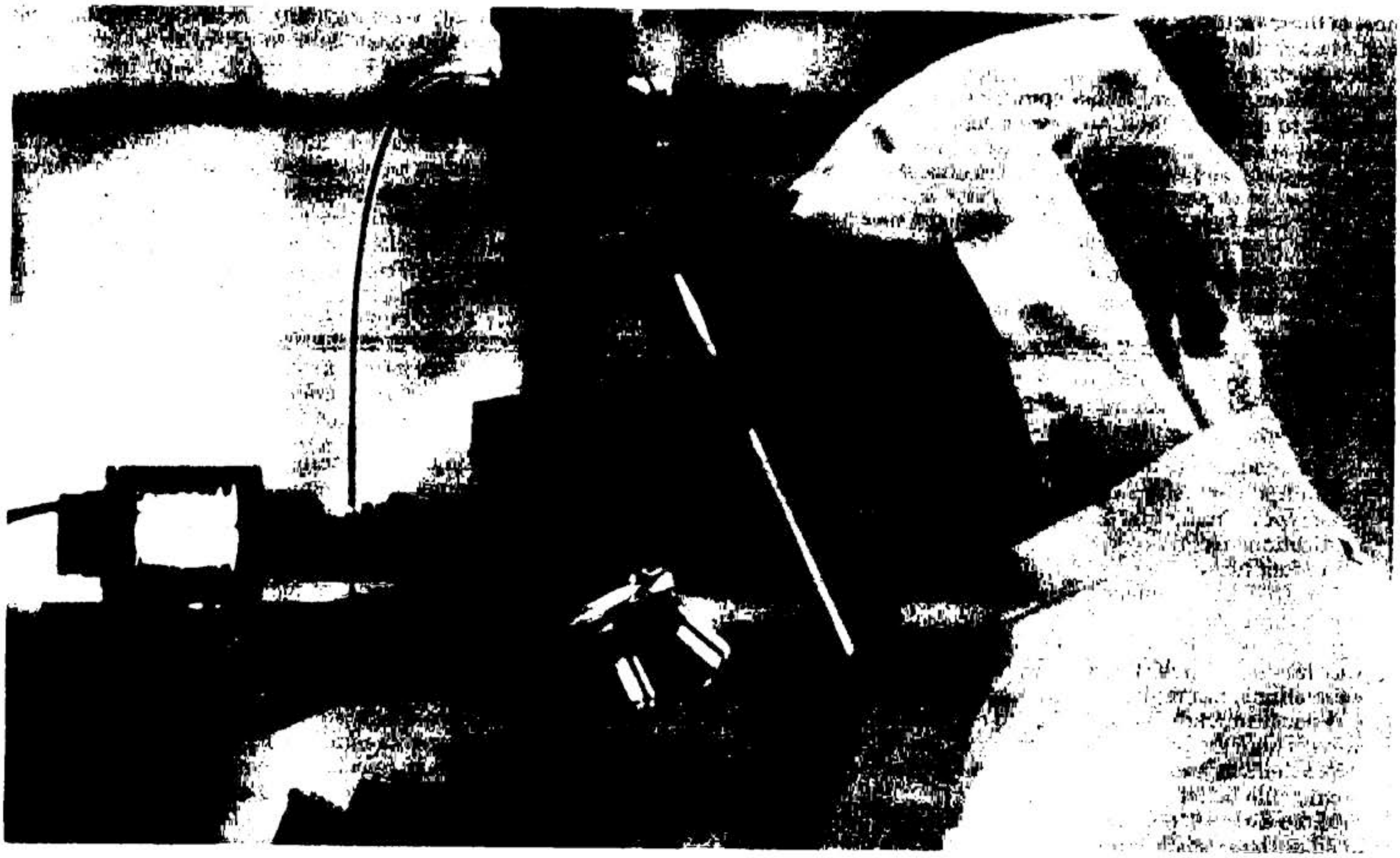
3. *Applications Technology*

Cheap, reliable, and powerful, integrated circuits have not only replaced vacuum tubes, transistors, and analog devices such as old-fashioned calculators, they have opened broad new markets for the electronics industry. Semiconductors are being used in super-fast computers, "smart weapons," digital watches, computer games, telecommunications equipment, industrial controls, and aids for the blind and deaf.

It has been no simple task to incorporate complex circuitry into specialized equipment. It requires knowledge of the circuitry and the application. Furthermore, certain applications have become viable only with the development of related technologies, such as light emitting diodes or liquid crystal displays.

Technically trained salespeople and software designers — programmers — are just as necessary as circuit designers in the growth of semiconductor applications. In fact, while microprocessors themselves have been harnessed to aid the design of integrated circuitry, people are still required to design software. As microprocessors "take over" modern industry, there will be a shortage of the "computer" programmers required to tailor them to the thousands of varied applications.

***A bit is the unit of binary digital storage, capable of storing information coded as a "1" or a "0."**



to compete with the U.S. or Japan in state-of-the-art technologies. (In fact, there is some question whether England and France can compete effectively.)

Their only hope, for now, is to find niches at the lower end of the semiconductor market. A Taiwanese executive said, "...with everybody concentrating on LSI there is a shortage of small-scale types."[8] There is litle realistic chance, however, that these government-backed programs will thrust any "export platform" center for offshore assembly into the race for global technological leadership.

Perhaps even steel mills make more sense as projects to enhance national development. At least poor nations can use the steel. The only major market for semiconductors in less developed East Asia is for assembly into exported electronics goods.

In the long run, it is possible that domestic IC production will fit into rational development plans oriented toward self-sufficiency. Should that happen, the technological infrastructure now being nurtured by South Korea, Taiwan, and other Asiangovernments will prove valuable. The programs, however, are costly, and do not owe their existence to the presence of semiconductor assembly plants.

Assembly subcontractors, however, will continue to grow and provide additional services, especially final testing. Stanford Microsystems, the first assembler of components in the Philippines when founded by a Stanford University graduate in 1972, is today the largest electronics company in the Philippines, and it is growing rapidly. Dynetics, the second largest Philippine subcontractor, has earned a reputation for technological sophistication by maintaining close links with its Silicon Valley area affiliate, Interlek. Dynetics employs 5000 workers in Manila, while Interlek employs only 30 professionals and office workers in San Mateo, California. Both Dynetics and Stanford Microsystems which place full page ads in publications like *Electronic News*, use the most modern automated assembly equipment and maintain sophisticated air and water purification systems.[9]

Subcontractors offer both benefits and additional costs to semiconductor houses. The assembly cost per unit may be twice as high as at wholly owned subsidiaries,[10] and wafer-makers cannot exercise tight control over operations at job shops. On the other hand, the subcontractors allow companies to expand production rapidly without committing capital or enlarging their workforce. It also absolves them of direct responsibility for working conditions.

A Changing Industry

As the market, design, and production technologies for semiconductors continue to change, so does the international structure of production. For instance, increasing air freight costs — due to climbing fuel prices, may make it uneconomic to ship certain components to Asia for assembly, or the increasing value per weight (and volume) of integrated circuitry may make it more economic.

From 1970 to 1973, the average value added through Asian assembly rose as a proportion of the value of the re-imported product, from 44% to 55%. That is, a decreasing share of the cost of production, including wafer fab, assembly, and some testing, was incurred in the U.S. The Commerce Department suggested that rising wage rates abroad, combined with the availabiliy of foreign sub-components such as packaging, were responsible for the shift.[11]

Yet the same measure of foreign value-added fell from 54% in 1976 to 40% in 1978. As the complexity of circuitry increases, wafer fabrication and computerized testing take up a larger share of product value, and these processes are done in the U.S.[12]

But new production technology may reverse the trend once again. Howard Dicken of Integrated Circuit Engineering predicts that the cost per good die, after wafer fabrication (a 16K RAM chip on a four-inch wafer) will fall about $1.17 to about 13 cents with the development of 1.5 micron lithography techniques. That is, the value added in wafer fabrication may be lowered significantly by technologie which squeeze more die onto each wafer.[13]

The dispersion of employment within semiconductor companies also changes over time. The proportion of foreign employees at a given firm varies with the amount of subcontracting, temporary lay-offs, and the introduction of labor-saving equipment either in the U.S. or abroad. Most semiconductor operations employ about half their workforce outside the U.S., but Intel, one of the largest, reports percentages varying from 36% in 1975 to 41% in 1976 and back down to 30% in 1979.[14]

In such a dynamic industry, influenced by so many factors, it is extremely important not to project current trends in global production too far into the future.

Cheap Labor

Semiconductor companies operate Third World assembly plants to save on labor costs. Consequently, in evaluating labor sites, they take into account wage rates, productivity, technical and language skills, and labor militancy.

Wage rates for operatives in most offshore assembly sites are about one tenth (or less) of U.S. pay. Mexico, and now Singapore and Hong Kong, have slightly higher rates.[15] Thus, those operations which require relatively little overhead (management, energy, transportation, etc.) benefit handsomely from offshore assembly. Figures are hard to come by, but the 43% savings (as a share of total production costs) cited for Singapore appears to be a low estimate. Savings were much higher in the early years of offshore manufacturing, when assembly costs represented the major cost of production. Back in 1962, assembly within the U.S. represented some 80% of the total cost of producing transistors.[16]

The industry argues that the availability of low cost Asian labor has actually led to the expansion of semiconductor employment in the U.S. by reducing production costs:

> Because offshore operations helped the U.S. semiconductor industry to offer lower prices and to grow in worldwide sales, they favorably influenced domestic employment. . .[17]

There is no doubt that the continuous lowering of prices has stimulated enormous growth in U.S. semiconductor employment, but cheap labor has taken a back seat to breakthroughs in technology. In the early years of offshore production, cheap labor may have allowed a reduction, but no more than a factor of three, in production costs. Today, with assembly representing perhaps 11 cents on a $6.50 memory chip,[18] even a tenfold increase in total assembly costs would increase prices by only 13%. Meanwhile, the price per function has dropped by as much as a factor of 100,000 in the past fifteen years.

The manufacturers, of course, compare more than wage and benefit rates. They are concerned about the productivity and discipline of the workforce, and they seek to match skill levels to production processes. Thus, U.S. firms have concentrated their more complex processes, such as testing, in sites such as Hong Kong and Singapore with better educated workforces.

In addition, U.S. companies are reluctant to invest resources in language training, either for Asian assemblers or American managers and engineers. Optimally, they seek locations where English is understood by large numbers of workers. This is the major reason why U.S. firms have established more assembly in the Philippines than Thailand and Indonesia, although the investment climate is otherwise similar in all three countries.

Semiconductor manufacturers have closed plants in countries where labor militancy threatened to disturb production. This is why Texas Instruments closed its Curacao facility and other firms shut down their Mexican plants during the 1970's. National Semiconductor's Thai plant, closed by a strike in 1976, re-opened only after a military coup placed an anti-labor government in power. Throughout Asia semiconductor firms flourish in lands where military and other authoritarian regimes keep a tight hand on the labor movement and labor laws are weak.[19]

In general, the semiconductor industry is not a classical runaway industry. . .

Sweeteners

Most centers of offshore manufacturing have active programs designed to attract foreign companies. Mexico, for instance, inaugurated the Border Industrialization Program in 1965, followed by programs to encourage investment in selected interior districts. Malaysia sent an economic mission to Silicon Valley in 1971 and by the end of 1972 twelve American firms were operating in that country. More recently, Sri Lanka's (Ceylon) Greater Colombo Economic Commission has placed ads in the *Wall Street Journal*, *Electronic News*, and other business publications promising an array of economic incentives.

Many locations in Africa, the Caribbean and Latin America attract electronics firms, but only those with the cheapest labor and best investment climate attract semiconductor assembly.[20] Because semiconductors are so inexpensive to ship, companies can select sites wherever conditions are best.

The standard offshore investment package contains a series of special "sweeteners" for foreign investors — at least those engaged in manufacturing for export. Sri Lanka, in big bold type, promises a "100% tax exemption for American business for up to 10 years." Other standard incentives include liberal foreign exchange rules, and the allowance of 100% foreign control.

While companies welcome these concessions, incentives are seldom the chief factor in selecting sites, for several reasons. First, most countries offer similar incentives. Second, U.S. tax laws often require that taxes foregone abroad be paid in the U.S.[21] And third, companies fear that governments — especially when new leadership takes power — will unilaterally remove some of the sweeteners.

More significant, however, are the political stability and bureaucratic efficiency of the host country. Singapore and Malaysia, in particular, have solid reputations in the international business community, while executives consider corruption and red tape the norm in Indonesia and Thailand.

Modern infrastructure — electricity, transportation and communications links, water, sewage and even industrial parks or estates — is perhaps the most important incentive for offshore investment. Many countries — Sri Lanka, for instance — undertake major infrastructure projects to attract export manufacturers and then include them in the package deal offered foreign investors.

Transportation is perhaps the most obvious infrastructure need of offshore assemblers. Wherever regular, reliable air freight operations are available, semiconductor companies can take advantage of low production costs. Without air freight production turnaround times are too long. Thus, most offshore bonding plants are near international airports. In fact, semiconductor firms avoided the Bataan Export Processing Zone, despite the Philippines government's extensive investment there, because of its inadequate transportation links. Instead, they established facilities near the Manila International Airport. Consequently, the Philippines has opened new zones near the airports at Cebu and Baguio City, attracting investments by Fairchild and Texas Instruments.

Semiconductor companies also need reliable, convenient telecommunications links. With production split between interrelated plants around the globe, companies attempt to coordinate their activities closely. Texas Instruments and Fairchild, for instance, have global, satellite-based computer networks to monitor and control production. Even the Dynetics/Interlek subcontracting team maintains daily computer contact, via telex.[22] Some countries, such as Hong Kong and Singapore, offer reliable modern local and international telecommunications. Executives in Indonesia, on the other hand, complain about the length of time it takes to hook up a telephone.

Semiconductor assembly operations not only require electrical power to run production equipment, but their plant-wide air conditioning equipment consumes a great deal of power. Some processes require reliable water supplies, and the disposal of chemicals — such as cleaning solvents — should require modern sewage treatment. All such infrastructure is provided by the host government.

Finally, some countries actually lease factory space to manufacturers eager to begin production. The companies provide the equipment. Singapore, with little land available, actually leases out "flatted factories," sections of multi-story industrial buildings, and provides adjacent high-rise housing for factory workers.[23]

Most successful host nations have combined infrastructure and incentives in "Export Processing Zones," specifically designed to provide a center for export manufacturing such as textiles, toys, and electronics. Not only do the governments provide infrastructure not available in the country as a whole, but generally, they offer more liberal trade, monetary, and tax rules than elsewhere. Some even enforce stricter anti-labor policies in export zones. The Philippines, for instance, maintain a lower minimum wage in the Bataan EPZ than elsewhere in the country.[24]

Nevertheless, the absence of tariffs and other trade restrictions is the chief factor that distinguishes most export processing zones from other factory sites. Thus the term "free trade zone" is nearly synonymous with "export processing zone." Singapore and Hong Kong, however, are essentially free ports, with no trade restrictions. Their export-oriented industrial estates provide the same trade-related advantages available elsewhere. Thus they are not properly considered free trade zones.

Since 1965, nine Asian nations have established a total of 49 export processing zones.[25] China, Thailand, Bangladesh, and Pakistan have zones planned as well.

Asian EPZ's As of May, 1975

	No.of zones	starting date
Hong Kong	9	1965
Taiwan	3	1966
S. Korea	9	1966
Singapore	14	1967
Malaysia	9	1972
India	1	1974
Philippines	2	1975
Sri Lanka	1	1978
Indonesia	1	1978

U.S. Policy

The U.S. government, in many ways, has long promoted export processing by U.S. manufacturers in Asia. Some policies are designed to serve U.S. business in general, while others are specifically tailored to the needs of the offshore manufacturers.

First, the U.S. military, intelligence agencies, and even private foundations have helped install and maintain governments sympathetic to U.S. business. Not only does the U.S. arm right-wing elites to seize power, but it has trained and backed groups of technocratic economists to supervise economic policy. These technocrats, who hold leading government positions in Indonesia, the Philippines, and Malaysia, do not always see eye to eye with other members of national elites, but they have played a key role in creating the conditions for foreign manufacturing investment.[26]

Second, the U.S. and U.S.-dominated international agencies such as the World Bank and Asian Development Bank have helped provide the infrastructure for export manufacturing, including electrical power generating and distribution systems, telecommunications, highways, and ports. For instance, the Asian Development Bank provided $11 million for improvements in the Penang, Malaysia International airport in 1972, just as the Malaysian electronics industry, centered in Penang, was getting started. The Morong nuclear power plant, under construction in the Philippines, is expected to be a major source of power for the nearby Bataan Export Processing Zone. The U.S. Export/Import Bank is providing loans worth more than $600 million to support the project.[27]

More specifically, the U.S. has supported the construction of export processing zones. Funds generated through the U.S. Food for Peace program help build the first Asian free trade zone, at Kaohsiung, Taiwan, in 1966. Subsequently, the United Nations Industrial Development Organization has provided technical assistance to other countries establishing export zones.[28]

Furthermore, the public-private U.S. Overseas Private Investment Corporation insures, among other ventures, offshore investments by U.S. electronics firms. The OPIC program is tailor-made for Asian ventures, for it protects businesses against losses from war, civil unrest, and currency inconvertability. In 1978, for example, OPIC provided coverage for Digital Equipment Corporation's IC plant in Taiwan, Intel's Malaysian operation, and Motorola's South Korea semiconductor facility.[29]

Finally, the U.S. government offers special tariff reductions to companies which export components from the U.S.,process them abroad, and then bring them back into the U.S. Under these provisions, companies pay duties only on the value added abroad. In calculating duties, the government exempts the original export value and any overhead (including research and development) included in the final price. Item 806.30, entered into the U.S. Tariff Schedule in 1956, covers metallic articles, while Item 807, essentially introduced through Customs Court rulings in 1954, and later codified in 1963, covers semiprocessed goods. Though semiconductor firms prefer 807, they utilize 806.30 more than any other U.S. industry.[30]

Semiconductor companies re-imported more goods duty-free than any other industry in 1978. In that year they imported a total value of $1,479 million under 806.30 and 807, $887 million (60%) of which was duty-free.[31]

At a tariff rate of 6%, this represents a noticeable, but not a dramatic cost savings.[32] In 1974, duty saved represented about 2.6% of the total value of the re-imported semiconductors and about 4.7% of the dutiable value (value added abroad). Even measured as a percentage of the duty free value (originally produced in the U.S.), the savings were 6%.[33]

In an economic environment where mere changes in currency values can have a great impact on production costs, it is unlikely that 806.30 and 807 influence many production decisions. Organized labor argues — for all manufacturing industries — that the two provisions are an incentive for U.S. companies to move production from the U.S., for they can do work abroad without paying full duties. The semiconductor industry, on the other hand, suggests that the savings from 806.30 and 807 enables U.S. companies to keep front-end processing, such as testing, in the United States. The exemption, they argue, compensates for lower labor costs abroad. There are certainly examples of both tendencies. But in most cases the savings are so small that labor costs — unskilled, skilled, and professional — easily overshadow the impact of tariff rules.

Notes

1. Commerce Department, pp. 84, 87.
2. American Indian activists occupied the plant, protesting lay-offs that were part of a worldwide cutback. Fairchild never re-opened the factory, blaming the activists, but the occupiers reported finding documents showing that the company planned to close the plant because federal training subsidies were due to expire.
3. "Trade Adjustment Assistance Calendar," U.S. Department of Labor Office of Trade Adjustment Assistance, December 31, 1977.
4. *Northern California Electronics News*, January 7, 1980, citing a 227-page report by Frost & Sullivan, of New York.
5. In a complex chip, assembly takes place after more than $1.00 has been spent producing each die, compared to $.015 for transistors or simple integrated circuits. Thus, each assemblyerror is much costlier in the newer, more sophisticated devices. See Commerce Department, p. 73, citing E.F. Hutton & Co.
6. *Northern California Electronics News*, January 7, 1980.
7. *Electronic News*, September 24, 1979.
8. *Ibid.*, February 18, 1980.
9. "Offshore Subcontractors Boom," *Electronics*, March 29, 1979, features Dynetics. More recently Interlek has spawned a domestic assembly subcontractor, Indy Electronics, at Manteca, 60 miles east of Silicon Valley.
10. See Howard Dicken, "How to Determine the Fair Market Prices for Integrated Circuits," *Defense Electronics*, June, 1980, p. 83.
11. Commerce Department, p. 61.
12. *Ibid*, p. 64; "Import Trends in TSUS Items 806.30 and 807.00," U.S. International Trade Commission Publication 1029, January, 1980.
13. Dicken, p. 83
14. Statement of Robert Noyce before the Subcommittee on International Finance of the Committee on Banking, Housing, and Urban Affairs, United States Senate, January 15, 1980, Intel Corporation, attachment 2.
15. Exact figures vary with currency adjustments and which allowances and benefits are included. In 1979 Rachael Grossman calculated the following figures for monthly wages after two years of employment: Indonesia — U.S. dollars $29.25; Philippines — U.S.$75.00; Malaysia — U.S. $100.00; Hong Kong — $187.00. "Changing Roles of S.E. Asian Women," *Southeast Asia Chronicle (January-February, 1979), Pacific Research* (July-October, 1978) joint issue, p. 10.
16. Commerce Department, p. 76, citing Crowell Weedon & Co., "World Semiconductor Industry," 1973. This figure is actually for 14-lead and 40-lead packages. Savings are reported at only 30% for 18-lead packages. For 1962, see *Electronics*, August 24, 1962, p. 56.
17. W.J. Sanders, III, *Special Duty Treatment or Repeal of Articles Assembled or Fabricated Abroad*, hearings, House Ways and Means Committee, March 24, 1976, p. 39.
18. Dicken, p. 8.
19. Singapore and Malaysia, though not ruled by military dictatorships, restrict labor organizing. Hong Kong, still a British colony, is more tolerant, but many of the labor unions appear more responsive to China's foreign policy aims than the immediate interests of their members.
20. Intel, for instance, just established an assembly plant in Puerto Rico, for the assembly of systems products (minicomputers, etc.), not semiconductor bonding. Puerto Rican wages are higher than those in Asia, but it is cheaper to ship the larger systems products to the U.S. and Europe from Puerto Rico than from Asia.
21. To avoid double-taxation on income, U.S.-based firms are allowed to credit against their U.S. taxes any income tax paid abroad. Thus, in many instances tax savings abroad merely represent lost domestic tax credits.
22. "Offshore Subcontractors Boom"; "Fairchild Streamlines Worldwide Shipping System," *Palo Alto Times*, October 3, 1977, p. 29; "When TI Talks, the Message Moves Fast," *Electronics*, January 17, 1980, p. 102.
23. Linda Lim, "Women Workers in Multinational Corporations: The Case of the Electronics Industry in Malaysia and Singapore" Michigan Occasional Paper No. IX, Fall, 1978.
24. Enrico Paglaban, "Philippines: Workers in the Export Industry," *Pacific Research, March-June, 1978*, p. 16.
25. *Far Eastern Economic Review*, May 18, 1979, p. 77.
26. See, for example, Waldo Bello, "Marcos and the World Bank," *Pacific Research*, September-October, 1976, pp. 8-9.
27. See "500 Mile Island: The Philippine Nuclear Reactor Deal," *Pacific Research*, First Quarter, 1979.
28. See "Free Trade Zones and Industrialization of Asia," AMPO (Tokyo), 1977.
29. OPIC 1978 Annual Report, pp. 33-35.
30. Measured by total value, the auto industry imports more under the provisions, but a much smaller portion of their imports are duty-free (U.S. origin).
31. "Import Trends in TSUS Items 806.30 and 807," tables.
32. As a result of GATT negotiations, U.S. semiconductor tariffs are due to fall to 4.2% by the end of the 1980's.
33. "Special Duty Treatment" hearings, p. 10.

The Asian Story

To many Asian governments —excluding Japan — a strong semiconductor industry is central to the strategy of industrialization through the export of light manufacturing goods. Foreign assemblers employ thousands of Asian workers, they generate foreign exchange for the local economies, and their modern plants and space-age products project an image of advancement.

The semiconductor industry, however, does surprisingly little for its offshore employees or the host economies. Details vary from country to country, but throughout East and Southeast Asia, the industry is creating a wide range of problems, many of which are the necessary result of the export-industrialization strategy.[1]

Roughly 200,000 Asians work in semiconductor plants all along the Eastern rim of Asia. Most of them — more than 90% — are young women. Most do assembly, the bonding of hair-thin wires to semiconductor chips, and the associated packaging. Though the work requires good eyesight and dexterity, little training is required. Women generally achieve peak productivity within a few months. Even operating the new, "automated" bonding machines requires little education or background.

The industry, from Bangkok to Seoul, has a consistent hiring policy. While men are hired to perform most technical and managerial tasks, women are employed in assembly. Managers sometimes explain that Asian women have small fingers, and thus are better suited for the work. but the most important reasons are cultural, not physical. Young Asian women are trained to be hardworking, patient and obedient. Those companies that have attempted to use men assemblers have found it difficult to enforce factory discipline.

In most countries, companies only hire unmarried women, of specific ages.[2] The workforce, therefore, ranges in age from about 16 to 26. By avoiding the employment of married women except during times of severe labor shortages, companies avoid paying maternity benefits and ensure that an employee's primary loyalty will be to the company, not to her family or household.

More important, by hiring young women, employers can get away with low wages and poor working conditions. In most cases, women assemblers are not heads of households. They are expected to supplement family incomes, even if they are living away from home, but they are not expected to earn enough to support a family by themselves. In the Philippines, for instance, where a starting assembly worker averaged US$34 to US$46 per month at the beginning of 1979, monthly expenses — for a woman renting a bunk in a dormitory or rooming house — were typically $37 per month. Experienced workers, however, could send more to their families, for the average wage was about US$75 per month for workers after two years continuous employment.[2]

Because women are expected to drop out of the laborforce when they reach their mid-twenties, employers do not worry about the long-term health impact of semiconductor work — such as deteriorating eyesight from constant microscope work. Furthermore, they are less hesitant to lay off women than men during slow periods, because Asian cultures consider women's income supplemental, although this is frequently not the case.[3]

Employers use both the carrot and stick to heighten production while keeping labor costs low. Women are offered pay bonuses for good attendance or speedy production. Many companies offer prizes — from cosmetics to trips to the U.S. — to their most productive workers. Most assemblers work harder to win the prizes, or collect bonuses, but few reap the rewards. Typically, when companies achieve higher production rates through the bonus system, they establish new production quotas, slightly higher. They thus ensure that productivity will increase and that they will never have to pay production bonuses to the entire workforce.

Supervisors closely monitor the productivity of each worker, sometimes with charts displayed in the production area. Assemblers who make repeated mistakes or do not meet production quotas are fired. Since male supervisors hold enormous leverage over their employees, workers report that they sometimes demand sexual favors as a condition for continued employment or advancement. In Singapore, if a fired worker is a Malaysian in the country on a work permit, she is deported. At some locations, companies refuse — except during severe labor shortages — to hire women who resign from or are fired by competitors.[4]

Foreign employers have developed sophisticated programs to make their workers loyal and competitive. They publish company newsletters and sponsor cultural programs, including picnics, films, sewing classes, libraries, formal dances, and even beauty contests. In Penang, representatives of various U.S.-owned firms compete to be Miss Free Trade Zone. The Japanese, specialists in corporate loyalty at home, emphasize athletic programs at their overseas plants. Dynetics, 75% -Filipino-owned, sponsors yoga classes for the stated purpose of improving productivity.[5]

To encourage loyalty, many employers provide distinctive uniforms or T-shirts with corporate emblems. Supervisors and production area banners exhort workers to outproduce other companies, other branches of the same company, and even co-workers. Though workers barely have enough money to subsist or to visit their families, some companies encourage the purchase of U.S. cosmetics by providing company stores and beauty classes. They thus hope that the glamor of modernity will rub off onto the workers.

Workers are frequently required to work overtime, yet the pay structure penalizes them. Many governments "require" time and a half for overtime, but that only applies to basic pay. Since much of a worker's paycheck is in bonuses or "living allowances," the actual rate for overtime is below normal pay!

Work is tedious and stressful. It requires intense concentration and pinpoint accuracy, constant coordination of hands, feet, and eyes — sitting in an arched position all day — and rapid movement. Microscopes, especially when used all day six days a week, can cause dizziness, eyestrain, and tension, as well as deteriorating vision. Few scientific studies have been done on the impact of scope work on Asian assemblers, but women who must have 20/20 vision to be hired usually end up wearing glasses after a few years. In Hong Kong, most assemblers over age 25 are called "Grandma," because they wear glasses.

Dr. Son Jun-Kyung, head of the Opthamology Department at Paik Hospital in Seoul, South Korea, conducted examinations in the mid-seventies on 64 women employed by three American microelectronics plants. Forty-seven percent suffered from near-sightedness conditions caused by long hours of concentrated eye-work on small objects and 19% from astigmatism. In addition, 88% had chronic conjunctivitis — eye inflammation — apparently caused by presence of toxic gases or dust in the factories.[6]

Assembly operations do not use as many chemicals as wafer fab plants, but workers must still contend with epoxies, solvents such as TCE, xylene, and methyl ethyl ketone, and metallic fumes from lead, zinc, and cadmium. Workers complain of rashes, headaches, and stomach problems, but governments are reluctant, and often incapable, of regulating such toxic substances. Some companies provide protective masks, but workers generally reject the protective equipment because it is uncomfortable and slows them down when they are supposed to be speeding up.

With a good portion of their pay going to support other members of their families, poorly paid assemblers live in inferior housing, be it with families an hour's commute away, in private rooming houses, or company-run dormitories. Singapore's industrial estates are planned to include housing for production workers. In a typical rooming house or dorm, four to six women share a room 12 feet by 15 feet or smaller. Overcrowding may be no worse than conditions at home, but hostel life lacks the continuity of family relations. Women have no say in choosing their roommates, even when they must share their bunkspace with women on other shifts.

Companies offer litle or no training which is transferable to other industries. In some countries — Taiwan, for example — thrifty workers can afford to attend school while working, but learning is difficult when you also work 48 hours or more each week over a microscope. In addition, many assembly operations, making full use of their equipment by running three shifts daily, require that women work rotating shifts — two weeks at night, then two weeks during the day. In those circumstances it is impossible to attend regular classes.

Though companies demand hard work and loyaly from their employees, most are quick to retrench them during slack periods. Electronics companies in Singapore laid off 15,000 workers during the recession of 1974-75.[7] Such lay-offs have provoked worker protests in most countries, and a few governments actually require severance pay. Singapore, however, merely deports Malaysian guest workers.[8]

Why then, do Asian women flock to semiconductor companies. In general, their families need the money, particularly since male unemployment is high in most Asian countries. National agricultural development plans may be helping some rich farmers, but they are forcing many poor peasants off their land into the wage-labor force. Though pay is roughly comparable to other industries, many women choose electronics because they are impressed by the air conditioning and apparent cleanliness of the factories, as well as the modernity of the products. They see assembly work as a way to find some independence from their authoritarian villages or families, as a chance to modernize or Westernize.

But conditions frequently are so bad the Asian women rebel. In Malaysia, an entire factory occasionally must close for hours or even days when the night shift is "possessed by spirits." Mass hysteria, marked by weeping, speaking in strange voices, and writhing on the factory floor, is an involuntary and socially acceptable reaction to factory pressures.

Though unions are usually controlled — or forbidden — by local governments, deteriorating conditions or inadequate wages have caused workers to strike spontaneously, organize independent unions, or take over union organizations. In 1973 Penang workers staged a general strike when companies did not provide a government-recommended pay allowance. Workers at Signetics, Korea staged a sit-in in the company cafeteria in 1977 while slowing down production. This action, in face of a government ban on strikes, won a 23% wage increase. In both 1978 and 1979, Fairchild's Hong Kong assemblers struck for — and got — higher pay.

Such victories are short-lived, for employers carry out

sophisticated anti-union strategies which include the firing of union militants, the buying off of union leadership, and the creation of alternative channels of communications such as Fairchild Hong Kong's Joint Consultation Committee, established after the 1979 strike.

Most Asian countries do have labor laws and even have bureaucracies for enforcing them. Though these agencies are generally ineffective, most companies abide by the legal minimum wage.[9] Singapore, carrying out its policy of upgrading its role in the international division of labor, has gradually been raising its wage levels. But the Marcos government, in the Philippines, recently decreed a minimum wage increase well below the rise in the cost of living. Technocrats in the government argued that any larger increase would make the Philippines less competitive with other Asian countries and would thus cause widespread lay-offs.[10]

Whether through lay-offs, bad eyesight, or tradition, women in their mid-twenties stop working in semiconductor assembly. Many, of course, get married and return to their traditional urban and rural roles. But a large number are not able to marry, or are pressured by their families to stay in the wage labor force to keep the paychecks coming. By the time they are thirty, many of these women are social outcasts. With poor eyesight, they are not easily employed. With new values and an affinity for western clothes — Levi's, miniskirts — and rock music, which is piped into many of the electronics factories, they cannot easily return to rural villages.

> . . .the traditional society does not provide a social role for the growing numbers of unmarried women past customary marriage age, and it is likely they will continue to pass their personal lives isolated and hidden in dormitories and rented rooms, but continually subject to social censure.[11]

Some observers, including a few employers, have suggested that bringing rural women from authoritarian village life into modern wage labor may be a springboard for their liberation. But employers, in their attempt to control and exploit the workers, either reinforce the authoritarian culture — with managers acting as father figures — or supplant it with an alien but likewise authoritarian organization.

Any liberation imposed from abroad in direct conflict with traditional values can backfire. The Malaysian Moslems who condemn the short dresses of women from their villages who migrate to urban factories resemble their Iranian brethren. Their distaste for foreign dominance could lead, at some point, to a sharp curtailment of the superficial personal freedoms enjoyed by many Malaysian women.

It is also possible that the proletarianization of Asian women may force them, like American mill women a century earlier, to organize for social change. Thus far collective action has been defensive and short-lived.

Therefore, while young Asian women get some spare change and a new vision of life from their factory lives, the benefits are minimal. They undergo intense exploitation for a few years; then they return to society — if accepted — with little to show except eyeglasses.

This is not because governments and companies are hostile to the workers, but neither is it accidenal. It is because the entire strategy of offshore assembly and export industrialization defines employees as short-term cheap labor. Workers are not expected to earn enough to consume the products that they make. They must be docile and productive, or their employers will move elsewhere.

National Goals

Asian governments encourage offshore assembly in pursuit of a number of national goals: increased employment, improved technological capability, and the generation of foreign exchange head the list. Those benefits, however, are largely illusory, while the social and environmental costs are significant.

Opening the doors to semiconductor assembly can provide a country with a large number of jobs quickly. Three years after National Semiconductor opened its first Malaysian assembly plant, Malaysian semiconductor employment exceeded 18,000. However, in all countries but city-states Singapore and Hong Kong, this is merely a drop in the workforce bucket.

Indirect employment benefits are limited, since the foreign semiconductor companies supply most of the materials, components, equipment, and technology. The construction of industrial infrastructure provides jobs, but those are paid for from national funds — either taxes or national debt. Furthermore, since semiconductor workers are paid wages near subsistence, their spending generates little secondary employment.

This last point distinguishes export-oriented manufacturing from balanced economic development. In the U.S., for instance, Henry Ford decades ago paid his workers $5 a day so they could buy the product of their labor. Money recirculated within the economy, constantly creating larger markets. In Asia, today, however, workers paid $5 a day or less will not be paid enough to establish any market for manufactured goods.

More important, offshore assembly does little to reduce unemployment even when it provides thousands of jobs. Companies do not hire the unemployed. Instead, they recruit new workers into the wage workforce, sending teams into the countryside to sign up young peasant women. In Penang, for instance, two thirds to four fifths of the workers are new entrants into the labor force.[12]

The foreign exhange benefits are likewise limited.[13] Since equipment, supplies, unassembled chips, and technology are all imported. Only the meager wages of assembly workers stay in the host country. Since most assembly operations are wholly owned by foreign semiconductor firms, profits are generally repatriated. Countries get little exchange from taxes, since they provide tax holidays and other exemptions to both foreign assemblers and locally owned subcontractors. Even in Singapore, where many tax holidays have expired, companies are offered new holidays as long as they upgrade their technology.[14]

Offshore production can also create cultural conflict. Bringing women into the workforce while men are unemployed creates social tension. The Western life-styles promoted by beauty contests and rock Muzak divide peasant women workers from their conservative communities. One need not con-

Major Steps in Semiconductor Manufacturing

Semiconductor manufacture begins with the growing of a crystal of pure silicon. The silicon producer, usually a chemical company, supplies the silicon to the semiconductor house either as a solid ingot or already sawn into thin (.5 mm) *wafers*, normally 4" in diameter.

Meanwhile, at the semiconductor manufacturer, designers create a succession of patterns, or *masks*, to permit the introduction of precise "impurities," such as arsine, diborane, and phosphine, into the silicon wafer. The patterns are etched on the silicon through a photolithographic process, involving a series of chemicals such as photo-resist, acids, and solvents, and the impurities are either baked on, in a 1000 degree (C.) furnace, or implanted in an electrical field. The features of the etched patterns are typically 4 microns (.000004) meters in width.

Each wafer is designed to contain some 1500 simple circuits (.07" square) or about 300 complex circuits, such as memory chips. Each circuit, or *die*, is then checked in a computerized testing device. Defective die are marked for eventual discard. On some product lines, *yields* of far less than 50 percent good die are commonplace.

The wafers are cut into individual die, and the good ones are mounted in epoxy or ceramic packages. Assemblers, using either microscopes or machines incorporating videoscreens as well as microscopes, bond hairlike alumninum or gold wires to the die and package.

Finally, the completed chip is tested once again for shipping to the customer, who normally "stuffs" it into printed circuit board assemblies to make a final product.

sider either traditional or industrial values as superior to recognize that changes introduced from abroad are fuel for a social explosion.

The political impact is particularly clear in South Korea, Taiwan, and the Philippines. Semiconductor companies would perhaps prefer not to have dictatorial governments in those countries, but authoritarian rule is absolutely necessary to hold wages down to the level that will attract foreign investment. Indepenent workers organizations — such as the pro-worker urban Industrial Mission in Yong Dong Po, Seoul — are consistently the first victims of the periodic government crackdowns in those countries. Singapore is perhaps more democratic or pluralistic than its militaristic neighbors, yet it has suppressed worker-student demonstrations against lay-offs in the electronics industry.

Semiconductor assembly can be as dirty as wafer fabrication. The same chemicals that endanger workers in the plants endanger the surrounding environment, despite tight regulations and modern sewage facilities, wholesale pollution is even more likely in the laxer regulatory environment of Asia.

In all arenas — economic, cutural, political and environmental — it is difficult to tailor the needs of the semiconductor industry to Asian needs. The host country is dependent upon the multinational corporations to provide market, technology, and capital. If U.S. semiconductor consumption slows down, if new technologies reduce the need for labor, or if wages get too high, the companies can reduce employment or shut down entirely and move elsewhere. In fact, National Semiconductor laid off one quarter of its Singapore workforce in 1974 while hiring at its nearby Malacca, Malaysia plant, which paid substantially lower wages and still qualified for tax breaks National offered Malaysian guest workers at its Singapore plant the opportunity to transfer to the Malacca plant and its older facility in Penang.[15]

In 1970 and 1974-5 the worldwide semiconductor industry underwent massive cyclical cutbacks. Though the industry has barely been scratched by the 1980 recession, growth cannot continue uninterrupted indefinitely. Countries hosting semiconductor production were hit by thousands of lay-offs in past recessions and they will suffer again during future semiconductor downturns because there is no way to re-orient production for domestic or third-country markets — as in textiles or food production.

Multinational electronics corporations, with international labor strategies, make decisions about hiring and firing, during periods of expansion as well as recessions. Business is growing so rapidly now that it is unlikely that any successful company will furlough large numbers of workers from any offshore facility, but it is likely that they will use the next slowdown to shift employment priorities and shake off "dead weight." For instance, several companies used the 1975 recession to retrench assembly workers from Singapore plants as part of their new international divisions of labor.

The host society — represented by the government or by workers' organizaions — has little leverage, even if it wishes to take on a multinational. Too much regulation, not enough subsidies, or tolerance of strikes may merely cause employers to close up shop. Threats to impound machinery — a policy in Mexico — are largely ineffective, because most assembly companies have relatively small investments in equipment.

Proponents of export industrialization argue that countries are better off with assembly plants than without them, even if one acknowledges the problems. But this is not the only alternative. The resources used to provide infrastructure, the skilled and professional personnel, and vast reserves of human labor could be mobilized for economic development plans based upon relative self-sufficiency and the home market.

In working toward that alternative, host countries need not close down assembly plants. Rather, they can stop giving export-oriented factories favored treatment. Those firms that provide decent wages, respect the environment, pay taxes, and contribute to balanced economic development, will remain.

Though companies demand hard work and loyalty from their employees, most are quick to retrench them during slack periods.

Notes

1. See, for example, the studies cited above by Grossman, Lim, and Paglaban, as well as Linda Gail Arrigo, "The Industrial Work force of Young Women in Taiwan," *Bulletin of Concerned Asian Scholars*, April-June, 1980. Conditions in Mexico are remarkably similar. See "Hit and Run: U.S. Runaway Shops on the Mexican Border," and "Electronics: The Global Industry," in *NACLA's Latin America and Empire Report*, July-August, 1975 and April, 1977, respectively.
2. Grossman, p. 10.
3. see Lim, p. 20.
4. *ibid.*, p. 16.
5. Paglaban, p. 21, cites a company newsletter.
6. Walter B. Watson, "Memorandum: Eyestrain Suffered by Women Factory Workers."
7. Hewlett-Packard was a notable exception. As in the U.S., it reduced its workweek rather than retrench workers.
8. Singapore's relatively successful application of the export industrialization strategy hinges directly on the fact that it has no hinterlands. By admitting and deporting guest workers it can exploit a reserve of industrial labor without bearing the social costs of unemployment.
9. It is a common practice, however, to keep workers on as trainees, who in most countries are subject to a slightly lower minimum wage. Paglaban, p. 19, describes a worker who was laid off and rehired two weeks later as a "casual."
10. *Far Eastern Economic Review*, August 22, 1980.
11. Arrigo, p. 34.
12. Lim, p. 30, cites two separate studies.
13. The value of foreign exchange itself may be questioned. In most Asian countries substantial sums are spent on foreign luxury goods, from white bread to refrigerators. Needless to say, the "benefits" of foreign earnings do not necessarily trickle down.
14. Lim, p. 9.
15. *Far Eastern Economic Review*, August 23, 1974, p. 51.

The Impact At Home

Workers in the domestic half of the U.S. semiconductor industry can be lumped into two major categories. Professionals and technicians, in short supply, can command high pay, a stimulating work environment, and unusual benefits. To entice engineers from other parts of the nation and the world, Silicon Valley companies offer substantial housing bonuses to help new employees overcome the high cost of living in the San Francisco Bay Area. Billboard, radio, and TV ads — AMD, whose slogan is "Catch the Wave," shows a young professional surfing — as well as bounties to employees and professional "headhunters" for finding new employees, are designed to attract specialists from other electronics firms. Corporations not only tout their technical leadership, but the availability of on-site recreational facilities and showers for joggers and tennis players.

To the casual observer — and all too many journalists — this is the image of the ultra-modern semiconductor industry in the U.S. But in reality, production assembly workers share little of the dream. As in Asia, companies prefer women workers for most semi-skilled tasks, including wafer fabrication and assembly. In fact, most of the managers, engineers, scientists, technicians, and marketing people are men, while nearly all clerical workers and 91% of the assemblers, processing workers, and inspectors are women.[1]

Within the least skilled job categories, such as assembly, minority groups and immigrants — Mexican-Americans, Filipinos, Azoreans, Indochinese, Koreans, etc. — make up about half of the workforce. In fact, some Silicon Valley companies hire Vietnamese "off the boat," working closely with resettlement agencies.

Hazardous chemicals are not only risky to workers, but to surrounding communities.

Companies hire women and minority production workers to minimize production costs. Though many women workers have families to support, the cultural image of women working for "pin money" still holds sway. Women workers, particularly those who have arrived recently from less affluent, more authoritarian societies, are less likely to agitate for higher wages or join the unions which are likely to eventually organize the industry.[2]

Ironically, the high cost of housing in Silicon Valley — caused by the influx of well-paid electronics professionals — is forcing many married women to work to help pay rent or make house payments. Between recent arrivals from Mexico and the Far East and new or temporary entrants into the Silicon Valley workforce, the industry has avoided shortages of unskilled workers. In other regions, finding new production workers is even less of a problem.

While severe competition leads merchant companies to offer low wages and to fight unionization attempts, firms cooperate closely in the area of labor relations. The American Electronics Association conducts regular surveys of pay rates among member companies and it sponsors seminars on blocking union organizing efforts. It is even possible that companies have an informal agreement not to use higher pay in their competition for production workers.

Companies oppose unions for reasons other than wages. Managers do not want workers' representatives telling them how to run the business. Without unions, companies are free to hire, fire, and re-assign workers as they please. Unions would demand improved working conditions, and they would back workers with specific grievances. In the rapidly changing, competitive merchant segment of the semiconductor industry, executives consider these to be unacceptable costs.

Unhappy employees therefore must quit if they don't like their pay or conditions, and turnover among employees remains high. Most employers accept turnover, however, for training for most tasks is minimal and pay is even lower for new employees. Some employers actually hire through temporary employment agencies. With the workforce constantly changing, union organizing is particularly difficult. Those unions that have qualified for representation elections — by submitting cards signed by half the workers in a bargaining unit — have lost critical votes when employees quit before the elections.

As in Asia, working conditions do not match the image. Even ultra-clean production rooms can contain toxic fumes. Organic solvents, acids such as hydrofluoric, metallic carcinogens, epoxies, photoresist chemicals, and deadly poisons such as cyanide and arsenic cause short-term problems such as headaches, dizziness, nausea, rashes, and eye problems. In the long run they contribute to disabling allergies, liver disease, heart disease, cancer, and birth defects.[3]

In the constantly innovating semiconductor industry, new chemicals are introduced long before health agencies can test them. When government reports or agitation by workers cause companies to drop a toxic chemical — trichloroethylene, for instance — other, less tested chemicals are substituted.

In most semiconductor companies semi-skilled workers are considered replaceable. Job hazards, often worsened by sped-up production, are acceptable risks. Growing pressure from workers groups and the U.S. government may lead to a gradual clean-up, of some dangerous materials, but as long as workers have no job security it will remain risky — financially — to complain.

Hazardous chemicals are not only risky to workers, but to surrounding communities. In 1978, fish in Stevens Creek were killed by chemicals reportedly spilled into storm drains by Fairchild Semiconductor in Mountain View. In 1979, investigators found cyanide waste at the Sunnyvale dump, in the heart of Silicon Valley. And Santa Clara County health officials in 1980 reported traces of TCE in Silicon Valley ground water. Companies are required to control the use and dumping of toxic chemicals, but many are careless. National Semiconductor allegedly disrupted the entire San Jose sewage plant in August, 1980 by releasing excess lime — a chemical supposed to aid the treatment of chemical effluents — into the sewage system.[4]

These conditions, of course, are not the direct result of overseas operations. Many, in fact, may be resolved as the industry and the agencies which regulate it mature. But the international division of semiconductor labor has slowed down regulation and unionization. Regulators and prospective union members have been reluctant to impose conditions on industry which would cause them to close their U.S. plants or shift additional production abroad.

This threat, rarely made explicitly by corporate managers, is usually hollow. Manufacturers have already moved abroad those tasks which they could move easily. Furthermore, if domestic plants were closed by strikes or by regulatory injunction, there is nothing that the assembly plants abroad could do to maintain production.

The complaint, by U.S. organized labor, that offshore production in general — garments, textiles, consumer electronics, toys, etc. — has caused a decline in U.S. employment is simply not true in the case of the semiconductor industry, at least when measured in isolation. U.S. semiconductor employment has risen from virtually nothing in the 1950's to 222,000 in June, 1980.

But the semiconductor industry has displaced workers in other industries which either produced electrical equipment — such as auto ignitions, vacuum tubes[5] — or apply electronic technology — such as machine tool work and bookkeeping. Depending upon how wide one casts the net, one can argue that semiconductors have added or removed thousands of workers from America's payroll.

Since the threat of Japanese competition is new, it is clear that American companies did not need to run to Asia or Mexico to stay in business or to maintain U.S. employment. They ran to Asia to lower costs, to compete among themselves. While the resulting lower prices helped enlarge the market for semiconductors, they have had only a marginal impact. Technology, as we have seen above, has been the driving force behind price reduction.

The U.S. semiconductor industry, with different priorities, could employ more workers in the U.S., even if it automated much of the work normally done overseas. But companies argue that they employ more domestic workers than necessary to supply the domestic market. The U.S. consistently has a positive semiconductor trade surplus of $150 million or more each year.

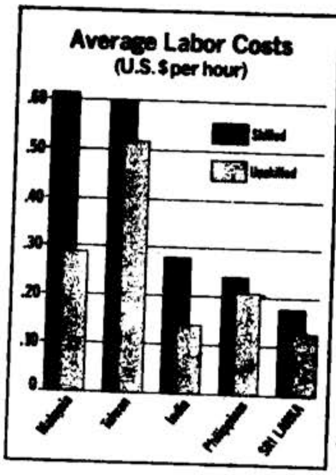
While the domestic semiconductor workforce is growing, the percentage of production workers is falling. The U.S. Labor Department currently classifies only 44% of the industry's employment as production workers. Most production employment, after all, is located at offshore assembly plants. Is this a denial of opportunity for less educated workers in the U.S., or does it mean that American workers are being given the opportunity to undertake more exciting, challenging work?

The debate can go on and on. *What if* the semiconductor companies had never established offshore assembly? Would that have provided semi-skilled job opportunities? Or would assembly have been further automated?

It's best to avoid such hypothetical questions. It is more valuable to determine what can be done to improve industry conditions given the existing international structure.

Notes

1. *Industry Wage Survey*, p. 7.
2. Many plants in the Northeast U.S. are already represented by unions.
3. For further information, contact the Project on Health and Safety in Electronics, 655 Castro St., No. 3, Mountain View, CA 94041, U.S.A.
4. Traces of valuable metals, such as gold and silver, are also flushed into local sewage systems. So rich is the sludge at the Northern Santa Clara County treatment plant in Palo Alto that the city is "mining" the sewage — profitably.
5. *Employment and Earnings* reports that U.S. electronic tube employment dropped from nearly 78,000 in 1966 to 45,500 in 1980. Some production may have moved abroad, but the segment has clearly not grown with the electronics industry as a whole.



Sri Lanka advertises its low wages in U.S. business publications.

Courtesy of Intel

The Japanese Challenge

For three decades, U.S.-based companies have dominated the worldwide semiconductor industry. Playing on public awareness of Japanese consumer electronics and automotive exports, U.S. semiconductor techno-entrepreneurs have recently conjured up a new threat; the Japanese challenge to American dominance in semiconductors. Jerry Sanders, head of Advanced Micro Devices and spokesman for the Semiconductor Industry Association (SIA) warned the U.S. International Trade Commission:

> If we are unable to maintain a technological superiority in the semiconductor field, we could soon find ourselves dependent on foreign sources for the electronics necessary for defense and communications systems — at risks and costs comparable to our present dependence on foreign sources of energy.[1]

How Serious?

How serious is the Japanese challenge? There is no doubt that the Japanese are catching up in certain areas of semiconductor technology. Japanese firms grabbed 42% of the U.S. market for 16-K random access memory chips in 1979. But United States firms still exported more semiconductors (about $380 million worth) to Japan than the Japanese shipped to the U.S. (about $270 worth).[2] In fact, Japanese IC exports exceeded imports for the first time in 1979, and by less than $25 million.[3]

The U.S. producers' share of the world semiconductor market has been falling, from 88% in 1963 to 63% in 1977.[4] But their sales have been growing rapidly nevertheless. The relative decline is merely a result of more rapid growth in the use and production of semiconductors in Japan and Europe, which got a later start. The U.S. industry still maintains a positive trade balance, which totalled $179 million in 1979 despite the hundreds of millions of dollars ($592 million in 1978) in net imports from U.S.-run offshore assembly plants.[5]

Some U.S. industry spokesmen suggest that Japanese success in the 16-K RAM market portends sharper competition in other segments of the market. Their warnings are exagerrated, for the Japanese lag significantly in microprocessor development, where design technology and programming are more important. Nevertheless, the Japanese semiconductor industry represents at least a potential challenge to American technological leadership, particularly if U.S. innovation declines.

Why are the Japanese such effective competitors?

The Japan scare in semiconductors began in 1976, when the Japanese government — the Ministry of International Trade and Industry — announced it was funding a consortium of five top Japanese electronics firms to research VLSI (very large scale integrated) circuits, the next generation of chips. MITI put the equivalent of $120 million into the four-year venture. Because the Japanese had quickly dominated other industries previously targeted by MITI, such as consumer electronics and shipbuilding, some American executives were worried.

Noyce of Intel, also speaking for the SIA, told a Senate committee in early 1980:

> Let me emphasize that we cannot allow investment in U.S. industries to be destroyed by the threat which targeting practices pose to free market companies. Our industry is determined to forestall such threats. We ask that Congress share our resolve.[6]

But if government support of semiconductors is unfair, the U.S. government was perhaps more culpable, since it has funded solid-state research for decades, supported the training of engineers on college campuses, and provided critical markets for both transistors and IC's in their early years of production.

The Japanese VISI research program generated several hundred new semiconductor patents, all of which were made available to American as well as Japanese companies,[7] but no spectacular breakthroughs. It did improve the Japanese technological base for further, private research, just as U.S.-funded programs have built the American technological base. Ironically, it provided a major market for U.S. manufacturers of semiconductor production equipment. By late 1977, U.S. companies, including Fairchild, had supplied more than $50 million in equipment to the VLSI program.[8]

The Japanese structure of production differs substantially from the American model, emphasizing corporate loyalty, success, and high quality. While there are cultural penalties for failure thereby discouraging innovative solutions to technological problems — the emphasis on quality pays off in mass production. While U.S. firms emphasize inspection as a means of quality control, the Japanese strive to build it into design and production processes. In fact, this is one of the reasons that the Japanese carry out much less assembly in Southeast Asia — their domestic automated facilities are much less error prone.[9] Though some U.S. manufacturers question Japan's reputation for superior reliability, tests conducted by Hewlett-Packard in 1980 showed that Japanese chips were in fact more reliable.

The structure of Japanese capitalism, as a whole, varies substantially from the U.S. model. Japanese electronics companies — as well as other industries — are members of industrial/financial groups that descend from the pre-World War II *Zaibatsu* monoliths. Each industrial group, in turn, is closely linked to MITI and government financial institutions. This integrated structure, colloquially known in the West as "Japan, Inc.," means that companies have relatively little independence. If the leaders of government and the private sector decide that a particular industry will be phased down — garments, for instance — individual companies have no power to resist. On the other hand, if the national leadership targets the industry for growth, then companies can count on support during times of trouble.

Instead of relying on equity financing — stock sales — Japanese companies obtain most of their funds from associated banks. As long as the industry is targeted, they can count on financing their expansion without fear of being bankrupted by high loan payments during marketing lulls. In contrast, the independent American companies are reluctant to borrow heavily for fear of being burdened with high fixed payments during slow periods, as in 1975.

This is the major reason that the Japanese took such a large share of the 16K RAM market in the U.S. America-based firms were unwilling to expand rapidly, so a shortage occurred. The Japanese, however, were prepared to commit their capital, so not only did they pick up a large chunk of the open market, but they ended up supplying American semiconductor companies such as National, which needed the chips for its computer systems.

Sales Barriers?

The Japanese structure of production differs substantially from the American model, emphasizing corporate loyalty, success, and high quality.

Critics of Japan charged that Japan excludes U.S. semiconductor chips formally and informally. Through 1979, Japan imposed a 12% duty on semiconductor imports, compared to 6% by the U.S. This is a legitimate tool for a government wishing to protect a weak industry. However the Japanese industry is no longer in infancy. Thus, when the multilateral trade negotiations considered semiconductors in 1979, the U.S. industry was able to pressure for a gradual equalization of U.S. and Japanese duties, scheduled to reach 4.2% in 1987. European tariffs, however, will reamin at 17%.

But American companies still have trouble selling as much as they would like in Japan. They charge that the Japanese — from a homogeneous society — choose to buy Japanese products even when U.S. goods are cheaper or better. The Japanese, on the other hand, suggest that American companies have not put much effort into marketing in Japan — learning the language, business culture, etc. Both are correct. The most successful American exporters are those which have teamed up with Japanese partners.

Some American firms also charge that the Japanese, unlike the Europeans, restrict American manufacturing investment in Japan. Although IBM has recently announced plans to make memory chips in Japan, and Motorola is exploring the possibility, thus far Texas Instruments is the only U.S.-based semiconductor firm with production facilities in Japan. TI won permission in 1968, reportedly only after it threatened to deny licenses to Japanese firms that produced circuits which were exported to the U.S., either as components or assembled into electrical equipment.[10]

Though Japan appears to be responding to pressure to open its doors to foreign investment, this charge is basically accurate. While the U.S. used the Marshall Plan to open the entire Western European economy to American investment after World War II, it feared the rise of Communism in East Asia sufficiently that it actually encouraged Japanese industrial groups to rebuild, allowing a more protectionist trade and investment policy.

One remaining bone of contention is the demand by U.S.

SEMICONDUCTOR SALES IN TOP THREE WORLD MARKETS

	United States	W. Europe	Japan	Total
		(millions of US$)		
Discrete transistors, diodes)	1137.1	1121.1	841.7	3099.9
Integrated Circuits	364.1	1566.3	1590.0	6840.4
Optoelectronics (displays, solar cells, etc.)	240.5	139.0	283.7	663.2
TOTAL	5061.7	2826.4	2715.4	10603.5

Source: Electronics: January 3, 1980 pp. 135, 147.

firms that Nippon Telephone and Telegraph, a huge quasi-governmental corporation, open its procurement to U.S. companies. The Japanese, however, insist that privately owned AT&T open more of its purchasing to Japanese firms in exchange. though AT&T has no "Buy American" policy, it purchases 80% of its equipment from its own subsidiary, Western Electric.[11]

In fact, the entire structure of captive production complicates the question of international markets, since all major Japanese semiconductor makers are diversified electronics companies. The U.S. companies most concerned about Japanese competition are independents, such as Intel and National, that sell most of their devices on the open market.

The S.I.A. Program

The U.S.-based merchant semiconductor industry formed the Semiconductor Industry Association in 1977 to coordinate and articulate its views on the Japanese challenge. In just three years, it has become a significant force on Capitol Hill. At first the semiconductor companies focused on what they considered unfair Japanese trade practices, and a few spokesmen even suggested that the U.S. be prepared to restrict Japanese imports. Some of those changes, such as high tariffs and the hoarding of VLSI patents, were well founded, so the U.S. was able to win concessions in those areas.

But U.S. companies still call Japanese practices unfair, merely because Japanese capitalism is structured differently. S.I.A. spokesmen do not ask that the U.S. government follow the Japanese model of integrating and assisting leading manufacturers, however. They have developed a program of tax subsidies for the semiconductor industry and its investors, and they are pressing Congress for rapid adoption.

The industry's techno-entrepreneurs do not suggest programs to aid American workers — or increase domestic employment — in fact, they rarely mention that half their own workers are in Asia. They do not suggest programs to build a strong U.S. industry based on the current trend of consolidation. Rather, they seek subsidies so they can make more profits as independent businessmen.

In fact, the Japanese challenge to U.S. semiconductor firms may at this point be a phony issue, drummed up by the industry to extract subsidies from Congress. The same U.S. companies that call for aid against the Japanese are supplying technology and equipment to Japanese semiconductor firms and buying or marketing their products. National Semi, for instance, not only buys Japanese memory chips, it is the U.S. distributor for Hitachi computers.

Nevertheless, the ruckus over Japanese competition has already borne fruit for the U.S. Four major Japanese semiconductor firms have already announced plans to produce memory chips in the U.S., largely because they fear trade quotas or forced "voluntary" restraints. This means more employment in the U.S., but the industry's executives may not view it too favorably. It also means increased competition.

Notes

1. "Semiconductor Industry Association: 1979 Yearbook and Directory," p. 20.
2. *Business Week*, December 3, 1979, p. 85 chart. National Semiconductor estimated in 1976 that Japanese semiconductor exports to the U.S. exceeded U.S. exports to Japan if semiconductors incorporated into finished equipment — computers, radios, etc. — were counted. National estimated $235,380,000 in shipments from Japan to the U.S., opposed to $217,000,000 in shipments from the U.S. to Japan. ("The Japanese Threat: Courteous Destruction," 1978.) (January 17, 1980)
3. *Electronics* reported that the surplus was $20.9 million for the first 11 months.
4. Commerce, p.91.
5. *Electronic News*, May 12, 1980.
6. Noyce, p. 20.
7. *Asia Record*, June, 1980, translated from *Nihon Keizai Shimbun*.
8. *Electronics*, December 22, 1977, p. 60.
9. Dr. A. Ouchi, cited in Campus Report, (Stanford University), October 1, 1980, p. 14.
10. Ironically, exports from Texas Instruments' Japanese plant are counted as part of the Japanese challenge.
11. *Electronic News*, June 9, 1980.

The Eastern Market: Frozen Out By The Cold War

In its fight to dominate the worldwide semiconductor market, the U.S. industry has for years been held back by one of its best friends, the Pentagon. The United States restricts the sale of semiconductor technology and components to Soviet Bloc nations because electronics is an area where the U.S. maintains clear technological leadership over the U.S.S.R. and its allies. Japan and Western Europe, in theory required to restrict the same exports, in fact are able to sell easily to Eastern Europe, called by Lester Hogan of Fairchild in 1974 "the last sizable, commercial market. . . This market, we estimate, will provide billions of dollars of semiconductor sales over the next decade.[1]

President Carter's January, 1980 embargo on high technology exports to the Soviet Union cut to a trickle the flow of U.S. semiconductors to the Soviet Union, but trade has always been difficult. Some U.S. conservatives have attempted to block the shipment of any product of technology of any utility to the Soviets, but the most effective opposition has been from the Pentagon, which has argued that the U.S. leadership in solid-state electronics is a key factor in the arms race.

> What they can't import from U.S. companies, the Soviets and their allies can get elsewhere

There is no doubt that the Soviets, particularly in their civilian equipment, are far behind the U.S., but some sources suggest that they can produce in small quantities nearly anything they want, as long as they're willing to pay the price. Control Data Corporation, having obtained samples from Soviet officials, determined that certain Soviet chips appeared to be close copies of advanced American products.[2]

It may be possible, even for U.S. intelligence agencies, to know how much Soviet military scientists have achieved, but the fear of adding to that has led the complex U.S. bureaucracy for controlling exports to Communist countries to ban certain key sales agreements. Fairchild, for instance, was in 1974 denied permission to sell Poland the technology and equipment to build a plant for manufacturing four-function calculator chips. Fairchild had spent nearly a half million dollars designing the project, selling it to the Poles, and trying to thread it through the U.S. bureaucracy. Despite the fact that the technology was neither "state of the art" nor readily applicable to military use, the export license was denied after 15 months of consideration. Sometime later, Fairchild officials reported that French sources had supplied the necessary equipment.[3]

Ironically, J. Fred Bucy, president of Texas Instruments — the world's top semiconductor supplier — chaired the Defense Science Board task force which recommended changes in U.S. export policy in 1976. Bucy appears to favor more restrictions on semiconductor exports than his smaller competitors, but the key proposal of the so-called Bucy Report was to restrict the

Silicon Age Theft

Thieves, legal and illegal, are also finding the semiconductor industry profitable. Reports of stolen chips, gold, and technology are on the rise.

Because chips are valuable for their size, they are a tempting target. In April, 1980, for instance, the Santa Clara County Sheriff's organized crime unit arrested executives of two small electronics firms following the theft of $300,000 in chips — 19,000 IC's — from Synertek and $400,000 from Intel.[1]

Sometimes thieves steal defective chips, counterfeit the manufacturer's trademark, and re-introduce them into channels of distribution. Not long ago Avco Medical Products had to recall an entire line of life-sustaining intra-aortic pumps when it discovered that it had assembled counterfeit, defective AMD chips into some of the devices.[2]

Chip theftsare frequent in Asia, as well, where an employee can black market a $6 chip for $1. This may not seem like a lot of money, but it takes a half-day over a microscope to earn the same dollar.[3]

Chip thefts can frequently be traced, because circuit architecture is distinctive. But gold and other precious metals used by the industry on both sides of the Pacific can be disposed of easily. Recently armed robbers lifted a $300,000 shipment of gold "waste" at the San Francisco airport, en route to Silicon Valley from National Semiconductor's Philippines plant.

Some companies find technology theft to be a major problem. For instance, as early as 1959 Fairchild Semiconductor accused disaffected engineers of taking Fairchild's "cookbook" with them when they formed Rheem Semiconductor. Industrial espionage remains a controversial fact of life in the Valley, where a judge recently ordered that Fairchild be allowed to monitor the activities of a top engineer who left to work for a competitor.[4]

Some trade secrets, however, are legally open. A semiconductor family squabble has arisen because Intel and Mostek have asked Congress to extend copyright laws to ban the copying of circuit designs, while National and Fairchild contend that such a restriction would do more harm than good for U.S. industry.[5]

1. *Peninsula Times-Tribune*, April 17, 1980, and April 28, 1980.
2. *New West*, July 28, 1980, pp. 57-8.
3. *Electronic News*, May 12, 1980
4. *San Jose Mercury-News*, January 28, 1979 ("Vantage" p. 45)
5. *Electronic News*, April 23, 1979 and *Peninsula Times-Tribune*, April 17, 1979.

flow of technology, or components and equipment from which the Soviets could glean technology, rather than to block the sale of finished goods.[4] The Pentagon adopted this policy, but the bureaucracy may never complete the task of establishing specific guidelines. More important, the industrial advanced countries of Eastern Europe are not willing to become permanently dependent on Western and Japanese goods. As large markets, they have the leverage to insist upon the transfer of technology.

What they can't import from U.S. companies, the Soviets and their allies can get elsewhere. Other channels include sending graduate students to the U.S., monitoring scientific literature, spying, theft, and illegal smuggling. In 1976, for instance, three Silicon Valley executives were indicted for shipping $3 million in semiconductor processing equipment to the Soviet Union, crated as washing machines and ovens.[5] Much more slips through undetected — the Soviets have apparently obtained an advanced IBM computer which is not legally available for export.

Europe

Western European electronics companies, governments, and even the Common Market are attempting to compete with the United States. The European Economic Community's Council of Ministers, is "studying a plan that is aimed at getting European nations to boost their share of world integrated circuit production from 6% to 12% by 1985.[1] The plan calls for a four-year, $70 million subsidy to Europe and research and development.[2]

Already European governments have committed upwards of $500 million to support semiconductor development. The U.K., for instance, spent $50 million to start INMOS — which built its first manufacturing facility in the U.S. in Colorado — and has approved another $50 million to start up production in Wales.[3] France is using its program to revitalize its communications system to form a market for its semiconductor industry, but contractors include French affiliates of U.S.-based firms. Furthermore, most major European electronics manufacturers have bought into Silicon Valley companies, rather than expand independently.

The close links between U.S. and European electronics companies partially explain why U.S. executives haven't gone to Congress warning that the Redcoats are coming. But there is another important reason. The Europeans still lag far behind in the semiconductor technology race.

More significantly, the Soviets can buy semiconductors and associated technologies from other Western countries and Japan. Switzerland and other neutral countries are not bound by the guidelines established by COCOM, the coordinating committee of 15 capitalist industrial governments. Even those countries that belong, such as France, put commercial success above the American perception of Western security. At times, when the U.S. moved to veto a French export, the French threatened to drop out of COCOM entirely.[6] Most important:

> American suppliers fear that the Japanese are making greater inroads in the Eastern Bloc market with the approval of their government. However, U.S. marketing officials said they are having trouble tracking down the Japanese exports to the Socialist Bloc because they believe sales are made quietly, without publicity.[7]

In fighting the technological Cold War against the Soviets, U.S. officials may be giving ground in the commercial war against the Japanese semiconductor industry. Yet if the doors are opened for additional high technology trade, U.S. electronics firms that contract with the Pentagon — by now, there are only a few firms that don't — will be open to the charge that they are fueling both sides of the arms race. Commercially, that may be their best strategy.

Notes

1. *Multinational Corporations and United States Foreign Policy*, hearings, U.S. Senate Committee on Foreign Relations, June-July, 1974, part 10, p. 361.
2. "Soviets Narrowing Microcircuits Gap," *Aviation Week & Space Technology*, March 19, 1979, Page 66.
3. "Red Bloc Seeks LSI Support From West," *Electronic News*, November 7, 1977, Page 48.
4. *An Analysis of Export Control of U.S. Technology – A DOD Perspective*, Office of the Director of Defense Research and Engineering, February 4, 1976.
5. *Business Week*, March 21, 1977, Page 39.
6. For a more detailed discussion of export controls, see John Markoff, "Strategic Failure: The Economic War Against the Soviet Union," *Pacific Research, Third Quarter*, 1979.
7. "Export Office Probing 'Clandestine' Sales to East Bloc," *Electronic News*, October 17, 1977, Page 1.

Conclusion

The international structure of semiconductor production is almost as revolutionary as semiconductor technology itself. The markets, production lines, and even ownership patterns transcend national boundaries. Nevertheless, the techno-entrepreneurs who run the U.S.-based merchant semiconductor industry are not reluctant to wave the flag before Congress, identifying their interests with the broader needs of their workforce or the American people as a whole.

Unfortunately, the industry's voice — articulated through organizations such as the Semiconductor Industry Association and the American Electronics Association — sings to policy makers alone. Organized labor, the most likely counterbalance, is unfamiliar with the unique characteristics of semiconductor production because the industry is essentially an open shop.

The time has come to create another voice, bringing together the perspectives of labor organizers, women's groups, human rights activists, and environmentalists concerned about toxic materials, to challenge the shiny image of microelectronic wizardry. Instead of further subsidizing the semiconductor industry's managerial and scientific elite, Congress should be urged to tighten up on labor and environmental standards.

More important, the U.S. government must be pressured to eliminate the policies which have created an artificially cheap workforce in Asia. First and foremost, military and economic support of authoritarian anti-labor regimes must be halted. Secondly, programs which train technocrats and urge adoption of export-oriented development strategies should be altered to encourage more self-sufficient economic growth. Third, specific subsidies, such as aid in the construction of industrial infrastructure or OPIC insurance for U.S. owned factories should be halted.

Such policy shifts would inevitably lead to a reduction of offshore electronics assembly in Asia, and would bring some work back to the United States. Since the new conditions in Asia would apply uniformly to all semiconductor manufacturers, no companies or groups of companies would be put at a competitive disadvantage.

In particular, more democratic regimes in Asia would permit genuine labor organizing, which would bring better wages and working conditions. This, in turn, would lead some firms to lose Asian operations, but it would also free national resources — including technically trained labor — to follow alternate economic development plans. The remaining firms, by paying wages higher than at present, could contribute to economic development based upon the local market.

In fact, a policy change away from export-oriented manufacturing could, by itself, prove to be an impetus for more democratic government. Repression, after all, will be needed to maintain labor peace only as long as working conditions are bad.

Of course, improvements in working conditions on both sides of the Pacific need not wait for major shifts in U.S. foreign and foreign economic policy. Although employers consistently attempt to encourage competition and breed suspicion between production workers in different countries, the women on the various shop floors do have similar interests.

Courtesy of Intel

Workers, too, need to develop an international strategy. Just as employers use the "threat" of low pay and high productivity elsewhere to dampen workers demands, so workers can use bargaining successes in other branches of a firm to add strength to their own organizing efforts. Employers can maintain production despite labor actions at one facility, they cannot ignore coordinated international action by employees.

Coordinated bargaining is a long way off. But the preliminary steps, information exhanges, are already being taken. In 1977, for instance, information supplied by workers and researchers in the U.S. helped Signetics workers in Korea win their sit-in for higher pay. Slide shows portraying factories and workers' dormitories in Malaysia and the Philippines have been shown to workers and activists in Silicon Valley.

Critical to this international workers' strategy is the unionization of Silicon Valley.

Critical to this international workers' strategy is the unionization of Silicon Valley. Accurate knowledge of foreign operations — and the structural limitations on "runaway" production — should prove valuable to union organizers. But it may take active pressure from outside the ranks of existing union leadership to ensure that rank-and-file workers are frequently reminded of the international nature of semiconductor class conflict.

A surprisingly large number of journalists and scholars are already studying the global impact of semiconductor manufacture. Much of the information, unfortunately, is underutilized. Researchers' findings are not always available to workers. Workers' reports are not always available to researchers. It is our hope, at the Pacific Studies Center, that this pamphlet and our "Global Electronics Information Newsletter" will help create a permanent network of people and organizations concerned about semiconductor production.

Gazing Into the Silicon Ball

Semiconductor executives already warn that government restrictions and labor organization could stifle the industry's remarkable pace of innovation. They argue, in essence, that scientists and engineers need both intellectual freedom and enormous financial incentives to continue making advances in product, production, and applications technology.

But the logic of capitalism, not the threat of government or organized labor, appears to be the greatest obstacle to the future of technoogical entrepreneurship. Most new firms in Silicon Valley, for instance, are actually backed by larger, established corporations, while even the largest semiconductor specialty houses are being swallowed by even larger multi-national corporations.

As the industry restructures, it will be no easy matter to ensure the continuing flow of new ideas. However, scientific innovation need not depend upon low production wages, inadequate environmental safeguards, and financial independence. AT&T, for instance, is a huge corporation, subject to an unusually large amount of government regulation as a public utility. It is one of the world's largest employers of unionized employees. Yet Bell Labs invented the transistor, the technological seed of the semiconductor industry, and it continues to innovate. Not all large, unionized companies innovate as well as Bell Labs, but AT&T's experience shows that it is possible.

We who wish to clean up the semiconductor industry, who wish to see its production workers treated with respect, are not enemies of progress. Rather, we firmly believe that the same human ingenuity which can squeeze a quarter of a million bits of information onto the head of a pin can be harnessed to improve people's lives, both in the U.S. and abroad.