Small business seeks new innovation policy

Small business R&D groups organize, press for innovation legislation against White House resistance; Small Business Administration aims at lead role

Wil Lepkowski
C&EN, Washington

To hear it told these days, unless the government gets serious, technological innovation in small, creative businesses is headed down a path to oblivion.

Uncle Sam sustains big business with fat procurement contracts on such things as cruise missiles, M-1 tanks, and synthetic fuel plants. It favors universities with billions of dollars in research grants while closing its eyes to fast and loose academic accounting practices. And through inequitable tax, regulatory, and investment rules, it stifles the entrepreneurial air around inventive people. Only the big will survive, small business fears in its darkest moments.

Elmer Fike, president of Fike Chemical Co. in Nitro, W.Va., says he has had to lay off his whole research staff over the past two years because his profits collided with government safety, health, and environmental regulations. "We're doing no innovation at all now," he broods.

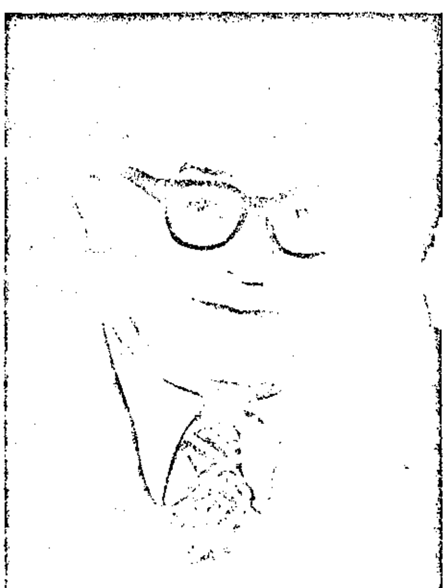
Fike is one kind of innovator, more or less out of the older chemical process industry school. Another kind is Charles Garber, president of Structure Probe Inc., in West Chester, Pa., which provides purely research and analytical services.

Garber is discouraged because of unfair competition from nonprofit institutions. "When an academic scientist uses an instrument given to him at government expense for his own profit, I call that white-collar crime," he says. The practice of academics doing commercial analytical services on the side with government equipment is widespread, he says, and he wants something done.

Stories abound of small laboratories shut out of contracts because a university researcher has a bigger name. Others receiving applied science grants from agencies complain that when a budget squeeze hits, the applied science budget gets whacked worst—as happened to the National Science Foundation's $10 million Small Business Innovation Program, cut back to $6 million during the recent budget revision. A third problem is that government contract officers hate to be bothered with what they see as piddling amounts going out for small business projects, regardless of their innovative value.

Meanwhile, small companies' problems with larger companies also weigh on the small business person. Especially infuriating to small companies is their big brothers' habit of dallying over a decision after a small business sales pitch. "The company will show interest at first, even enthusiasm. It might send a whole team of people to look at your idea," says one entrepreneur left dangling too often. "You wait and wait and wait and you often never hear from them."

More serious, though, is litigation over patent rights. Large companies can afford to spend hundreds of thousands of dollars in legal fees to win a patent case and secure an invention. Small companies cannot and usually give up. New patent legislation certain to pass, however, will change that. It will allow the patent office to do searches that will settle most claims at hardly any cost at all.



Stewart: waving small business flag

A third problem is a little more benign to companies, but still lethal to innovation. It is the old-fashioned merger. Big companies are buying up little companies instead of buying from them. The fear in the semiconductor industry, for example, is that innovation will wither now that small companies are being absorbed by the international electronic giants.

As corporate reorganization attorney Arthur Burke puts it in the spring issue of *Business and Society Review*, "Starved of capital, deprived of incentives, submerged in bureaucratic red tape, and surrounded by the burgeoning bigness of the corporate giants, the small business sector has become a victim of the upheavals of the 1970's."

But small business is fighting back, declaring that the 1980's will be a decade it can call its own. What it will be, too, is a decade of decision over the whole subject of innovation in a world suffering through painful economic change, the forecasters say. Good parsimonious ideas from all directions will be needed to pull the system out of chaos caused by shortages of energy, materials, and capital.

Even the American Chemical Society is being forced to give some notice to the many small chemical innovators within its membership. For a long time, the small chemical manufacturer and research laboratory pretty much ignored activity in the society, believing it to be oriented in leadership and policy priorities to big business and academic research.

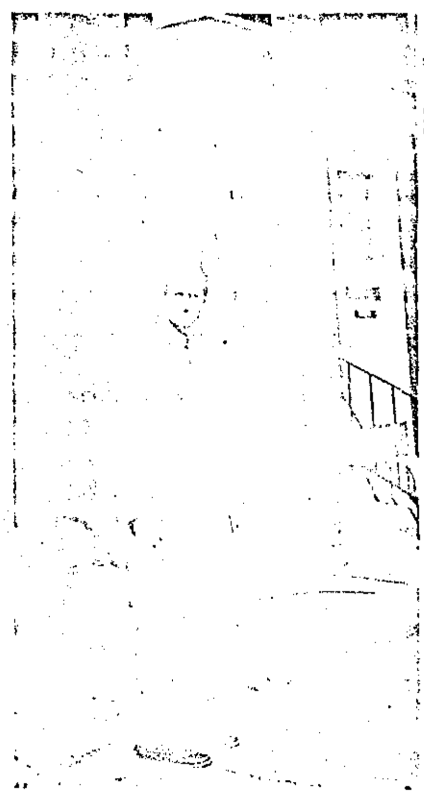
As a result, these people threw their energies into such smaller organiza-

Arthur Obermayer—portrait of one small business entrepreneur

The one thing about small business innovators is that they are individualists, and in one form or another idealists—for free enterprise, the "American dream," the thrill of risk taking. They live lives of hope, determination, and attraction to hard, vital work. They don't want to be caught up in institutionalized bigness. Obermayer is 48 and was born in the Philadelphia area. His Ph.D. in physical organic chemistry is from Massachusetts Institute of Technology, and after a short stint at the now-defunct Itek Laboratories near Boston, he founded Moleculon Research Corp. This is the way he sees himself as a small entrepreneur:

"I think it's most important for the individual to do his own thing. If I went to work at some big chemical company, would they let me testify at a public hearing on something I care about? I could support a lot of the things the company could support, such as attitudes about government. But I couldn't say anything that would offend the company. I'd hate to be put in a position where I would have to be restrained.

"Something happened to me a couple of years ago which marked a turning point in my life. Someone called me to ask if I could take part in an outside project that really interested me. My first impulse was to say no, the company needed me. But I started thinking about it and I told myself that the company had been running me too long and it was time I ran the company. If I do all the things the company needs, I get pushed too far.



C&EN staff photo

"When it comes right down to it, I'm interested in this small business innovation issue more than anything. I feel I have a responsibility to other small businessmen who have been swimming against the tide with me for many years. And I hope that what I put together doesn't look like an ego trip.

"I'm concerned about the little fellow, about everybody having a chance, about our own society becoming overinstitutionalized. This is not a country of cottage industries and I don't think it should be. But I am concerned about people in large organizations who don't speak out when they should. I care about what happens to whistle-blowers. They almost never end up on top anywhere."

tions as the American Council of Independent Laboratories, the National Council of Professional Service Firms, or the American Association of Small Research Companies.

Now ACS has a Division of Small Chemical Business. It is probationary because it is new. But founder Alexandra Melnyk of Chemical Abstracts Service expects it to receive full status by the end of 1981. Already the division has 300 members—up from only seven a year ago—and an active program. It also publishes a sprightly newsletter.

Another organization recently born is the National Council for Small Business Innovation whose cochairman is chemist Arthur S. Obermayer, president of Moleculon Research Corp. of Cambridge, Mass. Obermayer travels all over the country on behalf of the small innovative company movement, making speeches, testifying before Congress, and cheering his colleagues, besides laboring to market his cellulose triacetate membrane material Poroplastic. About a year ago, NCSBI opened a small office in Washington, D.C., in hopes of influencing federal programs and Congressional legislation on behalf of the 10,000 or so small business innovators.

A great deal is going on to establish a national small business innovation policy—almost too much for anyone to integrate. The politics is heavy; the issues are complex; and the feelings run high. But a revolution does seem to be occurring around technological innovation and the central question seems to involve how well big and small will serve each other.

Which of course they need to do. Small business largely supplies big business, and the little companies need those customers. Particularly in the high-technology field, it is only the large companies—in the U.S. or abroad—that have the funds and the manufacturing wherewithal to license small business inventions. It's a love-hate relationship that must be reconciled.

Many large companies understand the problem. Earlier this month in Baltimore, AASRC sponsored a meeting to help link up small high-technology companies with 10 big firms. The conference was largely underwritten by the big companies—General Electric, Monsanto, Control Data, and Procter & Gamble among them—and conference organizer Samuel Cardon of General Technical Services of Upper Darby, Pa., seemed pleased. "Everyone said they made useful contacts," he says. "We'll have to wait a few weeks to know better. But at least this conference showed that the big companies are out there looking."

In the Washington bureaucracy, small business's chief promoter is Milton R. Stewart, the peppery director of the Small Business Administration's Office of Advocacy. Stewart's job is to drum up zeal for small business everywhere. He certainly waves all the right flags.

"Big business is not innovating," he tells C&EN. "What fundamental overpriced material has been replaced by big business at one half to one third the price? What major corporation is *not* engaged in administrative pricing? Big business is no longer in price competition. It doesn't want to jeopardize the market. The real issue for the next decade is between big business and government bureaucracy on the one hand and the entrepreneurial sector on the other. The President has opened the door. Now we have to keep the bureaucracies from shutting it again."

Innovative small companies are only part of his mandate but clearly the main one. Stewart has even hired an "entrepreneur-in-residence," Andrew Luff, who in August will return to his small consulting firm in Kalamazoo, Mich. Luff indicates, though, that he will stay if the mood is right because he clearly sees the need to maintain the momentum that has been gathered so far.

Small business innovation advocates have considerable distrust for the Administration. They believe the White House, Office of Management & Budget, Presidential Science Adviser Frank Press, Department of

Commerce assistant secretary Jordan Baruch, and the various agencies are taking less than a half-hearted interest in the small business plight. They complain that the Small Business Administration was mentioned only once in the innovation initiatives organized by Baruch and announced by the White House last October. They point to Administration efforts to remove the innovation issue from the agenda of the White House Conference on Small Business held in February. And they charge that the Administration suppressed release of a report prepared in 1978 by Jacob Rabinow of the National Bureau of Standards for the Office of Management & Budget.

The OMB report was a powerful buttress for arguments favoring a strong federal small business innovation program. Yet, it was never featured and seldom mentioned as background material during the 18-month Domestic Policy Review leading up to the Administration's modest innovation program. The report says that half of the major U.S. innovations developed between 1953 and 1973 came from small businesses. It also says that the innovation-to-sales ratio for small companies is 33% better than that for large businesses.

Especially telling were data showing that although small firms produce four times as many innovations per R&D employee as large firms, the cost of supporting each person is about half, accounting for an eightfold advantage in productivity. Such data and their interpretation are always open to challenge and obviously research-intensive companies such as 3M, Dow Chemical, or Du Pont couldn't easily allow them to go unanswered. But these data are provocative and were convincing enough to lead the Rabinow panel to recommend a series of steps designed to give small business a bigger part of government business.

Small business innovators are banking heavily on Administration followup to the January White House Conference on Small Business.

The conference ringingly endorsed passage of twin innovation bills currently pending before the Senate and House: S. 1860 and H.R. 5607. The bills are sweeping in scope, ranging all the way from special R&D funding set-asides (opposed by the academic research world) to tax revision and patent reforms.

Baruch, technological innovation's crown prince in Washington, has privately told the small business innovation lobby that it is correct to push for passage of the legislation. But he does not say so publicly. He told both committees that the White House innovation initiatives put forth last fall are all that are needed for the moment, saying many of the provisions in the new bills "would be detrimental to other important national goals."

The small business community is ambivalent at best about Baruch. Alexandra Melnyk calls him a "charmer." A Capitol Hill staffer bitingly refers to him as "a snake oil salesman." Whatever his personal motives, he is still Washington's Mr. Innovation, Stewart or no Stewart. What is certain is that no one would want SBA to be running the innovation show, given SBA's overall reputation as a meddling, paper-shuffling agency.

Stewart, though, wears the whitest of hats. But he and Baruch do not get along, partly because of personality differences, and partly through the age-old antipathy between SBA and Commerce. One observer believes that if the breach between the two isn't healed, "it could tear the movement apart."

This raises the issue of SBA's anemic clout within the Administration. SBA is not and probably will not be the lead agency for coordinating small business innovation policy, although an argument can be made that it

Highlights of small business innovation bills S. 1860 and H.R. 5607

- The Small Business Administration would give management assistance to small research and development firms.
- SBA would be the government's chief R&D funding advocate of small R&D firms. Each federal agency would raise the level of R&D funding of small firms 2% a year up to an overall target percentage of 20%.
- Each federal agency with an R&D budget exceeding $100 million a year would establish a small business innovation research program of competitive grants modeled after the one pioneered at the National Science Foundation. Each agency would set aside 50% of its small business contract money specifically to fund the activity.
- The Office of Federal Procurement Policy in the Office of Management & Budget would give small firms "maximum practicable opportunity" to acquire federal R&D procurement contracts.
- Regulatory agencies would look for ways to make it easier, simpler, and less costly for small firms to comply with safety, health, or environmental laws.
- The Securities & Exchange Commission would conduct annual reviews of securities markets to determine if, where, and how small firms are excluded from such markets. It would report its findings every year and suggest any needed legislative or administrative changes.
- Taxes on capital gains realized on the sale of an equity interest in a small business would be deferred if the gains were rolled over or reinvested in another small business within 18 months after the sale.
- For any small business spending at least 3% of its gross revenues on R&D in each of three consecutive taxable years, or 6% in any one taxable year: restoration of qualified stock options, with maximum period for exercising such options extended from five to 10 years; taxation at half the normal capital gains rate on gains realized from investment in their firms, as long as the investment is held for a minimum of five years; extension of capital loss carryover period from seven to 10 years; and granting of a one-year write-off for otherwise appreciable R&D equipment and a 10-year write-off for R&D facilities.
- A small business would be allowed to establish a tax-free cash reserve for future R&D expenditures. The reserve would not exceed 10% of gross income, $100,000, or the actual amount of R&D expenditures, whichever is smallest.
- Subchapter S corporations would be permitted to have 100 shareholders instead of the present 15, and corporations of any size could be shareholders.
- Small business and nonprofit organizations would be allowed to retain patent rights on inventions developed under federally sponsored research, according to certain specified guidelines.
- The government retains the right to use any invention resulting from its funding of R&D projects.
- The government could require the licensing of inventions if the invention has languished without commercialization, has important health or safety applications, or is required by federal regulations.
- For a commercially successful invention, the government would recover its original funding commitment.
- The Patent & Trademark Office would be authorized to re-examine contested patents rather than requiring settlement in court. This would vastly reduce the cost of litigation to small business.

could be. Luff sees SBA as a wheel hub, with policy spokes running out from it. But SBA may not even be ready for that. It is too divided. "What is needed," says one source, "is strong leadership and SBA doesn't seem to have it. Milton has his hands tied and as a result you have Jordan running off on his own in his condescending, obsequious attitude toward small business."

The positive aspect to all this is that, with Baruch and Stewart making their own panzer thrusts, the innovation policy movement could move ahead anyway.

There are several programs for small business support ongoing in the federal government. The Minority Business Development Agency in the Commerce Department operates a $1 million "technology broker" program in nine regions that helps small minority firms get started with loans and licensing arrangements with larger companies. Agency director Theodore Lettes says 50 to 60 companies are being helped around the country.

Similarly, SBA in its traditional garb helps finance innumerable small businesses with high, low, or no technology at all. Sometimes the agency does it well, sometimes badly. The General Accounting Office has published dozens of reports over the past five years specifying the mismanagement of one program or another at SBA. Still, the process goes on because more companies are helped than are hurt.

Moreover, public law has required that every agency establish a small business support office. The motive isn't technological innovation and so the consciousness isn't so high as the innovation community wants. Both small business committee chairmen, Sen. Gaylord Nelson (D.-Wis.) and Rep. Neal Smith (D.-Kan.), want more visibility for innovation through the R&D funding set-asides, calling for at least a 2% yearly increase in small business grants and contracts, stopping when the small business percentage reaches 20%. The Administration objects to such a policy on grounds that it would tie the hands of agencies looking for simply the best know-how to meet their missions.

John A. Hewitt Jr., chief financial officer for the Department of Energy, acknowledges the department's "tendency to rely on other than small businesses for our research and development." But he says DOE's senior managers now have the message. As it is, he told the Senate Small Business Committee, DOE spent $1.32 billion with small firms, and in fiscal 1980 they will get 18.9% of the agency's total obligations.

The figures becloud the real picture around innovation, however. DOE is notorious for ignoring new R&D ideas emanating from small companies. And the great proportion of Hewitt's figures pertain more to services than to R&D.

Hewitt's response to S. 1806 fairly well typifies the Administration stance, given that it already has established its own innovation policy through the President's program. Hewitt says that DOE is trying to encourage more small business activity in its programs. DOE has several programs already in motion under existing law. It frowns on any mandated fixed percentage targeted solely for small business. It would be willing to try an NSF-modeled Small Business Innovation Research program, and the Solar Energy Research Institute already is devoting 23% of its R&D budget to small business proposals.

> **"If the invention doesn't have the potential of a $50 million market in five years, [big companies] aren't really interested"**

There is almost universal agreement that the agencies would do well to adopt programs identical to NSF's touted Small Business Innovation Program run by Roland Tibbetts. He and Robert Colton, who runs the somewhat less scintillating university-industry innovation centers program, are practically the lone small business lights in the entire $1 billion agency.

"Bright ideas come to all people in all places," Tibbetts says. "But they can't be exploited well except in a small business environment. Academia is not a good place because there innovative ideas frequently go nowhere. Except in small business, the radical idea has very little chance of successful transformation into a product. Another reason why small business has to struggle is that to most people innovative ideas look as if they have small markets. As far as the big companies are concerned, if the invention doesn't have the potential of a $50 million market in five years, they aren't really interested."

Tibbetts' program works in three phases. Phase one is an initial $25,000 grant to help the company develop the product concept. Then comes phase two to expand the base through research funding. Phase three involves development financing from private capital sources. Initial grantees begin phase three this fall.

"The program forces technology transfer from the beginning of the planning process. And we give patent rights to the developer-recipient," says Tibbetts.

It may well be that small is becoming beautiful. But one should be cautious. The overall trend remains in the direction of bigness. Facts show it—through the decline of the small farm, the accelerating merger movement, the international flow of capital and technology, the replacement of the corner grocery store with chain stores. Small business champion Arthur Obermayer says he wants to get as big as he can get. It may all come down to that purely western philosophical concept that you don't progress if you don't grow. Even the Soviets, with their different view of social evolution, envy old-fashioned Yankee ingenuity.

One small business innovation movement does question the direction of things. It is the "appropriate technology" community, led by those who believe that the economic and resource system is under such strain that communities must learn to become more self-sufficient and detach largely from large-scale technological, corporate and bureaucratic systems.

Its advocates have their venture capital cares, too. One Boston group called Accion works worldwide among the poor but also has a "microbusiness" project in Maine to seek small loans to develop community-based enterprises in depressed areas.

This "community technology" movement is highly distrustful of such activities as Control Data's program of nurturing small high-technology firms. The movement believes that Control Data, a big data technology company, is simply out to control the information on technology small firms are developing. But at the same time, the community groups seek the help of the business and banking community for the philanthropic support to keep going.

Because of coming clashes between "high" and "appropriate" technology, the eighties could be the decade when the nature of wealth will have to be reconsidered through some combination of business and community values. With less material goods to go around but with information flowing freely, something new seems bound to emerge. Milt Stewart may have the best definition of wealth. "The true wealth of this country," he says, "is between the ears." And with that, we're back to the uncertainties around small entrepreneurs. □

"REGULATION AND INNOVATION," REGULATION, JANUARY/FEBRUARY 1980

Regulation and Innovation

The Impact of Regulation on Industrial Innovation by Henry G. Grabowski and John M. Vernon, in cooperation with the Committee on Technology and International Economic and Trade Issues of the National Research Council and the National Academy of Engineering (Washington, D.C.: National Academy of Sciences, 1979), 64 pp.

This National Academy of Engineering monograph is the first of a series of commissioned studies on the effects of public policies on industrial innovation. Henry G. Grabowski and John M. Vernon, professors of economics at Duke University, were asked (1) to survey the literature regarding the effects of economic, environmental, and health-and-safety regulation on the innovation process and on the private and social returns from innovation and (2) to consider how regulatory activities might be modified so as to lessen any undesirable effects on innovation while preserving the benefits obtained.

In the area of health and safety, the authors find evidence that regulation has significantly retarded innovations in industries facing premarket regulatory approval for new products (pharmaceuticals, pesticides, medical devices, food additives, and certain chemicals). In particular, there are a number of academic studies suggesting that, in the past two decades, increasingly stringent pharmaceutical regulation has substantially increased the R&D costs and development times required for introducing new medicines in the United States. This in turn has contributed to increased delays to patients in obtaining new drugs, declining levels of annual new drug introductions, and an increased concentration of innovation among the larger firms in the industry. Similar tendencies also have been observed in the other industries subjected to premarket controls, although the experience in these cases is more recent and more limited in character and has been less systematically studied.

The authors also suggest that environmental and worker safety regulations have had significant derivative effects on industrial innovation. They cite a number of instances where these regulations have led to substantially increased business costs as well as uncertainties regarding investment in new facilities or technologies. Another effect has been to divert capital funds away from investment in R&D and innovation and toward capital improvements to meet regulatory requirements. At the same time, it is also clear that some environmental regulations have stimulated the development of important innovations to meet the objectives of pollution control.

By way of policy recommendations, Grabowski and Vernon emphasize that the health and safety agencies have traditionally had very narrow legislative mandates and, therefore, have not had strong incentives to give much attention to the effects of their actions on innovation, productivity, or overall consumer welfare. Consequently, the authors recommend that Congress broaden the mandates so as to require these agencies to consider such effects along with the benefits from regulation. They also recommend the use of outside professional experts for various purposes—for example,

"Eureka! The EPA willing."

medical specialists to review annually the progress of the Food and Drug Administration in clearing new medicines and to consider the experiences of new medicines being marketed abroad. Finally, the authors urge that economic incentives be substituted for direct regulatory controls in the environmental and other areas where this approach is feasible.

As for economic regulation in the electric utility, transportation, and telecommunication industries, the authors find that regulation's net effect on innovation is difficult to assess because of offsetting factors. In particular, rate of return regulation may reduce the incentives to innovation by restricting profits or add incentives by reducing risk; regulatory lag may delay innovative new products and services, but offer profit inducement for cost-reducing innovation; and regulated competition may retard innovation through entry restrictions, but substitute innovation for price reductions as a competitive weapon.

The case studies in the economic regulation area suggest, however, that regulation has retarded innovation most where new technologies have emerged that threaten the market shares or competitive positions of groups already under regulation. Thus, in the field of transportation, both the Big John hopper car and piggyback truck-rail system involved intermodal distributions of wealth, causing intermodal conflicts that produced long delays in the introduction of these innovations. Similarly, in the field of communications, the development of cable TV was significantly retarded by the Federal Communications Commission because it had the potential of adversely affecting existing broadcasting stations.

Because of the broad discretionary power that regulatory agencies have to limit new technologies that threaten the status quo, regulation should be invoked only where it is clearly needed—for example, in situations involving natural monopoly or economic efficiency. Grabowski and Vernon endorse deregulation in sectors such as transportation and cable TV, where the efficiency rationale for regulation is difficult to sustain and where, they predict, deregulation would have long-term favorable effects on innovation.

The Grabowski-Vernon study was developed in conjunction with a National Academy of Engineering committee workshop that provided the opportunity for contributions from business leaders, academic specialists, and government officials. In December 1979, the academy held a Colloquium on Industrial Innovation and Public Policy Options in Washington, D.C., at which panels of experts considered the recommendations in several recent studies and in the President's October message to Congress on industrial innovation initiatives. These proceedings will be available from the Office of the Foreign Secretary, National Academy of Engineering.

Capital-Intensive Firms Squeezed

Prescription for Ruin

WASH. POST 12/23/79

By Geoffrey Moss for The Washington Post

By James Gibson

Chrysler Corp. is appealing for federal aid, and Ford Motor Co. will lose $1 billion in its domestic operations this year. U.S. Steel Corp. is laying off 13,000 workers, and some railroads are already wards of the state. The obvious question is why so many of the nation's basic industries are in trouble.

Each industry has its own unique problems but most of them have a single major problem in common—they are capital-intensive industries operating in an inflationary economy. That is a prescription for slow financial ruin.

Capital-intensive industries must generate the funds to replace and renew their plant and equipment if they are to remain healthy. In a period of stable prices, depreciation allowances on old capital equipment provide adequate funds for new equipment.

Those depreciation allowances become increasingly inadequate as inflation heats up. A factory that cost $10 million generates depreciation allowances of that amount, but at today's prices it may cost more than $20 million to replace the factory as it wears out. That leaves at least another $10 million to be found somewhere else just to keep the factory in operation.

In practice, the additional funds come from reported profits. For some capital-intensive companies with low rates of profitability, the funds required just to maintain the existing capital equipment may exceed the firms' total financial resources. The greater a company's capital intensity and the higher the inflation rate, the worse the resulting financial squeeze becomes.

In time, the financial squeeze becomes a slow death. Research and development funds for future products dry up as the company struggles just to maintain the capacity to produce its current products. Promotion opportunities for the best people become scarce in a dying company, and they often go elsewhere. Eventually the lack of good products and good people undermines the company's ability to compete with financially stronger firms at home and abroad.

A company that is unable to generate capital internally usually has problems finding it externally, too. As a source of new funds, the stock market is closed in practice to companies such as Chrysler and U.S. Steel because investors realize their plight all too well. Many troubled capital-intensive companies can't sell long-term bonds because they face bleak long-term futures. Bankers may be willing to lend them short-term money, but a number of Chrysler's bankers probably wish they had been more selective. Bankers prefer to loan money to companies that don't really need it, and capital-intensive companies need it badly.

The financial squeeze is being felt throughout broad sectors of American industry, most of which is still very resilent. If double-digit inflation continues, however, Chrysler and U.S. Steel may be just the beginning of a wave of troubled major companies in the advanced stages of industrial decay.

None of this is to deny that particular companies have made their share of mistakes. Chryslers' inventory policy and selection of models leave much to be desired. The steel industry's approach to new technology has no more been creative than the steel billets it produces. The mistakes that weakened these capital-intensive companies made them most vulnerable to the long-term effects of inflation.

Inflation's financial squeeze on capital-intensive industries is not unique to this country. Britain's inflation has been worse than ours and so have its consequences. Our steel and auto industries are still in much better condition than loss-plagued British Steel and British Leyland.

It is no coincidence that the countries with the strongest capital-intensive industries also have low rates of inflation plus abundant, low-cost capital for their vital industries. Japan, West Germany and Switzerland are examples of how strong industrial performance accompanies low inflation.

When asked what the government can do to solve the problem, many executives would reply that government is the problem. They point to the government's role in causing inflation through monetary and fiscal stimulation. They point to heavy costs imposed by government in the form of environmental regulations, new mileage requirements, etc.

The best thing that government can do is to bring inflation under control because that is the basic problem. The next-most-direct action the government can take is to improve depreciation allowances, a proposal under discussion in Congress.

The least attractive long-run path of government action is also the most compelling in the short run. The British have fallen into the trap of subsidizing their problem industires while neglecting ones with long-run growth potential. Their economists recognize the futility of pumping money into their losers rather than into their winners, but that is what politics there demands. The funds diverted to rescue Chrysler would be used more productively in a growth industry such as semiconductors, but workers who are employed now have more political influence than those who would be employed in the future in a growing industry.

Even our technological lead in semiconductors is threatened as that industry becomes more capital-intensive. Japanese and European companies have the advantages of government subsidies and low-cost funds. In response to a question about what our government can do to help, Hewlett Packard's David Packard spoke for more than his own high-technology company when he said, "If the government will fix the tax structure and get out of the way, we will take care of ourselves."

Gipson is senior vice president of Batterymarch Financial Corp. of Boston.

FEB. 10, 80

WASH. STAR
FEB. 10, '80

Small-Firm Rules Break Draws Roundtable Fire

By Bailey Morris
Washington Star Staff Writer

James Severt is a Martinsville, Va., contractor who says it's high time Congress gave small business a regulatory break.

Thanks to Uncle Sam, Severt says, small businesses are having an even rougher time competing with large ones, mainly because of the time and money they are diverting into government-ordered projects.

In his case, he estimates, the annual cost of government paperwork alone is "$72,000 in money and 9,000 hours in time to fill out more than 1,100 forms a year." For a company with an annual gross of $22 million that is too high a price, Severt says.

Congress and the Carter administration agree. Several months ago, President Carter wrote a memo ordering executive-branch agencies to give small businesses the regulatory break Severt seeks.

And this month in Congress, both the House and Senate judiciary committees are expected to act on bills creating a two-tier system of regulation, distinguishing between large businesses and smaller ones.

"Regulatory flexibility" is the generic term used to identify the diverse congressional and administration proposals. Until recently, almost everyone was for it.

Nine days ago, however, the first big business opposition to the concept surfaced in testimony of the Business Roundtable, a powerful voice for the nation's largest businesses, before a House Judiciary subcommittee.

The Roundtable's basic position — as articulated by Richard D. Wood, chairman and chief executive of Eli Lilly & Co. — is that all businesses should be treated the same.

"Burdens on small businesses associated with the present regulatory system are generally the same as those imposed on all businesses," Wood said.

Special treatment for small businesses is inappropriate, said Bill Kennedy, counsel for General Electric Co., who also appeared at the hearing presided over by Rep. George Danielson, D-Calif. Danielson chairs the subcommittee on administrative law and government relations.

The Roundtable's opposition runs counter to overwhelming support for the concept in the Senate (which passed a similar bill last year); in the House (where half the members are co-sponsoring a two-tier bill); and in the administration, which supports flexibility for small firms.

But it is notable for one major reason, says a House small business expert.

"We think opponents of separate legislation giving small businesses a regulatory break will use the Roundtable's opposition to hold the bills hostage — forcing us to go with it as part of the overall regulatory reform package, which is complicated and has a lot of opposition," he said.

The fear, then, is that the generally non-controversial small business legislation will get caught up and lost in the very controversial omnibus regulatory reform package advocated by the Carter administration.

In the meantime, however, several agencies have taken their own steps to ease the regulatory burden on small firms, including the following:

- Both the Labor Department and the Internal Revenue Service are allowing companies with fewer than 100 participants in their pension and welfare plans to file greatly simplified annual reports with the government.
- The Environmental Protection Agency wants to exempt 500,000 companies from its new hazardous waste regulations, by excluding firms generating less than 100 kilograms of such waste each month.
- The Agriculture Department, pending a final regulation, plans to waive inspection and weighing requirements for grain elevator operators exporting less than 15,000 metric tons a year.
- Congress has adopted temporary legislation exempting an estimated 1.5 million companies with 10 or fewer employees from routine safety inspections by the Occupational Safety and Health Administration.
- OSHA is attempting to give small businesses as many options as possible to comply with its regulations.
- The Securities and Exchange Commission has adopted several special procedures for small firms, including one raising from $500,000 to $1.5 million the amount of securities a company can sell as a small firm. Simplified procedures for small companies to make public offerings of up to $5 million also have been

See BREAK, A-15

Break for Small Firms Assailed

Continued From A-14

adopted, along with a new way for firms to sell up to $2 million in securities over a six-month period.

It is hoped that the net effect of these and other small business initiatives will be to remove the artificial roadblocks that make them less competitive.

Milton A. Kafoglis, a former senior economist for the Council on Wage and Price Stability, said in a National Journal interview that the cost of regulation is pushing many small companies out of the market.

"It appears that the regulatory approaches that have been adopted tend to increase the size of the firm that can survive, thus leading to greater business concentration and possibly driving otherwise efficient firms out of business," he said in recent congressional testimony.

Despite these arguments, some labor and public-interest groups have doubts about two-tier regulation on grounds that it may compromise health and safety laws already on the books.

The Carter administration seems to share this concern, and another, that flexibility may further complicate an already cumbersome rule-making process.

Still, based on the strong support for the concept, action extending the two-tier concept to all government agencies appears likely.

It may be, however, that the action will be tied to the condition that the government devise a new, more restrictive definition of small business — one that would exclude some relatively large firms which, nonetheless, hold a small share of their respective markets.

Small-Firm Rules Break Draws Roundtable Fire

By Bailey Morris
Washington Star Staff Writer

James Severt is a Martinsville, Va., contractor who says it's high time Congress gave small business a regulatory break.

Thanks to Uncle Sam, Severt says, small businesses are having an even rougher time competing with large ones, mainly because of the time and money they are diverting into government-ordered projects.

In his case, he estimates, the annual cost of government paperwork alone is "$72,000 in money and 9,000 hours in time to fill out more than 1,100 forms a year." For a company with an annual gross of $22 million that is too high a price, Severt says.

Congress and the Carter administration agree. Several months ago, President Carter wrote a memo ordering executive-branch agencies to give small businesses the regulatory break Severt seeks.

And this month in Congress, both the House and Senate judiciary committees are expected to act on bills creating a two-tier system of regulation, distinguishing between large businesses and smaller ones.

"Regulatory flexibility" is the generic term used to identify the diverse congressional and administration proposals. Until recently, almost everyone was for it.

Nine days ago, however, the first big business opposition to the concept surfaced in testimony of the Business Roundtable, a powerful voice for the nation's largest businesses, before a House Judiciary subcommittee.

The Roundtable's basic position — as articulated by Richard D. Wood, chairman and chief executive of Eli Lilly & Co. — is that all businesses should be treated the same.

"Burdens on small businesses associated with the present regulatory system are generally the same as those imposed on all businesses," Wood said.

Special treatment for small businesses is inappropriate, said Bill Kennedy, counsel for General Electric Co., who also appeared at the hearing presided over by Rep. George Danielson, D-Calif. Danielson chairs the subcommittee on administrative law and government relations.

The Roundtable's opposition runs counter to overwhelming support for the concept in the Senate (which passed a similar bill last year); in the House (where half the members are co-sponsoring a two-tier bill); and in the administration, which supports flexibility for small firms.

But it is notable for one major reason, says a House small business expert.

"We think opponents of separate legislation giving small businesses a regulatory break will use the Roundtable's opposition to hold the bills hostage — forcing us to go with it as part of the overall regulatory reform package, which is complicated and has a lot of opposition," he said.

The fear, then, is that the generally non-controversial small business legislation will get caught up and lost in the very controversial omnibus regulatory reform package advocated by the Carter administration.

In the meantime, however, several agencies have taken their own steps to ease the regulatory burden on small firms, including the following:

- Both the Labor Department and the Internal Revenue Service are allowing companies with fewer than 100 participants in their pension and welfare plans to file greatly simplified annual reports with the government.
- The Environmental Protection Agency wants to exempt 500,000 companies from its new hazardous waste regulations, by excluding firms generating less than 100 kilograms of such waste each month.
- The Agriculture Department, pending a final regulation, plans to waive inspection and weighing requirements for grain elevator operators exporting less than 15,000 metric tons a year.
- Congress has adopted temporary legislation exempting an estimated 1.5 million companies with 10 or fewer employees from routine safety inspections by the Occupational Safety and Health Administration.
- OSHA is attempting to give small businesses as many options as possible to comply with its regulations.
- The Securities and Exchange Commission has adopted several special procedures for small firms, including one raising from $500,000 to $1.5 million the amount of securities a company can sell as a small firm. Simplified procedures for small companies to make public offerings of up to $5 million also have been

See BREAK, A-15

Break for Small Firms Assailed

Continued From A-14

adopted, along with a new way for firms to sell up to $2 million in securities over a six-month period.

It is hoped that the net effect of these and other small business initiatives will be to remove the artificial roadblocks that make them less competitive.

Milton A. Kafoglis, a former senior economist for the Council on Wage and Price Stability, said in a National Journal interview that the cost of regulation is pushing many small companies out of the market.

"It appears that the regulatory approaches that have been adopted tend to increase the size of the firm that can survive, thus leading to greater business concentration and possibly driving otherwise efficient firms out of business," he said in recent congressional testimony.

Despite these arguments, some labor and public-interest groups have doubts about two-tier regulation on grounds that it may compromise health and safety laws already on the books.

The Carter administration seems to share this concern, and another, that flexibility may further complicate an already cumbersome rule-making process.

Still, based on the strong support for the concept, action extending the two-tier concept to all government agencies appears likely.

It may be, however, that the action will be tied to the condition that the government devise a new, more restrictive definition of small business — one that would exclude some relatively large firms which, nonetheless, hold a small share of their respective markets.

I S. HARPS
vice president

ial Corporation for
to the additional
ceeds George W.
corporation as the

ident in the Wash-
ation's largest em-

director for Wash-
d Persons. She will
of AARP chapters

dent of Kennecott
president.
le Federal Energy
r of enforcement,
n. 1.
ohoe Construction
ob Superintendent
ociation.
eneral manager of
ice Furniture.
ranch manager of
nell is a 1975 grad-

ior partner to the
g firm, Seidman &
Bernstein, Mintz &
Seidman in 1969 to
ny.
vice president and
s Group of Arthur
ce president of Ar-

SCOTT CHASE

Working on Federal Contract Has Its Flaws, Inventor Finds

By Martha M. Hamilton
Washington Post Staff Writer

Working for the government has brought Gilbert V. Levin both satisfaction and frustration.

As an inventor-entrepreneur, contractor and consultant to various federal agencies, Levin has had the satisfaction of watching one of his experiments aboard the Viking spacecraft bring back the only evidence—albeit equivocal—suggesting life on Mars.

But as president of a small research firm, he has found the government sometimes hostile to both innovation and small businesses.

His firm, Biospherics, a life sciences research company, sits on the edge of a large asphalt parking lot in Rockville flanked by body shops.

About 70 percent of the company's business is with the government—a potpourri of projects including the Viking experiment, writing and producing anti-smoking and antialcohol literature, doing aquatic toxicology tests, designing monitors for the Navy to use to measure oil discharges from its ships and checking industrial hygeine in government agencies including the Bureau of the Mint and the Central Intelligence Agency.

"We went in there and sniffed around to see if it was a safe place to work," said Levin, a civil engineer who once worked for both the Maryland and District public health departments.

Levin's concerns are how the government treats innovation in general and small businesses in particular.

"To do innovative work is very difficult," he said. "There's the NIH problem—the not-invented-here syndrome," he continued, describing agency officials who are unwilling to entertain proposals along new lines of inquiry.

And there is the clear predilection among some procurement officials for big business, Levin said. He is part of a group of officials of small businesses who are campaigning to get small firms a bigger share of the federal research dollar.

Small firms produced about 24 times as many major innovations as large firms and nearly four times as many as medium-sized firms per research and development dollor expended, but less than 4 percent of total federal government expenditures on R&D went to small firms, according to a paper prepared for the White House Conference on Small Business. Levin and others hope to alter what they see as an imbalance.

Attitudes are changing slowly, Levin said. A few years ago, "I went down to see the research head of a major agency, and he told me the truth—that I was wasting my time because the era of small business was gone," Levin said. The federal officials said then that the agency intended to deal only with large aerospace firms for research, he recalled.

"Technical progress is more complex than it used to be. It takes a lot of dollars," Levin said.

Selling innovation isn't easy, he said, citing one of Biospherics' first products. In 1971 Biospherics developed a new waste-water treatment process that Levin says "produced astoundingly good results." I thought everybody was going to line up, but they didn't." It was 1973 before the process had a full-scale test in a municipal plant. "In 1974 Union Carbide signed a licensing agreement. Ever since, we've let them do the selling," he said.

"Federal contracting has severely constrained innovating," Levin said. "During the Nixon era, the Environmental Protection Agency came out with a mandate that no research contract should be let that couldn't be reduced to practice within three years. In effect that ended research. What it does is limit research to hole-plugging."

Levin said "there are problems" in working on innovation for the government, but citing the Viking experiment, he added, "There are delicious rewards."

This is another in a series of occasional articles on area firms working primarily for the federal government.

request.

WASH. POST 7/26/85

U.S. Said to Have Lost Space Monopoly

■ The United States "has lost its monopoly in Western space technology and operations" and has not developed policies to meet increased increased foreign competition in space, according to a government report released yesterday. The country also has not developed plans for increasing private commercialization of space technology in areas beyond satellite telecommunications, said the U.S. Office of Technology Assessment report.

Report called:

"International Cooperation and Competition in Civilian Space Activities."

600 PA SE 1st Floor Personnel

OTA: [p. 279 Congressional Staff Directory]

Director 224-3695

377-4621 messenger: Jimmy

Harvard Business Review
March–April 1986

Robert B. Reich and
Eric D. Mankin

Joint ventures with Japan give away our future

Listen to what these four businessmen have to say about U.S.-Japanese joint ventures:

"They buy energy-intensive components here, like glass, tires, and steel. But when it comes to things that are labor-intensive, that stays in Japan."–Terrence J. Miller, official, Automotive Parts and Accessories Association.

"People we used to do business with, we can't anymore [because they aren't competitive]. Instead of buying a given part from a supplier down the street in Chicago, I buy it from a supplier down the street in Osaka."–Robert W. Galvin, chairman, Motorola.

"Cross & Trecker is committed to the business of machine tools, but it is not committed to build in the United States all or any portion of the machine tools that it sells here."–Richard T. Lindgren, president, Cross & Trecker.

"First you move the industrial part to the Far East. Then the development of the product goes there because each dollar you pay to the overseas supplier is ten cents you're giving them to develop new devices and new concepts to compete against you."–C.J. Van der Klugt, vice chairman, Philips N.V.

Each of these businessmen is commenting on aspects of a trend that is reshaping America's trade relations with Japan and creating a new context for international competition. Very simply, this is the situation: to avert rising U.S. protectionist sentiment, Japanese companies are setting up plants in the United States, either as joint ventures or on their own; to obtain high-quality, low-cost products and components, U.S. companies are making joint venture agreements with Japanese companies. At the same time, U.S. companies are licensing their new inventions to the Japanese. (The *Exhibit* lists recent U.S.-Japanese coalitions in high-technology industries.)

> *"The big competitive gains come from learning about manufacturing processes–and the result of the new multinational joint ventures is the transfer of that learning from the United States to Japan."*

On the surface, the arrangements seem fair and well balanced, indicative of an evolving international economic equilibrium. A closer examination, however, shows these deals for what they really are–part of a continuing, implicit Japanese strategy to keep the higher paying, higher value-added jobs in Japan and to gain the project engineering and production process skills that underlie competitive success. (+)

In contrast, the U.S. strategy appears dangerously shortsighted. In exchange for a few lower skilled, lower paying jobs and easy access to our competitors' high-quality, low-cost products, we are apparently prepared to sacrifice our competitiveness in a

Mr. Reich, who teaches political economy and management at Harvard's John F. Kennedy School of Government, was director of policy planning at the Federal Trade Commission during the Carter administration. His most recent book is New Deals: The Chrysler Revival and the American System *(Times Books, 1985).*

Mr. Mankin is a doctoral candidate in economics and business at Harvard University. His research focuses on production management and industrial organization.

(+) Assumes that J. [illegible] has a nationalist perspective. Is this true?

host of industries – autos, machine tools, consumer electronics, and semiconductors today, and others in the future.

Before this trend becomes an irrevocable destiny, U.S. business and government leaders need to review the facts carefully and decide if they should follow a different course. Two questions, in particular, frame the issue: What skills and abilities should be the basis for America's future competitive performance? And how does the current strategy of Japanese investments and joint ventures affect those skills and abilities?

The quotes cited earlier and an examination of U.S.-Japanese coalitions across a range of industries suggest disturbing answers to these questions. Through these coalitions, Japanese workers often gain valuable experience in applications engineering, fabrication, and complex manufacturing – which together form the critical stage between basic research and final assembly and marketing. U.S. workers, in contrast, occupy the two perimeters of production: a few get experience in basic research, and many get experience in assembly and marketing.

But the big competitive gains come from learning about manufacturing processes – and the result of the new multinational joint ventures is the transfer of that learning from the United States to Japan. The Japanese investment in U.S. factories gives the Americans experience in component assembly but not component design and production. Time after time, the Japanese reserve for themselves the part of the value-added chain that pays the highest wages and offers the greatest opportunity for controlling the next generation of production and product technology.

In the auto industry, for example, General Motors has formed a joint venture with Toyota, while Chrysler has teamed up with Mitsubishi, and Ford with Mazda. All three deals mean that auto assembly takes place in the United States. But in each case, the U.S. automakers delegated all plant design and product engineering responsibilities to their Japanese partners. The only aspect of production shared equally is styling. Under the Chrysler-Mitsubishi agreement, the joint venture will import the engine, transmission, and accelerator from Japan.

Or take the example of the IBM PC, which is assembled in the United States. The total manufacturing cost of the computer is about $860, of which roughly $625 worth, or 73%, of the components are made overseas. Japanese suppliers make the graphics printer, keyboard, power supply, and half the semiconductors. America's largest contribution is in manufacture of the case and assembly of the disk drives and the computer.

This trend spells trouble. If a Japanese company handles a certain complex production process, its U.S. partner has little incentive to give its

Exhibit **A sampling of U.S.-Japanese joint ventures**

Bendix-Murata Manufacturing Company	Machine tools
Boeing-Mitsubishi Heavy Industries Boeing-Kawasaki Heavy Industries Boeing-Fuji Heavy Industries	Airplanes
Armco-Mitsubishi Rayon	Lightweight plastic composites
General Motors-Fujitsu Fanuc	Machine tools
General Motors-Toyota	Automobiles
Ford-Mazda	Automobiles
Chrysler-Mitsubishi Motors	Automobiles
Westinghouse-Komatsu Westinghouse-Mitsubishi Electric	Robots and small motors
IBM-Matsushita Electric	Small computers
IBM-Sanyo Seiki	Robots
Allen Bradley-Nippondenso	Programmable controllers and sensors
General Electric-Matsushita	Disc players and air conditioners
Kodak-Canon	Copiers and photographic equipment
Sperry Univac-Nippon Univac	Computers
Houdaille-Okuma	Machine tools
National Semiconductor-Hitachi	Computers
Honeywell-NEC	Computers
Tandy-Kyocera	Computers
Sperry Univac-Mitsubishi	Computers

skilled workers the time and resources required to design and debug new products and processes. Thus as their employers turn to Japanese partners for high value-added products or components, America's engineers risk losing the opportunity to innovate and thereby learn how to improve existing product designs or production processes.

Unless U.S. workers constantly gain experience in improving a plant's efficiency or designing a new product, they inevitably fall behind the competition. This is especially true in high-technology sectors, where new and more efficient products, processes, and technologies quickly render even state-of-the-art products obsolete. For example, as the Japanese moved from supplying cheap parts to selling finished products in the consumer electronics industry, vital U.S. engineering and production skills dried up through disuse. The U.S. work force lost its ability to manufacture competitive consumer electronics products.

The problem snowballs. Once a company's workers fall behind in the development of a rapidly changing technology, the company finds it harder and harder to regain competitiveness without turning to a more experienced partner for technology and production know-how. Westinghouse, for example, closed its color television tube factory in upstate New York ten years ago because it could not compete with Japanese imports. That same plant will soon reopen as a joint venture with Toshiba – but only because Toshiba is supplying the technology. Westinghouse engineers, who had not worked on color television tubes for at least a decade, could not develop the technology alone.

On the other hand, continual emphasis on and investment in the production part of the value-added chain will result in low-cost, high-quality products and a steady stream of innovations in products and processes. If current trends persist, Japanese companies will keep gaining experience and skill in making products. They will continue to develop the capacity to transform raw ideas into world-class goods, both efficiently and effectively.

The implications of this trend for U.S. companies, workers, and the national economy are uniformly bad. The Japanese are gradually taking charge of complex production – the part of the value-added chain that will continue to generate tradable goods in the future and simultaneously raise the overall skill level of the population. The entire nation benefits from a large pool of workers and engineers with skills and experience in complex production.

The United States, however, will own only the two ends of the value-added chain – the front end, where basic research and invention take place, and the back end, where routine assembly, marketing, and sales go on. But neither end will raise our overall skill level or generate a broad base of experience that can be applied across all kinds of goods.

As more and more production moves to Japan, our work force will lose the capacity to make valuable contributions to production processes. An economy that adds little value to the production process can hardly expect to generate high compensation for less valuable functions. If the current trend continues, our national income and standard of living may be jeopardized.

Japan's investment in America

Japanese investment in the United States has given rise to automobile plants producing Nissans, Hondas, Toyotas and, in the near future, Mazdas and Mitsubishis. Japanese semiconductor and computer manufacturers have helped create a "silicon forest" in Oregon. In the last four months of 1984, Japanese electronics companies established 40 new plants in the United States that produce everything from personal computers to cellular mobile telephones. According to the Japan Economics Institute, there are now 522 factories in the United States in which Japanese investors own a majority stake.

Japanese companies are also building laboratories here. Nippondenso's research center in Detroit will focus on automobile electronics and ceramics, and Nakamichi's in California will develop innovations in computer peripherals. Furthermore, nearly every major Japanese company now funds research at American universities in return for the right of first refusal in licensing any products or technologies that are developed.

Although Japanese companies fund basic research at American universities, the results of that research go back to Japan for commercialization. At the other end of the manufacturing process, Japanese plants in the United States take the results of complicated production done in Japan and assemble the final products. NEC's new computer facility in Massachusetts assembles computers from Japanese central processing units and memory chips. The most sophisticated components and systems of automobiles are apt to be produced in Japan, even if the car is assembled in Michigan, California, or Tennessee.

Heart of the matter

At the heart of a growing number of U.S.-Japanese joint ventures is the agreement that the Japanese will undertake the complex production processes. These agreements need not automatically turn out this way. In fact, there are many different types of international joint venture, and each type has different implications for production, distribution, and division of profit between the partners.

Consider the recent agreement between AT&T and Philips N.V., under which Philips will distribute AT&T products in Europe. The two companies each contributed resources to the formation of a new jointly owned entity. AT&T's stated goal was to enter the European market; Philips presumably wanted access to AT&T's products. AT&T could have sold Philips an exclusive European license to manufacture and distribute its products; it could have leased Philips's factories or built its own in Europe and used Philips as a distributor; or it could have bought Philips, a move that would have given it the Dutch company's factories and distribution network, as well as all of its proprietary products.

U.S. companies planning joint ventures with Japan usually find that at least one of these options is unavailable: they cannot buy a Japanese company. Still, U.S. companies can enter a wide range of potential joint venture agreements. Most of the high-technology joint ventures that we examined, however, were agreements in which the U.S. partner would sell and distribute the Japanese product; our study of 33 joint ventures between U.S. and Japanese companies in consumer electronics industries showed that roughly 70% took this form.

Under the typical agreement, the U.S. company buys products from its Japanese partner and sells them in the United States under its own brand name, using its own distribution channels. The IBM graphics printer is made by Epson in Japan. The Canon LBP-CX laser printer is manufactured in Japan and sold in the United States by Hewlett-Packard and Corona Data Systems. Even Eastman Kodak is joining the bandwagon: Canon of Japan will make a line of medium-volume copiers for sale under Kodak's name; Matsushita will manufacture Kodak's new video camera and recorder system, called Kodavision.

This type of arrangement is not unique to U.S.-Japanese joint ventures; European high-technology computer, semiconductor, and telecommunications companies are also entering into a disproportionately large number of sales and distribution agreements with the Japanese.

For many U.S. managers, these joint ventures make good business sense. Faced with seemingly unbeatable foreign competition, many U.S. companies have decided that it is more profitable to delegate complex manufacturing to their Japanese partners. Consider Houdaille Industries, a Florida-based manufacturer of computer-controlled machine tools. Beginning in 1982, the company set out to block imports of competing Japanese machine tools. It petitioned Washington for protection, accusing the Japanese of dumping and receiving subsidies from the Japanese government. When that strategy failed, Houdaille tried to persuade the Reagan administration to deny the 10% federal investment tax credit on equipment to U.S. buyers of Japanese machine tools. The administration rejected this proposal as well. Finally, Houdaille announced that it would seek a joint venture with Japan's Okuma Machinery Works.

The machine tool story

Houdaille is not the only machine tool manufacturer to look for Japanese partners. James A.D. Geier, chairman of Cincinnati Milacron, the nation's largest machine tool manufacturer, noted in 1984 that "50% of the products we sold last year did not even exist five years ago. We've gone from being an industry with very little change in products to one with a revolutionary change in products." Many U.S. companies were unprepared for such a transition and as a result can make money only by selling advanced products manufactured in Japan. In 1983, more than 75% of all machining centers sold in the United States were made in Japan (even though many ended up with American nameplates), and domestic production has declined dramatically.

As imports have increased, international joint venture activity in the machine tool industry has accelerated. A recent National Research Council report on machine tools noted that "most of these joint ventures have offered the potential for low-cost, reliable overseas manufacturing for the U.S. partner, and an enhanced marketing network in this country for the foreign one."[1] For example, Bendix sells a small turning machine in the United States for $105,000. It can produce the device in Cleveland for $85,000. The same machine, produced in Japan by Bendix's new partner, Murata Manufacturing, and then shipped to Cleveland, costs the company only $65,000. Such compelling economics underlie Bendix's decision to transfer nearly all its machine tool production to Japan.

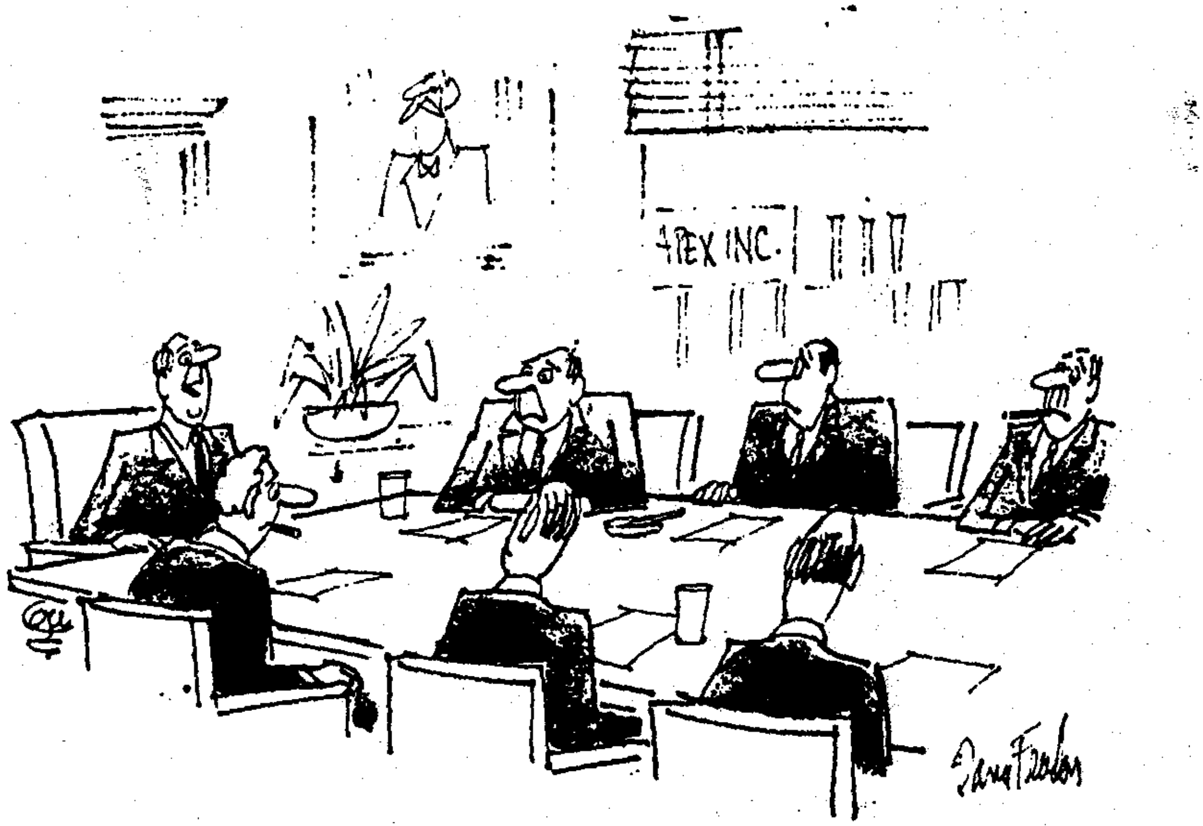
Or consider the case of Pratt & Whitney, which earns profits by distributing foreign-made machine tools. In July 1984, its president, Winthrop B. Cody, told the *New York Times*: "I wish we could make some of these machine tools here, but from a business point of view it's just not possible." Even U.S. companies that develop new products look to Japan for manufacturing. Acme-Cleveland's state-of-the-art numerically controlled chucker, jointly developed with Mitsubishi Heavy Industries, will be produced in Japan.

The semiconductor story

While not in quite the same straits as machine tool producers, U.S. semiconductor manufacturers also face increasing competition from Japan and thus increasing pressure to enter into coalitions with Japanese companies. Traditionally, the Japanese have entered semiconductor markets as followers, thereby enabling U.S. companies to reap high profits before the product's price drops. Once the Japanese enter, they rapidly gain market share by competing on the basis of a lower price.

Some of the most famous examples of the "Japanese invasion" come from the memory chip wars of 1973-1975 and 1981-1983, when U.S. chip makers ceded a large part of the 16k and then the 64k dynamic memory market to Japanese manufacturers producing at lower cost. In the spring of 1984, Japanese manufacturers controlled about 55% of the U.S. market for 64k RAM chips. Taking a lesson from these bat-

1. Committee on the Machine Tool Industry, Manufacturing Studies Board, Commission on Engineering and Technical Systems, National Research Council, *The U.S. Machine Tool Industry and the Defense Industrial Base* (Washington, D.C.: National Academy Press, 1983), p. 44.



"Look at it this way, gentlemen. Minimum tax is better than maximum tax."

ties, some U.S. companies decided to delegate production to the Japanese at the start of a new project: in 1982, Ungermann-Bass made an agreement with Japanese chip maker Fujitsu by which Ungermann-Bass designs very large scale integrated circuits for local area networks. The company then sends the designs to Fujitsu in Japan for manufacturing.

Innovations and new products in the semiconductor industry are a predictable function of experience and engineering know-how: 16k RAM chips precede 64k RAMs; the development of the 16-bit microprocessor follows logically from the existence of its 8-bit forebear. Since technological leadership is linked so closely to production experience, the emergence of pioneering Japanese products will only be a matter of time. In December 1984, for example, Hitachi introduced a 32-bit microprocessor, thus signaling its intention to compete aggressively against U.S. companies in leading-edge semiconductor technologies. While both Motorola and National Semiconductor are producing a 32-bit chip, Hitachi's entry predates Intel's new product announcement. Intel introduced its new 32-bit microprocessor in October of 1985.

Hitachi's push toward state-of-the-art semiconductor production foreshadows a new round of sales and distribution agreements. Soon executives at Intel or National Semiconductor will realize that Hitachi or another Japanese semiconductor manufacturer can sell advanced semiconductor products at prices that U.S. companies cannot match. These semiconductor companies might go to Washington looking for trade protection. More likely, however, they will try to preserve their profitability by negotiating sales and distribution agreements. National Semiconductor already has trading ties with Hitachi through which it markets Hitachi's computer in the United States.

A comparison of two joint ventures – National Semiconductor-Hitachi and Amdahl-Fujitsu – illustrates the different approaches U.S. and Japanese companies take toward joint ventures. Fujitsu and National Semiconductor both fabricate integrated circuits, while Hitachi and Amdahl manufacture IBM-compatible mainframe computers. Both ventures link a computer and a semiconductor manufacturer.

The agreement between National Semiconductor and Hitachi is similar to sales and distribution agreements in other industries. In an attempt to diversify downstream, National Semiconductor will sell Hitachi's IBM-compatible mainframe computers in the United States. Hitachi, however, will be under no obligation to use any National Semiconductor products in making its computer. National Semiconductor may thus find itself in the position of manufacturing chips for Hitachi's competitors while selling a Japanese-made computer that contains none of its own components.

In contrast, Fujitsu purchased a controlling interest in Amdahl in 1983. As a result, Amdahl will now buy from Fujitsu most of the semiconductors it uses in the manufacture of its mainframe computers. Fujitsu will not, however, sell Amdahl computers in Japan. In both cases, Japanese companies add to their manufacturing experience. Complex production stays in Japan, and the final products are sold in the United States.

The story behind the stories

What lies behind Japan's direct investment in the United States and the coalition-building activities of U.S. and Japanese high-technology companies? What motivates U.S. and Japanese managers?

The Japanese hope to mitigate future U.S. trade barriers by investing in the United States and allying with U.S. companies. In 1981, nontariff import restrictions protected about 20% of U.S. manufactured goods; by 1984, protection covered 35%. To the Japanese, the trend is clear. If the Reagan administration succumbed so readily to protectionism, what can the Japanese expect from future administrations that may be less ideologically committed to free trade? Mazda is investing $450 million in a new auto assembly plant in Flat Rock, Michigan because quotas had prevented Mazda from importing enough cars to meet demand. Despite the recent expiration of voluntary import restraints on Japanese automobiles, Chrysler and Mitsubishi came to an agreement in April 1985 to assemble Mitsubishi automobiles in Illinois. Concern over future trade barriers was a strong motivating factor for Mitsubishi.

From the Japanese perspective, joint ventures with U.S. companies will also help forestall further protectionism. RCA was notably absent from the 1977 dumping case over Japanese color television sets. Because it had licensed technology to Japanese television manufacturers, RCA was benefiting from Japanese imports. In the same way, now that RCA is distributing a PBX system manufactured by Hitachi, it has no interest in pushing for trade barriers in telecommunications equipment.

In both joint ventures and direct investments, U.S. companies and workers become partners in Japanese enterprises. Japanese direct investment puts Americans to work assembling Japanese-made components. Joint ventures and coalitions employ Americans selling Japanese products. If trade barriers limit the flow of products from Japan, American workers will lose their jobs assembling and distributing these goods and U.S. corporations will lose money.

Why do U.S. companies find joint ventures with Japanese companies so attractive? Companies in emerging industries often view a joint venture with a Japanese company as an inexpensive way to enter a potentially lucrative market; managers in mature industries view the joint venture as a low-cost means of maintaining market share. In industries ranging from consumer electronics to machine tools, the Japanese have the advanced products American consumers want. Joint ventures allow U.S. companies to buy a product at a price below the domestic manufacturing cost. The Japanese partner continues to move down its production learning curve by making products destined for U.S. markets. Thanks to these joint ventures and coalitions, the efficiency gap between U.S. and Japanese manufacturing processes will continue to widen.

A Japanese strategy

The trends of the past 40 years as well as current Japanese actions in the United States suggest the existence of a long-term Japanese strategy. The overriding goal of Japanese managers is to keep complex production in Japan. They intend to develop national competitive strength in advanced production methods. U.S. managers who want to take advantage of Japan's manufacturing strength may do so by selling Japanese products in the United States. They may also set up production facilities in Japan, provided they are run and staffed by Japanese.

Increasingly, American managers are aiding the Japanese in achieving their goals by channeling new inventions to Japan and providing a sales and distribution network for the resulting products. Burroughs and Hewlett-Packard, for example, have just set up buying offices in Japan to procure high-tech components from Japanese manufacturers. Over the next five years, we expect sales and distribution agreements to result in lower profitability and reduced competitiveness for the U.S. companies that enter into them.

The reason is simple: the value provided by the U.S. partner in a sales and distribution agreement is potentially replaceable. The U.S. company gives away a portion of its market franchise by relying on a Japanese company for manufactured products – in essence, it encourages the entry of a new competitor. As shown by the Japanese-dominated consumer elec-

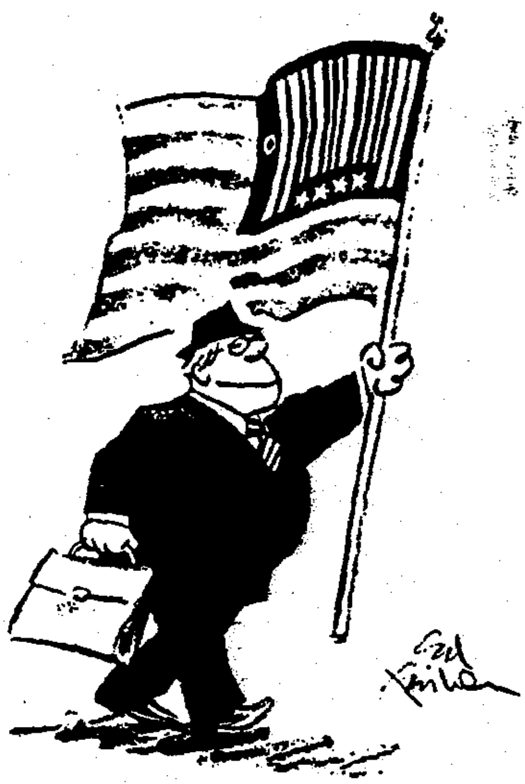
(*) there, nature is economic/business. But not (*) here tronics industry, these agreements can act like a Trojan horse: the U.S. company provides the Japanese company access to its customers, only to see the Japanese decide to go it alone and set up a distribution network on the basis of a reputation gained with the help of the U.S. partner. Even if the Japanese do not terminate the agreement after establishing a presence in the United States, Japanese manufacturers are in a position to squeeze their U.S. distributors' profit margins precisely because sales and distribution functions are so vulnerable to replacement.

U.S. companies are selling themselves too cheaply; in letting their Japanese partners undertake product manufacturing, they are giving away valuable production experience. Instead, U.S.-based companies could begin to invest in more sophisticated production within the United States. They could seek to develop in our work force the same base of advanced manufacturing experience that Japanese managers are now creating among their workers. Unfortunately, from the standpoint of a typical U.S. company, the guaranteed return on this sort of an investment is often not enough to justify its cost, especially when the alternative of Japanese manufacture is so easy to choose.

Production experience is essentially social. It exists in employees' minds, hands, and work relationships. It cannot be patented, packaged, or sold directly. It is thus a form of property that cannot be claimed by the managers who decide to invest in it and the shareholders they represent. This form of property belongs entirely to a company's work force. It will leave the company whenever the workers do.

An economic fable

Imagine the following: the chief executive of a U.S. company decides to invest in production experience. Instead of relying on a Japanese supplier for a complex component, top management decides to produce it in America, inside its own operation. The component costs more to produce here than in Japan – the equivalent of $1,000 more per employee. The higher cost partly reflects the overvalued dollar, but it occurs mainly because the Japanese have already invested in producing this component cheaply and reliably. The chief executive sees the added expense as an investment. Once the workers and engineers gain experience in making the component, they will be better able to make other products. They will learn about the technology and will be able to apply that learning in



countless ways to improve the company's other processes and products. As a result, the company will gain $1,500 per worker in present-value terms. Thus the initial $1,000 investment is well worth it.

As might be imagined, the chief executive cannot get anywhere near the $1,500 return envisioned from this investment. As soon as the workers and engineers realize their increased value, they ask for more money. In this fable, they can, of course, ask for $1,499, since they are now worth an extra $1,500.

If the executive refuses to give the workers a raise, they can simply leave the company and work for the competition. Faced with a sizable loss on the investment, our executive vows that from now on the company will buy advanced components from Japan.

This fable is not so farfetched. Studies show that companies retain an average of only 55% of their engineering trainees after two years. In one study, the factor cited most often by departing engineers was "inadequate compensation," followed closely by "uncertain future with the company" and "higher salary offer elsewhere."[2] Thanks to such high job mobility, the engineers responsible for developing a new product or designing a cost-saving manufacturing process at one company in one year may find themselves using their expertise to help another company in another year – perhaps their first employer's chief competitor. Thus, companies that invest in production experience may ultimately produce profits for the competition.

2 Eugene Raudsepp. "Reducing Engineer Turnover," *Machine Design* September 9, 1982, p. 52.

3 Andrew Weiss. "Simple Truths of Japanese Manufacturing," HBR July-August 1984, p. 119.

The Japanese system of lifetime employment eliminates this problem. While not all Japanese companies subscribe to such a policy, most of the large companies making advanced products for export do. This system makes it unthinkable for workers to join the competition; they would leave behind friends, homes, social status – in short, much more than a job. In this atmosphere, an investment in production experience comes quite naturally. Benefits resulting from such an investment tend to remain with the company.

Furthermore, because of the abundance of engineers and because engineers stay with their original employers, Japanese managers can give factory workers more engineering support. As Andrew Weiss noted in an HBR article, for high-volume, low-technology products like radios, the ratio of production workers to engineers in Japan is about four to one. In divisions making more sophisticated products, such as very large scale integrated circuits, the Japanese manufacturers observed by Weiss employed more engineers than production workers. Weiss attributes the high levels and rapid increases in Japanese companies' labor productivity to heavy investment in engineering.[1] Most conventionally organized U.S. companies, faced with high turnover, cannot afford to invest so heavily in their engineers.

As a result of these organizational differences, U.S. managers have little incentive to invest in production experience. The Japanese, however, will be able to capture most of the returns from their investments in Japanese workers. U.S. managers are happy to buy components from the Japanese or build new factories in Japan, thus further contributing to the production experience of the Japanese work force. But what is really at stake is not where company headquarters are located or profits remitted, but rather the value added by a nation's work force to an increasingly global process of production and the capacity of that work force to generate new wealth in the future. We are falling behind in this high-tech race, and actions taken by both U.S. and Japanese companies only serve to further weaken the U.S. work force.

Changing course

The current situation has severe drawbacks for U.S. companies over the next five years. Over the long term, U.S. companies that enter joint ventures with Japan cannot maintain high profitability by providing services, such as assembly and distribution, which add very little value to the product being sold. The resulting interplay, while superficially promising, could really be just an extended dance of death.

Profit sharing?

As profits dwindle, management might at last look to profit sharing or other forms of employee ownership that reduce turnover rates. The lower the turnover, the more profitable are investments in the work force. Furthermore, profit-sharing programs will enable workers to gain directly from a company's investments in them. To return to our fable, when workers in a company practicing profit sharing demand their raises, our chief executive need only say, "Wait, and you will get higher compensation when our investments start paying off and the company makes more money."

In practice, however, it may be impossible to devise a profit-sharing system that solves the problem. In a large company, for example, employees of different divisions would have to be compensated based on their divisional performance – a difference sure to create resistance to transfer among divisions, which makes it hard to share production experience. Furthermore, a new system of ownership and an immediate change in managerial or worker attitudes do not automatically go together. Consider Hyatt Clark Industries of Clark, New Jersey, a worker-owned company in which management refused to distribute company profits, or the Rath Packing Company of Waterloo, Iowa, a worker-owned company in which the workers went out on strike.

Moreover, corporate objectives are often inconsistent with a goal of profit sharing or employee ownership. Unlike workers, corporations can move overseas. Why make risky investments in workers when safer Japanese alternatives present themselves? If we wait for U.S. corporations to increase their investments in their workers, we may have to wait too long. The plants that these companies will eventually sell to their workers will be obsolete, and America's comparative disadvantage will be too great to overcome.

Public benefits, private costs

In this situation, government has an appropriate role. The difference between the social and private returns on investments in production experience is an example of what economists call an "externality." Other examples of externalities abound: when a company pollutes the air, it is using a public resource – clean air – for which it is not paying. The private company is, in essence, shifting a cost to the public – and thereby boosting its rate of return at public expense. In this case, government's role is to ensure that the company's costs reflect the value of resources used in production. The clean air regulations of the

1970s made managers include the costs of pollution—or pollution cleanup—in their investment decisions.

In the case of production experience, the balance between cost and reward is reversed: society as a whole benefits more than do most companies from investments in workers and engineers. Government should thus create incentives for companies that are doing business in the United States—regardless of where the company is headquartered—to invest in complex production here, using American workers and engineers. Companies should reap an extra public reward for investing in production experience to make up for the diminished short-term private reward of doing so. The government could subsidize investments in production experience through, for example, a human investment tax credit. The object would be for government to accept part of the economic cost of creating an important national economic good: more highly skilled, trained, and experienced workers and engineers.

In addition, government could support private investment in production experience in other, less direct ways. Federal and state governments could sponsor "technology extension services" modeled on the highly successful agricultural forerunner. An extension service could inform smaller businesses about the latest methods in manufacturing technology and undertake pilot programs and demonstrations. By sharing information and conducting classes, an extension service could help smaller manufacturers—the underpinnings to the industrial base—keep pace with change.

For another perspective on this same topic, see "Cooperate to Compete Globally" by Howard V. Perlmutter and David A. Heenan on page 136 of this issue.

Antitrust laws could be modified to permit American companies to invest jointly in complex production in the United States, thereby spreading the cost of the investment over several companies. The Federal Trade Commission allowed General Motors and Toyota to form a joint venture; would it have also approved a GM-Ford deal?

Our future national wealth depends on our ability to learn and relearn how to make things better. The fruits of our basic research are taking seed abroad and coming back home as finished products needing only distribution or components needing only assembly. America's capacity to produce complex goods may be permanently impaired. As a production-based economy, the United States will be enfeebled. What will also be lost is the wealth—the value added—contributed by the center of the value-added chain. And that is a prospect that should concern executives and government leaders alike. ∇

The New York Times
Business
Sunday, March 22, 1987
Section 3

Stopping the High-Tech Giveaway

By STEVEN PROKESCH

WHEN Reagan Administration opposition forced Fujitsu Ltd. to drop its plans to buy control of the Fairchild Semiconductor Corporation last week, Fujitsu and Fairchild executives immediately made it clear that their relationship was not dead. The two companies now plan to enter into a series of technology-exchange and development programs and joint manufacturing projects that will enable the companies to make and sell each other's products.

By teaming up with a foreign company in such a fashion, Fairchild is merely joining the pack. So-called cooperative ventures or strategic alliances with foreign companies have become a way of life in nearly every industry: Hundreds of American companies have turned to foreign partners for assistance in dealing with intensifying global competition, penetrating foreign markets and shouldering the big costs of developing sophisticated new products.

But even though there was no immediate outcry from Washington, Fujitsu's and Fairchild's plans to live together rather than marry still carry some of the same risks of transferring technology to Japan that had caused Government officials to oppose the proposed acquisition. Indeed, there are growing concerns in business, Government and academic circles that such American-foreign alliances have resulted in a largely one-way flow of technology and other critical skills from the United States to foreign nations, especially Japan. And while many American companies are loath to talk about it, a broad reassessment of alliances with foreign companies is clearly under way.

American businesses have given away precious technology in ventures with foreign companies. Now they share less, and try to get something in return.

Many of the competitive problems now plaguing American manufacturers of such products as semiconductors, machine tools and consumer electronics stemmed from ties with foreign companies.

When the RCA Corporation licensed its color television technology to the Japanese decades ago, its leaders saw the deals as a low-risk way to make some easy money. RCA is still pocketing handsome royalties, but the Japanese now have a bigger share of the American market than the RCA brand.

More recently, cooperative ventures have come back to haunt the semiconductor industry. As recently as the early 1980's, American semiconductor makers were a symbol of America's technological might. But by entering into a range of licensing, marketing and manufacturing ties with American companies, the Japanese assimilated everything the masters had to teach. Now the Japanese are the masters, and the Americans are scrambling to catch up.

The big worry is that what happened in color televisions and electronics is happening everywhere. If American companies do not change their approach to cooperative ventures, the resulting transfer of technology to foreign countries, especially Japan, could ultimately threaten the nation's dominance of other key industries, including biotechnology, telecommunications, computers and aerospace, according to Government and business officials and experts who have studied the phenomenon.

"There is hardly an industry where we haven't transferred technology to Japan," said Clyde V. Prestowitz, who as counselor to the Secretary of Commerce was one of the nation's top trade negotiators with Japan from 1981 to mid-1986. "If we give our technology away, we have nothing to compete with," he added.

Mr. Prestowitz may sound like he was stating the obvious, but it was something that a lot of managers

Continued on Page 8

1. Superconductor Articles
2. 2-Pager
3. Executive Order

Continued from Page 1

were painfully slow to recognize.

Many American executives clung to the belief that the Japanese had no technology of worth long after that was no longer the case. Why? Tradition was one reason. Sheer arrogance was another.

After World War II, the United States Government encouraged American companies to share their technology to help rebuild the war-ravaged economies of Europe and Japan. Long after that task was accomplished, the technology outflow continued. Having dominated the world markets for so long, many American businessmen seemed incapable of seeing the Japanese as their equals let alone their superiors. Confident of their ability to stay at least one step ahead of the Japanese, they did not worry that they were helping the Japanese become formidable competitors.

Such talk can still be heard at aerospace companies such as Boeing and Pratt & Whitney, which enjoy a technological lead — at least for now. "I don't see the Japanese or anyone else developing competitive technology by associating with us," said Robert Rosati, a recently-retired Pratt & Whitney official who led its joint venture with companies from Japan and three other nations to develop jet engines. "They don't have the design or development capability to do any kind of engine, and they're not going to get them."

But plenty of humbled executives in industries ranging from chemicals and cars to semiconductors and machine tools have wised up. "Anytime you license a foreign company to manufacture and perhaps sell for you, you're in effect putting another competitor into the marketplace," said B. Charles Ames, chief executive of the Acme-Cleveland Corporation. "Anybody who doesn't realize that is pretty damn naïve."

"Giving up technology is now far more suspect," said John M. Stewart, who advises major corporations on technology issues for McKinsey & Company, the consulting firm.

ALARMED by the travails of the semiconductor industry, executives at the Ford Motor Company recently decided against entering into a venture with the Japanese to produce a high-technology component for the power train of its cars. And General Electric has become much more cautious about licensing its "best high technology" to the Japanese, said Philip V. Gerdine, a G.E. executive. General Electric's "wariness" of the Japanese "has gone up as our respect for them has gone up," he said.

The Intel Corporation, the semiconductor maker, licensed a half-dozen domestic and foreign manufacturers, including Fujitsu and NEC, to make its first microprocessor for the International Business Machines Corporation's personal computer and compatible machines. For its new third-generation microprocessor, it will license no more than two companies and maybe none.

Acme-Cleveland once licensed Mitsubishi Heavy Industries to manufacture and sell one of its machine tools only to watch Mitsubishi become its rival in the United States market. Acme-Cleveland incorrectly assumed Mitsubishi's ambitions were limited to Asia. Now, in choosing a Japanese company to make some of its telecommunications equipment, Acme-Cleveland is being "darn careful to make sure the company that is going to manufacture it for us does not have any apparent interest in getting into this market," said Mr. Ames. And Acme-Cleveland, he said, will make sure that its licensing agreements include market restrictions.

Companies that had relied on joint ventures to compete in Japan are now establishing wholly owned subsidiaries. Duracell, Kraft Inc.'s battery subsidiary, did that last November, when it canceled a venture with Sanyo Electric. E.I. du Pont de Nemours & Company is operating new businesses in Japan on its own and is shifting some activities of its existing Japanese ventures to a subsidiary, according to William H. Davidson, an associate professor at the University of Southern California's Graduate School of Business. Carl De Martino, a Du Pont group vice president, said: "Given our free choice, we would prefer to have a 100-percent-owned company anywhere."

American companies, when they do contribute technology to a venture, are demanding technology of equal value in return, something many had not done as recently as five years ago.

"There's a greater sensitivity to the need to get a two-way exchange as opposed to the one-way flow, which was fundamentally the way most joint ventures in the last 20 years were structured," said S. Allen Heininger, a vice president of Monsanto and president-elect of the Industrial Research Institute, an organization of senior research officials from major companies.

Under the terms of a new joint venture in semiconductors with the Toshiba Corporation, for example, Motorola Inc. will give Toshiba some of its microprocessor technology but will receive Toshiba's "very leading edge" technology in memory chips and manufacturing, said Keith J. Bane, Motorola's director of strategy.

To insure that the technology flows both ways, a growing number of American companies are insisting that their managers be involved in ventures in Japan. Celanese (which was bought by Hoechst of West Germany earlier this year) trained two of its employees to speak Japanese and put them into a joint venture with Daicel Chemical Industries to soak up Daicel's expertise in automotive plastics. They are now back in Detroit working to apply what they learned.

While many joint ventures in Japan have been confined to manufacturing and marketing, more American companies are insisting that they do research and development. Only 8 percent of the new ventures formed in Japan in 1973 involved research and development, but 35 percent of those formed in 1985 did, according to a study by Laurent L. Jacque, an assistant professor at the University of Pennsylvania's Wharton School.

At the very least, some American companies are using ventures as a way to master Japanese management techniques. That was a key motive for General Motors's joint venture with Toyota to make small cars in California.

UNLIKE American managers, foreign businessmen, especially the Japanese, long ago realized that they could exploit these alliances for more than just quick gains in market share or short-term profits. For them, ventures were a way to gain the technology and skills needed to achieve global leadership.

In his studies of such ventures, including five of Du Pont's in plastics, Professor Davidson found a pattern. The Japanese company would assimilate its American partner's technology or production skill and then squeeze out the American partner.

Such a squeeze led to the split-up last summer of a venture between Humphrey Instruments, a California concern, and Hoya Glass of Japan. "Hoya developed the ability to produce the machines on its own and effectively terminated the agreement," Professor Davidson said.

One reason that the Japanese often seem to end up with the upper hand is that they frequently wield total management control of the venture. Several of the Du Pont ventures that Professor Davidson studied had no American managers.

An even more basic problem, according to several experts, is that many more Japanese speak English than Americans speak Japanese.

This has made it difficult for Monsanto, the chemicals concern, to make sure it was getting as valuable technology from its Japanese partners as it is giving to them.

"We have few scientists who are proficient in Japanese," Mr. Heininger said. As a result, "we don't have the fluency to probe in detail their technical people the way they can probe in detail our technical people."

The Japanese have not been nearly as generous about sharing their technology and manufacturing expertise, contends Robert B. Reich, professor of political economy and management at Harvard University's Kennedy School of Government. In his study of 100 ventures, he found that Japanese companies almost always tried to keep the highest value-added parts of production for themselves.

If this trend continues, he worries that the Japanese will increasingly be the ones who turn American breakthroughs in basic science into useful products. Americans, he said, will become second-class assemblers and distributors of Japanese goods.

In many cases, though, American companies have had little choice but to form disadvantageous relationships to do business in Japan.

Until the mid-1970's, the Japanese prohibited Americans from setting up wholly owned subsidiaries in Japan. Instead, they had to enter into jointly owned enterprises with Japanese companies. And the price of entry into Japan included a requirement to license their technology to Japanese concerns.

Even after these laws were relaxed, American companies frequently found it difficult to break into the Japanese market on their own. This has been especially true in such expensive, technologically sophisticated products as telecommunications equipment and commercial aircraft, where the Japanese Government — like the governments of most countries — plays a big role in determining which vendor wins an order. As is still the case in most countries, including Japan, sharing technology and production with local companies is a prerequisite for winning an order.

Cultural differences have also made it virtually impossible for American companies to compete on their own in Japan.

The long-term relationships between suppliers, manufacturers and distributors so valued in Japan hinder American companies. With acquisitions frowned upon in Japan, American companies have often had little choice but to team up with a Japanese company to break into the market.

DESPITE all the dangers, strategic alliances with foreign companies, including the Japanese, seem here to stay. Indeed, even with the reassessment of ventures going on, no one expects any significant slowdown in their formation.

American inventiveness is admired throughout the world, but small companies, which account for so many discoveries, must often turn to foreign partners for help in maki[illegible] distributing their products — and for the capital needed to stay alive.

Even giants, though, will continue to link up with foreign companies. General Motors, Ford and Chrysler now import not only components but entire cars from Asia. Companies in businesses ranging from appliances to photocopiers to machine tools have resorted to the same tactic. Such arrangements often force the American company to disclose vital design or product information.

Business leaders have also come to view strategic alliances as a necessity in industries where product development costs are exorbitant.

It costs $50 million to $100 million to bring a new drug to market, so pharmaceutical companies have to market it rapidly throughout the world to recoup the investment. That requires strategic alliances, said Henry Wendt, president and chief executive of the SmithKline Beckman Corporation, which has joint development and marketing agreements with Boehringer Mannheim of West Germany, Fujisawa of Japan and Wellcome P.L.C. of Britain.

Similarly, virtually no single company can afford the billions of dollars it costs to develop a new commercial jet — not to mention the $500 million to $700 million to develop the engines to power it. For that reason, international consortiums have become a way of life in the aerospace industry.

In a recent interview, Makoto Kuroda, a senior official of the Japanese Ministry of International Trade and Industry, reiterated his Government's assertion that Japan has abandoned all ambitions to become an independent power in commercial jets. At least publicly, such aerospace companies as Boeing and Pratt & Whitney, the jet engine maker, say the Japanese lack the design and systems ability and the innovativeness to threaten American leadership in aircraft or engines. But privately, industry officials are nervous, said Leslie Denend, a McKinsey consultant.

Whatever their long-term intentions might be, Japanese clout — and expertise — is clearly growing.

Boeing will allow its Japanese partners to design and produce components equal to 25 percent of the value of the 7J7, the 150-seat, fuel-efficent jet that Boeing plans to have in service in the early 1990's. That is about twice the share that the Japanese produced of the 200-seat 767.

Even if the Japanese pose no immediate threat to prime contractors such as Boeing, they are already taking business away from American component suppliers, said David C. Mowery, an aerospace expert at Carnegie-Mellon University. Eventually, they may do the same to the prime contractors, according to many experts.

SLOWLY, painfully, American managers are learning that doing business in a global economy carries enormous dangers along with opportunities. Having been burned by foreign alliances, some managers, at least, have lost the arrogance that made them such easy prey. The question is whether managers in other industries will learn from their example, or have to learn on their own. ■

The Government **Tries to Help**

Government officials are attempting to limit the dangers posed by the proliferating ties between American and foreign companies by enacting new laws and relaxing old ones.

Until a new law was enacted last year, pharmaceutical companies could not sell products for clinical testing or sale abroad unless the Food and Drug Administration had approved them for testing or sale in the United States. That forced such biotechnology companies as Genentech to license their technol to foreign companies instead of supplying their products abroad themselves. "We now have less need to transfer technology," said Thomas D. Kiley, Genentech's vice president for corporate development.

Once it was virtually impossible for American semiconductor companies to protect their mask designs — the "negatives" from which semiconductors are made — from foreign pirates. But new laws have substantially strengthened copyright protection of masks and microcoding, instructions implanted in semiconductors. Combined with the designation of a special Federal court to hear patent-infringement cases, that has had a dramatic effect: 70 to 80 percent of such suits are now upheld, up from 20 to 30 percent before.

A 1984 law enabled semiconductor makers to engage in joint research. A group of electronics companies then formed a reseach consortium, the Microelectronic and Computer Technology Corporation. A Pentagon advisory group is supporting the formation of a semiconductor consortium to develop manufacturing technology and engage in limited production of chips.

To keep the aerospace industry competitive, the President's Office of Science and Technology Policy recommended in February that American companies be allowed to collaborate not only on research for superfast aircraft but also on development — something antitrust laws now bar.

"There is no hysteria now" about the aerospace industry's competitiveness, said Crawford F. Brubaker, Deputy Assistant Secretary of Commerce. "But given what has happened in other industries, we don't want it to happen in this one." ■

The Varieties of Business Alliances

Joint Ventures involve the creation of an enterprise jointly owned by the parent companies to develop or manufacture or sell particular products often in a particular market. In many American-Japanese joint ventures, the Americans contributed the technology, only to find themselves discarded when their Japanese partner had mastered the innovation.

Licensing Agreements typically permit the licensee to manufacture and sell a product incorporating the owner's technology in return for royalty payments. But in electrical power plant equipment, color television sets, machine tools, electronic components and many other industries, agreements have not limited licensees to a given market or product application. By improving on the technology itself, capitalizing on their lower manufacturing costs or applying the technology to new products, Japanese companies have used the license to become strong competitors in the United States and abroad.

Marketing/Manufacturing/Supply Arrangements enable a partner to make or sell and service the other's products. American companies have used these arrangements to import low-cost foreign components or entire products, and to distribute American-made products in foreign markets. Because such alliances often involve sharing American technology and design specifications with the foreign partner, the result has often been one-way technology transfer.

Through gift, theft and license, our technology is leaking abroad almost as fast as we develop it. So scratch the long-term dream of a U.S. living off exports of high-technology goods and services.

Does anyone really believe in free trade?

By Norman Gall

NEVER MIND if the U.S. loses its manufacturing skills; we'll just import manufactured goods and pay for them by exporting high technology and knowledge-oriented products. Steel in, software out. Autos in, microchips out.

That's a comforting theory held by a lot of people. Is it workable? Increasingly it looks as if it is not workable. The whole concept is being seriously undermined as U.S. innovations in technology are adopted not only by Japan but also by such fast-developing countries as South Korea, Brazil, Taiwan, even India.

While these countries are more than happy to sell us manufactured goods, they closely control their own imports of technology goods they buy from us. Exports of computers and other high-technology products from the U.S. are still huge, but the long-term prospects are in question. In areas of medium technology, minicomputers in particular, developing countries are adapting or stealing U.S. technology or licensing it cheaply to manufacture on their own. Many of the resulting products are flooding right back into the U.S.

The Japanese developed this policy to a fine art: Protect your home market and then, as costs decline with volume, manufacture for export at small marginal cost. A good many developing countries have adopted the Japanese technique.

Against such deliberate manipulation of markets, what avails such a puny weapon as currency devaluation? Whether the dollar is cheap or dear is almost irrelevant. Free trade is something we all believe in until it clashes with what we regard as vital national economic interests.

These are the broad trends. Now meet Touma Makdassi Elias, 41, an engineer born in Aleppo, Syria. Elias has a master's degree in computer science from San Jose State, in Silicon Valley, and a doctorate from the Cranfield Institute of Technology in England. Grounded in European and U.S. technology, Elias is now a Brazilian.

His company, Microtec, is Brazil's first and biggest producer of personal computers. Elias came to São Paulo eight years ago to teach night classes in engineering. In 1982 the Brazilian government banned imports of small computers. Seizing the opportunity, Elias started making the machines in the basement of a supermarket in the industrial suburb of Diadema.

Technology? "We worked from IBM technical manuals," Elias told FORBES. "We had a product on the market by 1983. We started making 20 machines a month. Soon we'll be making 2,400. Now my brother may be joining our firm. He's a graduate of the Sloan School of Management at MIT. He's been managing an investment company in Dubai, in the Persian Gulf, but we need him here. Brazil is one of the world's fastest-growing computer markets."

There you have it in a nutshell: foreigners, some of them U.S.-educated, copying—stealing, to be blunt—U.S. technology and reproducing it with protection from their own governments. An isolated development? No, this is the rule, not the exception, in much of the world. How, under such circumstances, can the U.S. expect to reap the fruits of its own science and technology?

Time was when technology spread slowly. Communications were sluggish and nations went to great lengths to keep technological innovations secret. In northern Italy 300 years ago, stealing or disclosing the secrets of silk-spinning machinery was a crime punishable by death. The machines were reproduced in England by John Lombe only after he spent two years at risky industrial espionage in Italy. At the height of the Industrial Revolution, Britain protected its own supremacy in textile manufacture through laws banning both exports of machines and emigration of men who knew how to build and run them.

These embargoes on the export of technology were eventually breached. France sent industrial spies to England and paid huge sums to get British mechanics to emigrate. By 1825 there were some 2,000 British technicians on the European continent, building machines and training a new generation of technicians. A young British apprentice, Samuel Slater, memorized the design of the spinning frame and migrated to the U.S. in 1789, later establishing a textile factory in Pawtucket, R.I. So, in the end, the technology became commonplace, but it took decades, and, in the meantime, England was profiting handsomely from its pioneering.

Not so today, when 30% of the students at MIT are foreigners, many destined to return to their native lands and apply what they learn of U.S. technology. What once was forbidden, today is encouraged. Come share our knowledge.

Consider the case of Lisiong Shu Lee, born in Canton, China in 1949, raised in Rio de Janeiro, now product planning manager for SID Informatica, one of Brazil's big three computer companies. Like many leading Brazilian computer technicians, Lee is an engineering graduate of the Brazilian air force's prestigious Aerospace Technical Institute near São Paulo. Born in China, raised in Brazil, educated in the U.S. "When I was only 24," Lee says, "I was sent to the U.S. to debug and officially approve the software for the Landsat satellite surveys devised by Bendix Aerospace." Lee later worked eight years with Digital Equipment's Brazilian subsidiary.

Like Microtec's Elias, Lee had learned most of what he knew from the Americans. In teaching this pair—and tens of thousands like them—U.S. industry and the U.S. academies created potential competitors who knew most of what the Americans had painfully and expensively learned. Theft? No. Technology transfer? Yes.

In Brazil over the past few years, the Syrian-born, U.S.-educated Elias played cat-and-mouse with lawyers representing IBM and Microsoft over complaints that Microtec and other Brazilian personal computer makers have been plagiarizing IBM's BIOS microcode and Microsoft's MS-DOS operational software used in the IBM PC. The case was settled out of court. Brazilian manufacturers claimed their products are different enough from the original to withstand accusations of copyright theft.

Where theft and copying are not directly involved in the process of technology transfer, developing countries find ways to get U.S. technology on terms that suit them. They get it cheaply. Before President José Sarney departed for his September visit to Washington, the Brazilian government tried to ease diplomatic tensions by announcing approval of IBM's plans to expand the product line of its assembly/test plant near São Paulo. IBM will invest $70 million to develop Brazilian capacity for producing the 5-gigabyte 3380 head disk assembly (HDA).

Ah, but there is a tradeoff involved in the seeming concession by the Brazilians. The tradeoff is that IBM's expansion will greatly improve the technical capabilities of local parts suppliers to make a wider range of more sophisticated products. About a third of the key components in IBM's HDA catalog will be imported, but Brazilian suppliers will get help in providing the rest, some involving fairly advanced technologies.

But does what happens in Brazil matter all that much? Brazil, after all, is a relatively poor country and accounts for a mere $3 billion in the U.S.' $160 billion negative trade balance. Brazil matters very much. For one thing,

Photos by Paulo Fridman/Sygma

Microtec's personal computer factory in São Paulo
Designs cribbed from IBM technical manuals, but different enough to withstand accusations of copyright theft.

Mictrotec founder Touma Makdassi Elias
From Syria to São Paulo via Silicon Valley.

Newsstand in São Paulo
Plenty of reading choices for computer hackers, too.

what happens there happens in similar ways in other developing countries—and some developed ones as well. Brazil, moreover, is fast adapting to the computer age. The Brazilian computer industry employs over 100,000 people. It includes everything from the gray market of São Paulo's Boca de Lixo district to the highly profitable overseas subsidiaries of IBM and Unisys. Both subsidiaries have been operating in Brazil for more than six decades and, for the time being, have been profiting from Brazil's closed-market policies. It includes many manufacturer/assemblers of micro- and minicomputers and of peripherals. Companies also are appearing that supply such parts as step motors for printers and disk drives, encoders, multilayer circuit boards, high-resolution monitors, plotters and digitizers. The Brazilian market is bristling with new computer publications: two weekly newspapers, ten magazines and special sections of daily newspapers.

Brazil is only a few years into the computer age. Its per capita consumption of microchips works out to only about $1.40 per capita among its 140 million inhabitants, vs. $100 in Japan, $43 in the U.S. and about $6 in South Korea. But given the potential size of the market and Brazil's rapid industrialization, it could one day absorb more personal computers than France or West Germany.

The point is simply this: In their natural zeal to make Brazil a modern nation rather than a drawer of water and hewer of wood, its leaders are determined to develop high-technology industry, whether they must beg, borrow or steal the means. Failing to develop high-technology industry would be to court disaster in a country where millions go hungry. But in doing what they must, the leaders of Brazil and other developing countries run strongly counter to the economic interests of the U.S.

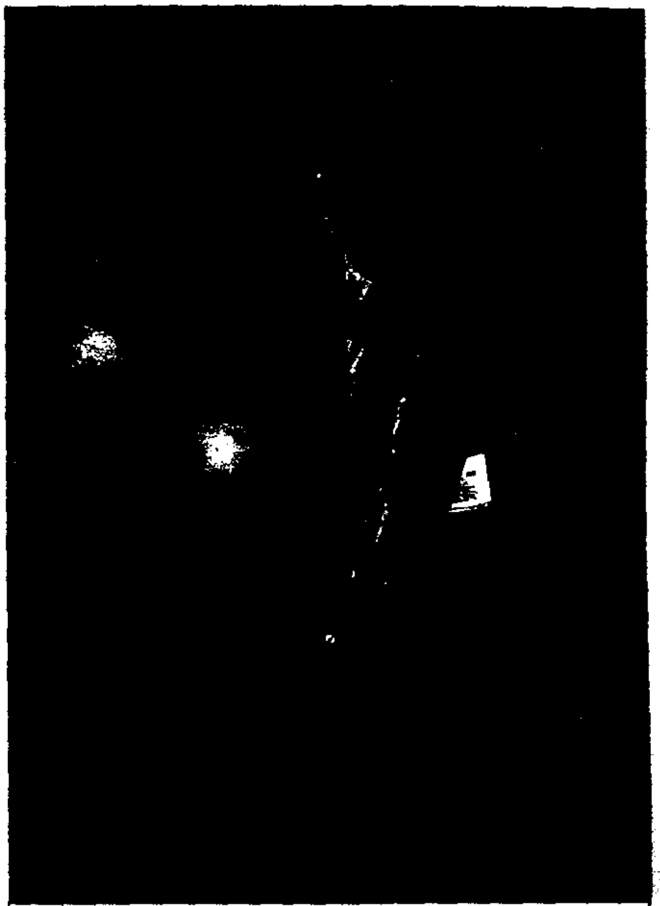
Because of these nationalistic policies, foreign-owned firms are banned from competing in Brazil's personal computer and minicomputer market. Brazil's computer industry is not high tech, if that means being near the cutting edge of worldwide technological advance. But it does show the ability of Brazilian businessmen and technicians to shop for and absorb standard technology, without paying development costs. In computers, where knowledge is the most expensive component, it becomes cheap to manufacture if you get the knowledge free or almost free. The U.S. develops, Brazil copies and applies. There are perhaps a dozen Brazils today.

"We're a late entry and can pick the best technology," says Ronald Leal, 36, co-owner of Comicro, a CAD/CAM equipment and consulting firm. "We don't waste money on things that don't work. In 1983 we saw a market here for CAD/CAM done with microcomputers. We shopped around the States and made a deal with T&W Systems, a $10 million California company that has 18% of the U.S. micro CAD/CAM market. T&W helped us a lot. We sent people to train and they came to teach us."

Comicro learned fast. Says Leal: "We developed new software applications that we're now exporting to T&W."

Brazil exporting computer designs to the U.S.? Only five years after IBM began creating a mass market for the personal computer, the U.S. home market is being invaded by foreign products—of which Comicro's are only a tiny part. Technological secrets scarcely exist today.

Aren't the Brazilians and the others simply doing what



Lisiong Shu Lee of SID Informatica
Theft? No. Technology transfer? Yes.

the U.S. did a century and a half ago—protecting its infant industries?

If that were all, the situation might not be so serious for the U.S. But pick up any U.S. newspaper these days and count the advertisements for Asian-made personal computers claiming to be the equivalent of the IBM PC but selling at maybe two-thirds of IBM's price.

According to Dataquest, a market research firm, Asian suppliers will produce nearly 4.5 million personal computers this year. At that rate, they should capture one-third of the world market by next year. Taiwan now is exporting 60,000 personal computer motherboards and systems monthly, 90% of which are IBM-compatible. Of these, 70% go to the U.S. and most of the rest to Europe. Korea, Hong Kong and Singapore together ship another 20,000 each month.

Dataquest says it takes only three weeks after a new U.S.-made product is introduced before it is copied, manufactured and shipped back to the U.S. from Asia.

Thus the U.S. bears the development costs while foreigners try to cream off the market before the development costs can be recouped. That is the big danger. The days when a person could be executed for industrial espionage are gone.

President Reagan recently warned that the U.S. is being victimized by the international theft of American creativity. Too many countries turn a blind eye when their citizens violate patent and copyright laws. In 1985-86 U.S. diplomats successfully pressured Korea, Singapore, Malaysia, Taiwan, Hong Kong and Thailand to pass or at least to draft legislation enforcing patents and copyrights more strictly. Brazil is a major holdout.

The difficulties between Brazil and the U.S. over computers crystallized in the 1984 Informatica law, which Brazil's Congress passed overwhelmingly near the end of two decades of military rule. The law, in effect, legalizes stealing—so long as the victims are U.S. technology exporters. Complains the head of a leading multinational whose business has been curtailed under the new law: "They want our technology but want to kill our operations. This whole show is sponsored by a handful of sharp businessmen with connections in Brasília who are making piles of money from their nationalism."

The new law formally reserved the Brazilian micro- and minicomputer market for wholly owned Brazilian firms. It allowed wholly owned subsidiaries of foreign companies—IBM and Unisys—to continue importing, assembling and selling mainframes, but not out of any sense of fairness. It was simply that Brazilian companies were unable to take over that end of the business.

Under the law, joint ventures with foreign firms were allowed only if Brazilians owned 70% of the stock and had "technological control" and "decision control."

The main instruments for implementing this policy were tax incentives and licensing of imports of foreign hardware and knowhow, all to be approved by the secretariat of information science (SEI).

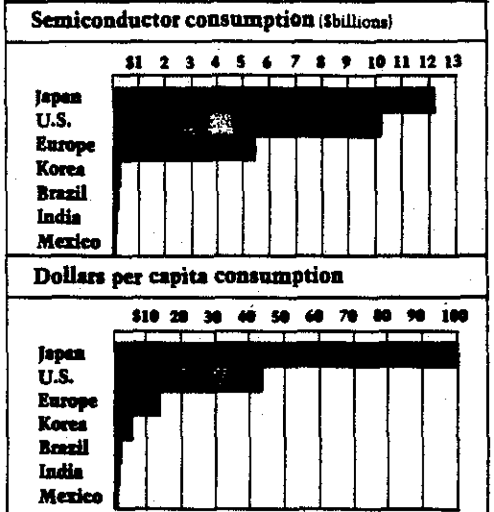
In 1981 Brazil's then-military government decreed that SEI would control the computer and semiconductor industries and imports of any and all equipment containing chips. The implications are especially ominous for U.S. interests: Brazil's SEI is modeled, quite openly, on Japan's notorious Ministry of International Trade & Industry (MITI). Brazil's computer policy today follows the line of a mid-Fifties report by MITI's Research Committee on the Computer.

In the 1950s and 1960s MITI used Japan's tight foreign exchange controls to ward off what its nationalist superbureaucrat of the day, Shigeru Sahashi, called "the invasion of American capital." In long and bitter negotiations in the late Fifties, Sahashi told IBM executives: "We will take every measure to obstruct the success of your business unless you license IBM patents to Japanese firms and charge them no more than 5% royalty." In the end, IBM agreed to sell its patents and accept MITI's administrative guidance on how many computers it could market in Japan. How many Japanese products would be sold in the U.S. today if this country had imposed similar demands on the Japanese?

Some U.S. economists are describing the result of the Japanese policy as the "home market effect." They mean that protectionism in the home market tends to create an export capability at low marginal cost.

Where the chips fall

No matter how you slice it, per capita or by dollar volume, most of the world's semiconductors go to the U.S., Japan and Europe. Don't be misled, though. The smaller markets matter, especially to the governments that work so hard to protect them.



"Home market protection by one country sharply raises its firms' market share abroad," says MIT's Paul Krugman, reporting the results of computer simulations of international competition in high technology. "Perhaps even more surprising, this export success is not purchased at the expense of domestic consumers. Home market protection lowers the price at home while raising it abroad."

Brazil surely has similar intentions. IBM and other U.S. computer companies are transferring technology to Brazil as never before.

The Brazilians may have grasped a reality that the U.S. has been unable politically to address: that while there is no way to check the fast dissemination of technology today, the real prize in the world economy is a large and viable national market—a market big enough to support economies of scale and economies of specialization. In short, while a country can no longer protect its technology effectively, it can still put a price on access to its market. As owner of the world's largest and most versatile market, the U.S. has unused power.

Taiwan, Korea, Hong Kong and Singapore, lacking large internal markets, could develop only because they had easy and cheap access to the rich U.S. market.

Why doesn't the U.S. reciprocate? The Reagan Administration has threatened to restrict imports of Brazilian exports to the U.S. by Dec. 31 if Brazil doesn't 1) protect software with new copyright legislation, 2) allow more joint ventures with foreign firms, and 3) publish explicit rules curtailing SEI's arbitrary behavior.

But the Brazilians are hardly trembling in their boots. Brazilian officials hint that if Brazilian exports to the U.S. are curbed, Brazil won't be able to earn enough dollars to service its crushing external debt. Diplomats of both countries want to avoid a showdown, so they keep talking. And while they talk, the Brazilians do what they please.

U.S. Customs has responded to manufacturers' complaints by stopping pirated products at the border. But the Taiwanese now have such cost advantages that they can easily afford to license technology that they have already copied. The Koreans are more scrupulous, but pirated technology not reexported to the U.S. is very hard to control.

More than three years ago Edson de Castro, president of Data General, told a Commerce Department panel that foreign nations' computer policies "threaten the structure and future of the U.S. computer industry." De Castro explained why: "U.S. computer companies are reliant on international business and derive a substantial portion of revenues from exports. Because of the rapid pace of technological development, the industry is capital intensive. Growth and development rely heavily on an expanding revenue base. This can only come from full participation in established and developing global markets. Reliance upon domestic markets is not enough."

Yet after resisting the Brazilian government's demands for a decade, de Castro's Data General is selling technology for its Eclipse supermini to Cobra, the ailing government computer company. Other U.S. computer manufacturers are following suit.

Hewlett-Packard, in Brazil since 1967 with a wholly owned subsidiary to import and service the company's products, has just shifted its business into partnership with Iochpe, a Brazilian industrial and finance group. A new firm, Tesis, 100% Brazilian-owned, will make HP calculators and minicomputers under its own brand name.

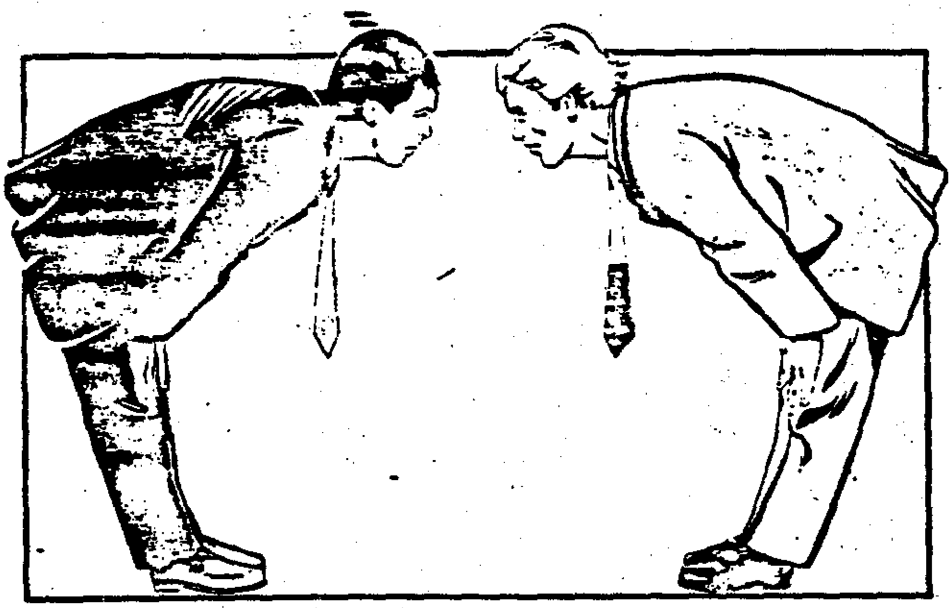
"Only a few years ago HP refused to enter joint ventures, but now we have ones going in Mexico, China, Brazil and Korea," says a company executive. "In the past we felt, since we owned the technology, why share the profits? Then we found we couldn't get into those foreign markets any other way."

Harvard Professor Emeritus Raymond Vernon, a veteran analyst of international business, says of world technology markets: "Except for highly monopolistic situations, the buyer has a big advantage over the seller. Countries like Brazil and India can control the flow of technology across their borders and then systematically gain by buying technology cheaply."

Vernon draws an ominous parallel: "A century ago the multinationals were in plantation agriculture and electric power. Now they're all gone because their technology and management skills were absorbed by local peoples. The same thing is happening in other fields today, including computers."

This is why it makes little difference whether the dollar is cheap or dear. In this mighty clash between nationalism and free trade, nationalism seems to be winning. Where does this leave the U.S. dream of becoming high-technology supplier to the world? Rudely shattered. ■

HIGH TECHNOLOGY



Clash of the titans

After steel, motor cars, consumer electronics and cheap microchips, Japan has begun to challenge American pre-eminence in the one industrial area the United States has long cherished as its own: high technology. The two are girding up for a trade war in high-tech that threatens to be bloodier than anything yet. Nicholas Valéry reports on the strengths and weaknesses of the two technological superpowers

The recent movie "Gung Ho" gets a lot of laughs out of the many misunderstandings that ensue when a Japanese car firm moves into a sad little town in Pennsylvania. Stereotypes abound: dedicated Japanese managers putting in double shifts, lazy American loudmouths slowing down the assembly line—with the locals winning a baseball match between the two sides only through brute force and intimidation.

All good clean fun. In real life, however, American workers—despite the popular myth—remain the most productive in the world (see the feature on the next page). In terms of real gross domestic product (GDP) generated per employed person, the United States outstrips all major industrial countries, Japan included (chart 1). The problem for Americans is that the rest of the world has been catching up. In the decade from the first oil shock to 1983, increases in annual productivity in the United States had been roughly a seventh of those of its major trading partners.

In the 1960s, American companies held all the technological high cards and dominated the world's markets for manufactured goods. The United States supplied over three-quarters of the television sets, half the motor cars and a quarter of the steel used around the world. Yet, a mere two decades later, Japan had taken America's place as the dominant supplier of such products.

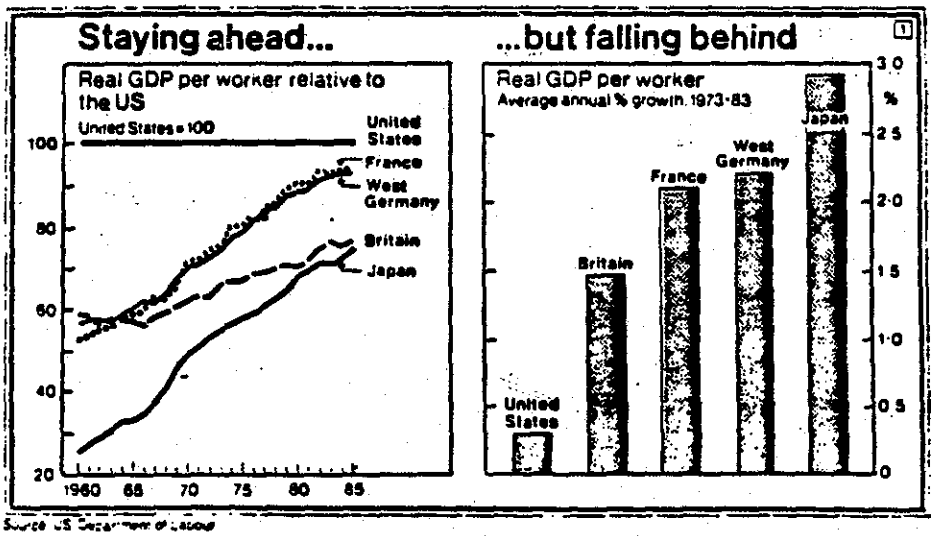
The agony for Americans does not end there. Over the past 25 years they have seen:

- Their share of world trade fall from 21% in 1960 to 14% in 1985.
- The American trade balance go from a surplus of $5 billion in 1960 to a deficit of $150 billion last year.
- More worryingly still, the country's trade balance in manufactured goods slip from a healthy surplus of $11 billion as recently as 1981 to a deficit of $32 billion last year—approaching 1% of America's total output.
- The volume of its manufacturing exports tumble 32% over the past five years—with every $1 billion of exports lost costing an estimated 25,000 American jobs.

Angry and confused, businessmen in the United States have had to stand by and watch as "smokestack" industry all around them has been snuffed out. Then came the unthinkable: if the Japanese could thrash them in mainstream manufacturing, would they give them a mauling in high technology, too?

By the beginning of the 1980s, it began to look as if they would. It became clear that the Ministry of International Trade and Industry (MITI) in Tokyo had "targeted" not just semiconductors and computers but all of America's high technology industries—from aerospace to synthetic materials—for a blitzkrieg attack.

Six years on, Japan has scored some



Source: US Department of Labour

Power to the elbow

Americans work every bit as hard as (and often a lot harder than) the Japanese—and generate proportionately more wealth in the process. The average output of American workers last year was $36.800. The Japanese equivalent was $22.500 (at an average 1985 exchange rate of Y220 to the dollar).

But labour productivity is only half the story. The amount of capital applied to a worker's elbow is crucial, too. The traditional definition of productivity (output per hour of all workers) makes it difficult to measure these inputs separately. True, the definition reflects all the factors that contribute to rising output—from advances in technology, better utilisation of capacity, improvements in the way production is organised and sharper management, to harder efforts by the workers themselves as well as the impact of changes in the amount of capital employed.

In 1983, the American Bureau of Labour Statistics introduced a yardstick called multifactor productivity. This shows the changes in the amount of capital as well as labour used in production. Reworking its data for 1950-83, the bureau found that multifactor productivity in the United States increased at an average annual rate of 1.7% for the period. As output per hour over the same period increased by an annual 2.5%, capital productivity inched up by only a modest 0.8% a year.

Overall, America's multifactor productivity has shown two distinct trends over the past 35 years. Up till the first oil shock of 1973, the country experienced an annual 2% multifactor growth: then an annual average of only 0.1% from 1973 to 1981. The post-OPEC slowdown seems to have resulted from high interest rates keeping the brakes on capital spending, while more people were having to work longer hours to hang on to their jobs.

How did the Japanese fare? The driving force behind the Japanese economy over the past 25 years has been the high growth in capital input. Mr Dale Jorgenson and his colleagues at Harvard University reckon it has been roughly double that in the United States. Growth rates in labour productivity have been much the same for the two countries. All told, the growth in Japanese productivity outstripped that in the United States until 1970, when productivity growth began to slow dramatically in Japan. Thereafter, with Vietnam behind it and two oil shocks ahead, the American economy flexed its muscles and coped more effectively. Then the competitive advantage started to move back in America's favour.

The interesting thing is what has happened since the last recession. Multifactor productivity in the United States has been running at an average of 5% a year, while the growth in labour productivity is now averaging nearly 4% a year. That means that productivity of capital employed is now growing at well over 6% a year.

Could this be the first signs of the productivity pay-off from the $80 billion that Detroit spent on new plant and equipment over the past half dozen years; the combined (additional) $180 billion invested by the airlines since deregulation, telecommunications firms since the AT&T consent decree and the Pentagon since President Reagan's defence build-up began in 1980? It looks remarkably like it.

notable hits. A group of American economists and engineers met for three days at Stanford University, California, last year to assess the damage*. They concluded that Japanese manufacturers were already ahead in consumer electronics, advanced materials and robotics, and were emerging as America's fiercest competitors in such lucrative areas as computers, telecommunications, home and office automation, biotechnology and medical instruments. "In other areas in which Americans still hold the lead, such as semiconductors and optoelectronics, American companies are hearing the footsteps of the Japanese", commented the Stanford economist Mr Daniel Okimoto.

How loud will those footsteps become? American industry may have been deaf in the past, but it certainly isn't any more. And never forget that Americans are a proud and energetic people. More to the point, they are prone to periodic bouts of honest self-reflection—as if, throughout their two centuries of nationhood, they have been impelled forward by a "kick up the backside" theory of history.

Once every couple of decades, America has received a short and painful blow to its self-esteem; Pearl Harbour, Sputnik, Vietnam are recent examples. What follows then is usually a brief and heart-searching debate along with a detailed analysis of the problem, then an awesome display of industrial muscle coupled with unexpected consensus between old adversaries—most notably between Congress, business and labour.

With its ceaseless shipments of cameras, cars, television sets, video recorders, photocopiers, computers and microchips, Japan unwittingly supplied the latest kick up the broad American buttocks. After witnessing Japanese exporters almost single-handedly reduce Pittsburgh's steel industry to a smouldering heap, drive Detroit into a ditch, butcher some of the weaker commodity microchip makers of Silicon Valley, and threaten America's remaining bastions of technological clout—aircraft and computers—then, and finally then, American lethargy ceased.

This survey tries to assess the strengths and weaknesses of the world's two technological superpowers. For if the past decade has seen some of the ugliest recrimination between Washington and Tokyo over trade issues generally, imagine what the coming decade must have in store. Henceforth, industrial competition between America and Japan is going to range fiercely along the high-tech frontier—where both countries take a special pride in their industrial skills and cherish sacred beliefs about their innate abilities.

The question that ultimately has to be answered is whether America is going to allow the Japanese to carry on nibbling away at its industrial base without let, hindrance or concession? Or are the Americans (as some bystanders have begun to suspect) "about to take the Japanese apart"?

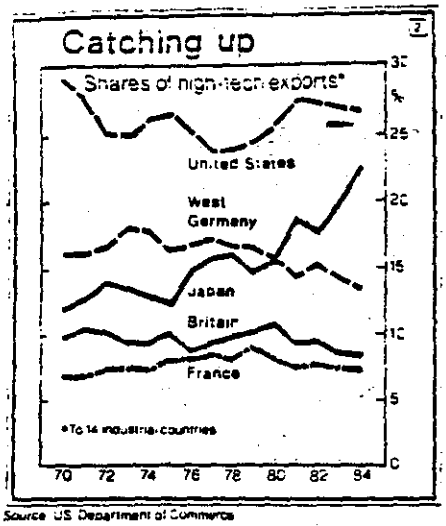
With the gloves now off, which of the two technological heavyweights should one put some money on? In the blue corner, Yankee ingenuity? In the red, Japanese production savvy?

*Symposium on Economics and Technology held at Stanford University, March 17-19 1985. Now published as "The Positive Sum Strategy: Harnessing Technology for Economic Growth" by National Academy Press, Washington, DC.

Copycat turns leader?

Is Japan still a technological free-loader—or has it become a pacesetter in high-tech?

America may still have the largest share of high technology exports, but Japan is catching up fast. It skipped smartly past West Germany to become the second largest supplier of high-tech goods in 1980 (chart 2 on next page). Only in three high-tech industries—communications and electronics, office automation, and ordnance—have American companies increased their market share.



Source: US Department of Commerce

The Japanese know they do not have a chance in fields that are either defence-related (for example, weapons, aircraft, satellites and avionics) or too dependent on imported energy or raw materials (like petrochemicals). But they see everything else as up for grabs. Even in lasers, software and computer-integrated engineering—where American pre-eminence was long thought unassailable—the Japanese have begun to make inroads.

Who would have thought it possible a decade ago? Of the 500 breakthroughs in technology considered seminal during the two decades between 1953 and 1973, only 5% (some 34 inventions) were made in Japan compared with 63% (315 inventions) in the United States. Despite its large, well-educated population, Japan has won only four Nobel prizes in science; American researchers have won 158. It is not hard to see why Japan has been considered more an imitator than innovator.

Stanford University's Mr Daniel Okimoto lists half a dozen reasons for Japan's lack of technological originality in the past:

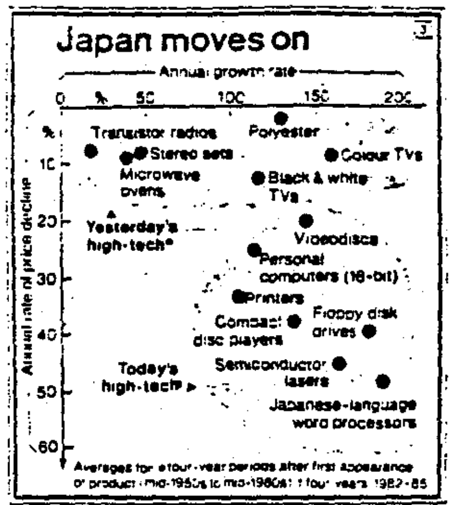
- As an industrial latecomer, it has always been trying to catch up.
- The Japanese tendency towards group conformity has made it difficult to win a hearing at home for radical ideas.
- Research in Japanese universities is bureaucratic, starved of cash and dominated by old men.
- The venture-capital market is almost non-existent.
- Lifetime employment, along with a rigid seniority system, stifles innovation inside industry.
- And the traditional heavy gearing (high debt-to-equity ratio) of much of Japanese industry has made firms think twice about taking risks.

All these things—and more—have been true to some extent in the past; but all are also changing. The deregulation of Tokyo's financial markets, for instance, is forcing Japanese companies to reduce their levels of debt (see accompanying feature on next page). This, in turn, is making them more adventurous, while at the same time helping ferment a number of venture-capital funds.

Japan's "invisible" balance of technological trade (its receipts compared with payments for patent royalties, licences, etc) which had a ratio of 1:47 a couple of decades ago came within a whisker of being in balance last year. That said, Japan still buys its high-tech goods and knowhow predominantly in the West and sells them mainly to the developing world.

In certain industries, however, Japanese manufacturers have already started bumping their heads against the ceiling of current knowhow. There are no more high-tech secrets to be garnered from abroad in fibre optics for telecommunications, gallium arsenide memory chips for superfast computers, numerically-controlled machine tools and robots, and computer disk-drives, printers and magnetic storage media. In all these, Japan now leads the world. Today, Japanese-language word processors represent the cutting edge of high-tech in Japan—taking over the technological (but hardly export-leading) role that colour television played earlier (chart 3).

Although it is no longer quite the technological free-loader it was in the past, is Japan's new reputation as a pace-setter in high-tech justified? A new image has certainly emerged over the past few years of Japan as an invincible Goliath, capable of vanquishing any rival, whatever the field. Yesterday, the smokestack



Source: Mitsubishi Bank

sectors. Today, high technology. Tomorrow, services... "Which is the 'real' Japan?" asks Mr Okimoto:

> **Is it a technological imitator and industrial over-achiever? Or is Japan an astute learner and unbeatable colossus? Will Japan dislodge the United States from its current position of dominance in high technology as convincingly as it did in the smokestack sectors? Or has it reached the limits of its phenomenal postwar growth?**

Japan is all these things and more. And to understand what the future holds, and whether America is up against a David or a Goliath, means looking closely at the frontiers of modern electronics. For the country that commands the three most crucial technologies of all—semiconductors, computing and communications—will most assuredly command the mightiest industrial bandwagon of the twenty-first century.

Made in the USA

Just as Japan has begun to muscle into high-tech, America has raised the technological stakes. The name of the game now is ultra-tech

High technology is an American invention. Despite the near meltdown at Three Mile Island, broken helicopters in the Iranian desert and recent disasters on the launch pad, Americans remain the supreme practitioners of this demanding and arcane art. And while the United States has racked up large deficits on its international trading account, it has enjoyed growing surpluses in its worldwide sales of high-tech goods. Or, rather, it did so until recently. Once again, blame the Japanese.

Five years ago, America sold the world $23.6 billion more technological widgets than it bought. That handy surplus had dwindled, says America's Department of Commerce, to a token $5 billion by 1984 (chart 7 on later page). Meanwhile, foreigners had grabbed three-quarters of the world's current $300 billion in high-tech trade. In the process, Japan has gone from being a small-time tinkerer in the 1960s to becoming (as in everything else) the Avis of high technology to America's Hertz.

Even so, trade in high-technology goods remains a crucial breadwinner for the United States. Since the mid-1960s, high-tech's share of American manufactured goods sold around the world has gone from a little over a quarter to close to a half.

Office automation is now America's most competitive high-tech industry as well as its biggest revenue-earner abroad. Selling its trading partners computers, copiers and word processors brought in

Crying all the way to the bank

One thing Americans have learned is that having the world's most productive labour force does not guarantee industrial competitiveness. At least three other things are needed. The first is to keep a lid on wages. The second concerns exchange rates. The third involves the return on capital employed. All three have been seen lately as spanners in the American works.

Take wages. During the ten years before 1973, real wages for American workers had increased steadily at an average rate of 2.6% a year. But ever since the first oil shock, real wages in the United States have stagnated. So American labour is becoming more competitive, yes?

Unfortunately no. When fringe benefits are included, hourly compensation for blue-collar workers in the United States has continued to rise. American labour has sensibly been taking raises less in cash than kind. Total compensation for American industrial workers—a modest $6.30 an hour in 1975—had climbed to $9.80 an hour by 1980 and to $12.40 by 1983.

Compared with Japan, hourly labour costs in America went from being on average a little over $3 more expensive in 1975 to becoming nearly $6 more so by 1983 (chart 4). So much for narrowing the $1,900 gap between making a motor car in Nagoya compared with Detroit.

Ah, yes, but hasn't the dollar tumbled dramatically? It has indeed—from a 1985 high of over Y260 to the dollar to a low this year of Y150 or so. In trade-weighted terms, that represents a drop for the dollar of 28% in 15 months. Meanwhile, the trade-weighted value of the yen has appreciated by over 40%.

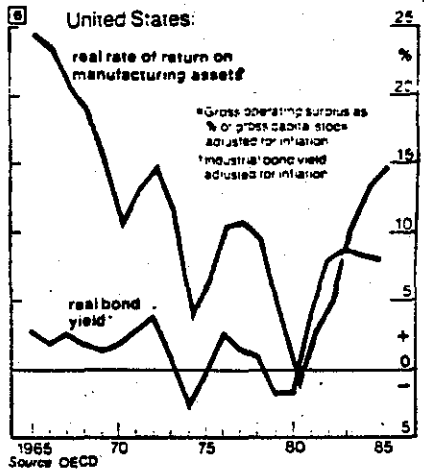
What about differences between America and Japan in terms of return on capital? Here things are actually better than most American businessmen imagine. True, real rates of return earned by American manufacturing assets in the 1960s were substantially higher than investments in financial instruments, while things were briefly the other way round during the early 1980s (chart 6). On the face of it, capital for buying equipment or building factories seems twice as expensive in America as in Japan.

Today's most cited account comes from Mr George Hatsopoulos of Thermo Electron Corporation in Massachusetts. Comparing the cost of (non-financial) capital in the two countries between 1961 and 1983, Mr Hatsopoulos found real pre-tax rates ranged between 6% and 10% for Japanese firms and anything from 13% to 20% for their American counterparts.

The conventional explanation for this difference is that Japanese firms are more highly geared (leveraged) and thus benefit because debt generally costs less than equity—interest payments being deducted from pre-tax profits, while dividends come out of taxed earnings.

Then there is Japan's two-tier interest rate structure, which is carefully regulated to favour business debt at the expense of consumer credit. Throw in a banking system that is bursting at the seams with yen being squirrelled away by housewives worried about school fees, rainy days and the ever-present threat of their husband's early (and often unpensioned) retirement. All of which, say American trade officials, adds up to a financial advantage that makes it tough for American firms to compete.

What is studiously ignored in the financial folklore about Japan Inc is the fact that, over the past decade, Japanese manufacturers have been getting out of debt as fast as decently possible (see the survey on corporate finance in *The Economist*, June 7 1986). The most compelling reason right now is because Tokyo's financial markets have joined the fashionable trend towards liberalisation. With old controls over the movement of capital going out of the window, Japanese interest rates are destined to become more volatile. So who wants to be highly geared when interest rates are rising or (worse) becoming less predictable?



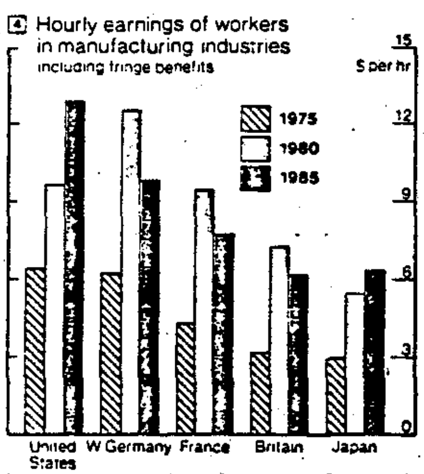
Source: OECD

Another thing Japanese manufacturers resent about some of these allegedly cheap industrial loans are the strings and hidden costs involved. The most punishing are the so-called "compensating balances" which a borrower has to deposit (at a considerably lower interest rate) with the bank offering the industrial loan. And so he has to borrow more money—at higher cost and with greater restrictions—than he actually needs.

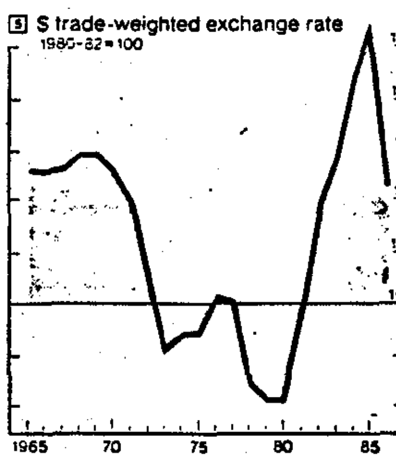
Yet another thing that muddies the water is the way debt in Japanese balance sheets is grossly overstated by western standards. For one thing, the compensating balances, though they are actually deposits, are recorded as borrowings. Then there is the habit Japanese companies have of doing much of their business on credit, especially with suppliers and subsidiaries. This makes their accounts payable and receivable look huge—in fact, twice as large as in America.

Other factors inflating debt among at least the bigger Japanese companies are things like non-taxable reserves for special contingencies and (if they pay them) pensions. The last time figures were collected in Japan (in 1981), employees in large corporations with established retirement plans were divvying up 15-20% of their companies' capital through their pension contributions. All of which showed up in their corporate accounts as debt.

All that said, Japanese companies are on balance more highly geared than American corporations; and, overall, the cost of financing industry has been lower in Japan than in the United States. But at most only 20% lower, and nothing like the 50% lower claimed by lobbyists in America.



Source: US Department of Labour, Bureau of Labour Statistics, 1984



Source: DRI

Technology's top ten

How high is the high in high-tech? Difficult to say. Most economists at least agree that high technology products embody an "above average" concentration of scientific and engineering skills. As far as the National Science Foundation in Washington is concerned, this means anything produced by organisations employing 25 or more scientists and engineers per 1,000 employees and spending over 3.5% of net sales on R&D.

The American Department of Commerce is a bit more scientific. Its definition of high-tech is derived from input-output analyses of the total R&D spent on a spectrum of individual products. Thus an aircraft gets credit for not only the R&D done in developing the airframe, but also the relevant contribution of the avionics supplier and even the tyre maker. Using this definition, high-tech industry is a ranking of the ten most "research-intensive" sectors, where the tenth has at least double the R&D intensity of manufacturing generally (table 1).

A laudable effort, but not without criticism. First, such a definition focuses entirely on products, ignoring the booming business in high-tech processes—and, increasingly, high-tech services as well. Second, it favours systems (that is, collections of interdependent components) over individual widgets, as well as products manufactured by large companies rather than small firms.

Third, because the data come of necessity from broad industrial categories, anomalies crop up—like cuckoo clocks being labelled high-tech because they fall within the eighth-ranking group, professional instruments.

Fourth, and perhaps most damning, the Commerce Department's definition is based on Standard Industrial Classification (SIC) codes—many of which have been rendered irrelevant by technological changes that have occurred since the SIC codes were last overhauled in 1972.

Table 1: Product range

	HIGH-TECH SECTOR	EXAMPLES OF PRODUCTS
1	Missiles and spacecraft	Rocket engines; satellites and parts
2	Electronics and telecoms	Telephone and telegraph apparatus, radio and TV receiving and broadcast equipment, telecoms equipment, sonar and other instruments, semiconductors, tape recorders
3	Aircraft and parts	Commercial aircraft, fighters, bombers, helicopters, aircraft engines, parts
4	Office automation	Computers, input-output devices, storage devices, desk calculators, duplicating machines, parts
5	Ordnance and accessories	Non-military arms, hunting and sporting ammunition, blasting and percussion caps
6	Drugs and medicines	Vitamins, antibiotics, hormones, vaccines
7	Inorganic chemicals	Nitrogen, sodium hydroxide, rare gases, inorganic pigments, radioactive isotopes and compounds, special nuclear materials
8	Professional and scientific instruments	Industrial process controls, optical instruments and lenses, navigational instruments, medical instruments, photographic equipment
9	Engines, turbines and parts	Generator sets, diesel engines, non-automotive petrol engines, gas turbines, water turbines
10	Plastics, rubber and synthetic fibres	Various chemicals derived from condensation; polycondensation, polyaddition, polymerisation and copolymerisation; synthetic resins and fibres

$20 billion in 1984. Along with aircraft, electronics and professional instruments, these "big four" account for more than three-quarters of the United States' exports of high technology (table 2). Despite the popular myth, America exports only modest amounts of missiles and aerospace products. But fears that foreigners may eventually storm even the high frontier of aerospace keep Washington officials awake at night.

Of the ten industrial sectors designated high-tech (see feature above), America has managed to increase its share of the global market in only two: office automation and electronics. For which, it should thank the likes of IBM, Hewlett-Packard, Digital Equipment, Xerox, ITT, RCA, General Electric, Texas Instruments and a host of brainy technological-based businesses scattered around the West Coast, Rockies, Sunbelt, Mid-Atlantic and New England.

A common cry in Washington is that this "narrowing" of America's high-tech base is one of the most disturbing problems facing the United States today. Others see this trend as more or less inevitable—and perhaps even to be encouraged. Trade ministers in Western Europe, for instance, only wish they had such "problems"; Japanese bureaucrats are doing all they can to create similar "problems" back home.

The reason is simple. These so-called "problems" concern a focusing of all the underlying technologies that have come to drive the computing, office automation and communications industries. All three provide the tools for handling information; and information—its collation, storage, processing, transmission and use elsewhere—will, quite literally, be the oil of the twenty-first century (see the survey on information technology in *The Economist*, July 12 1986).

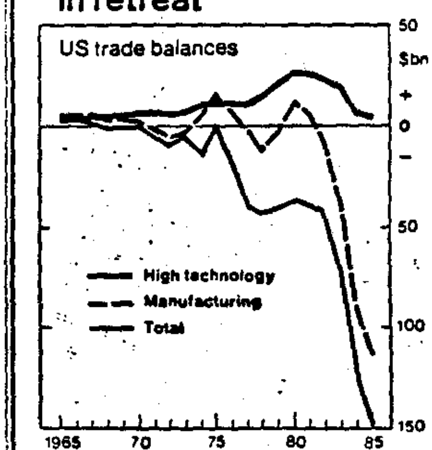
All that noisy jostling going on right now between the IBMs, Xeroxs and AT&Ts of the corporate world is merely the

Table 2: High-tech exports in 1984

High-tech sector	American exports		Others' exports*	
	Value	% of total	Value	% of total
Office automation	$19.7bn	22.4	$6.5bn	14.5
Electronics & telecoms	$14.4bn	22.0	$53.8bn	29.4
Aircraft and parts	$13.5bn	20.7	$15.4bn	8.4
Profess'l instruments	$7.2bn	11.0	$27.0bn	14.7
Plastics, rubber, etc	$4.4bn	6.7	$26.5bn	14.5
Inorganic chemicals	$3.5bn	5.4	$10.9bn	6.0
Engines and turbines	$3.2bn	4.9	$10.7bn	5.9
Drugs and medicines	$2.7bn	4.1	$10.7bn	5.9
Missiles and spacecraft	$1.0bn	1.5	$0.6bn	0.3
Ordnance	$0.8bn	1.3	$0.7bn	0.4

*Of the 14 other countries (apart from America) exporting high-tech goods, France, West Germany, Japan and Britain accounted for three-quarters of total trade.
Source: US Department of Commerce

In retreat



Source: US Department of Commerce

clatter of these three industrial sectors (each with its own distinctive style of manufacturing, procurement and customer support) being forged together by their underlying technologies into a single, ultra-tech activity called information services.

Yes, beyond high-tech in the industrial spectrum lies ultra-tech—today a mere multi-billion-dollar stripling of a business, but by the year 2000 potentially a trillion-dollar leviathan. As such, ultra-tech alone will come to dwarf all manufacturing sectors before the century is out. America is well on the way to making that happen. A lap or two behind, Japan at least is getting up speed. Europe is barely in the race.

Chips with everything

Gone are the days when American semiconductor firms short-sightedly sold their licences and knowhow to Japanese microchip makers

America's electronics firms have maintained their global leadership in all branches of their business save one. They kissed goodbye to consumer electronics (television, hi-fi, video recorders, etc) as customers across the country voted with their pockets for shiny boxes with flashing lights and labels like Panasonic, Technics, JVC and Sony.

The American electronics industry came close to allowing much the same to happen in microchips. In 1982, Silicon Valley took a caning when the Japanese started flooding the market with cheap 64k RAMs (random-access memory chips capable of storing over 64,000 bits of computer data). Most beat a hasty retreat up or out of the market.

From having a dozen mass producers of dynamic-RAMs in 1980, only five American chip makers were still in the high-volume memory business by 1983. Today, there are effectively only two or three with the capacity to produce the latest generation of memory chips (1 megabit RAMs) in anything like economic volumes. Meanwhile, the six Japanese firms that plunged into the memory-chip business back in the early 1970s are still around—and now have a 70% share of the dynamic-RAM market in America.

Microchips have been the engine powering Japan's drive into high-tech generally. But before it could join the microchip generation, Japan had to find a way of disseminating this vital American technology throughout its fledgling semiconductor industry. The trick adopted was, first, to protect the home market, and then to bully abler firms into joining government-sponsored research schemes—one run by the Japanese telephone authority NTT and the other by the Ministry of International Trade and Industry—to develop the knowhow for making their own very large-scale integrated (VLSI) circuits.

Next, by "blessing" VLSI as the wave of the future and crucial to Japan's survival, the government triggered a scramble among the country's electronics firms (encouraged by their long-term investment banks) to build VLSI plants. The net result was massive over-capacity (first in 64k RAMs and then in 256k versions), abundant local supply for the domestic consumer electronics makers and an impelling urgency to export (or dump) surplus microchips abroad.

This targeting ploy had been tried before. Japanese manufacturers found it worked moderately well with steel, much better with motorcycles, better still with consumer electronics and best of all with semiconductors. The only requirement was a steeply falling "learning curve" (that is, rapidly reducing unit costs as production volume builds up and manufacturers learn how to squeeze waste out of the process).

The trick was simply to devise a forward-pricing strategy that allowed Japanese manufacturers to capture all the new growth that their below-cost pricing created in export markets, while underwriting the negative cashflow by cross-subsidies and higher prices back home.

The Americans finally lost their patience when the Japanese tried to do a repeat performance with pricier memory chips called EPROMs. The price fell from $17 each when the Japanese first entered the American market with their EPROM chips early in 1985 to less than $4 six months later. Intel, National Semiconductor and Advanced Micro Devices promptly filed a joint petition, accusing the Japanese of dumping EPROMs on the American market at below their manufacturing costs in Japan (then estimated to be $6.30 apiece). The issue is currently being used by Washington as a battering ram to breach the wall Japan has erected around its own $8 billion semiconductor market back home.

For America, this get-tough policy has come only just in time. Japan now enjoys a 27% share (to America's 64%) of the world's $42 billion semiconductor market. And while cut-throat competition may make memory chips a loss-leader, acquiring the technology for producing RAMs has given Japan's microcircuit makers a leg-up in getting to grips with more complex semiconductors used in computer graphics, communications and video equipment.

So far, however, it has not helped Japanese chip makers to loosen the stranglehold that American semiconductor firms have on the lucrative microprocessor business. Where 256k RAMs have become commodity products that sell wholesale for $1 or so each, 32-bit microprocessors from the likes of Motorola, Intel, National Semiconductor, Texas Instruments, AT&T and Zilog cost hundreds of dollars apiece. Between them, these six American chip makers control 90% of the world market for the latest generation of microprocessors, leaving just 10% for the rest of the American semiconductor industry, Europe and Japan.

Fortunately for the Americans, micro-

Street map for a microchip circuit

processors are not like memory chips. Being literally a "computer-on-a-chip", they are vastly more complex and cannot be designed in any routine manner. Sweat, insight and inspiration are needed every step of the way. And they have to be designed with their software applications in mind. Americans have been doing this longer, and are better at it, than anyone else.

More to the point. American firms are not parting with their patents as readily as they did in the past. Hitachi has been trying (with little luck) to persuade Motorola to sell it a licence for making its advanced 68020 microprocessor. Meanwhile, Japan's leading electronics firm, NEC, is having to defend itself in the American courts for infringing one of Intel's microprocessor patents.

With America's new, stricter copyright laws making it difficult to imitate American designs. Japanese chip makers are being shut out of all the major markets for microprocessors. Fujitsu, Matsushita, Mitsubishi and Toshiba are all gambling on a microprocessor design called TRON developed at the University of Tokyo. But nobody, least of all NEC or Hitachi, holds out much hope for the TRON design winning a big enough share of the market in its own right to be economic—at least, not until the mid-1990s. And, by then, Silicon Valley will have upped the technological stakes again.

When, late at night, the conversation gets down to *honne* (brass tacks), even Japan's ablest microchip wizards despair at ever matching Silicon Valley's mix of entrepreneurial and innovative flair. "Japan is powerful in only one sub-field of a single application of semiconductors tied to a specific line of products", bemoans Mr Atsushi Asada of Sharp Corporation.

Calculus of competition

Aping IBM has given Japan's computer makers a toe-hold in the market—but largely on Big Blue's terms

America's response to Japan's challenge in microchips is being repeated in computers. Here, Japan's specialty has been making workalike copies of IBM's big office machines (mainframes). The most one can say about these "plug-compatible" computers is that they have managed to prevent IBM from swamping the Japanese home market completely. Big Blue has to put up with being number two in Japan. Overall, however, Japanese compatibles have had only a marginal impact on the $150 billion computer business worldwide.

American manufacturers have established an almost impregnable position in mainframes and minicomputers—the stuff of corporate sales and accounting departments. And in the push to put a microcomputer on every desk, a handful of American firms (IBM, Compaq, Apple, Atari and Commodore) have been feeding the market a feast of cleverer, faster and (in many cases) cheaper machines that have left Japan's "IBMulators" nibbling on the leftovers of yesterday's lunch. In the personal-computer market, the IBM clone makers having the most impact come mainly from low-cost South Korea and Taiwan rather than Japan.

Meanwhile, in developing the programs that make computers tick, American software engineers have been every bit as clever as their chip-designing colleagues in Silicon Valley. In the process, they have increased their share of the world's software market (worth $40 billion a year) from under 65% a decade ago to over 75% today.

All this does not mean Japan's computer industry is a write-off. Its component suppliers have quietly established a significant position for themselves in the United States and elsewhere. In personal computers, for instance, Japanese machines account for less than 2% of the $14 billion annual sales of PCs in America. But Japanese components and peripherals (chips, disk-drives, keyboards, monitors, printers, etc) account for nearly 30% of the market's wholesale value.

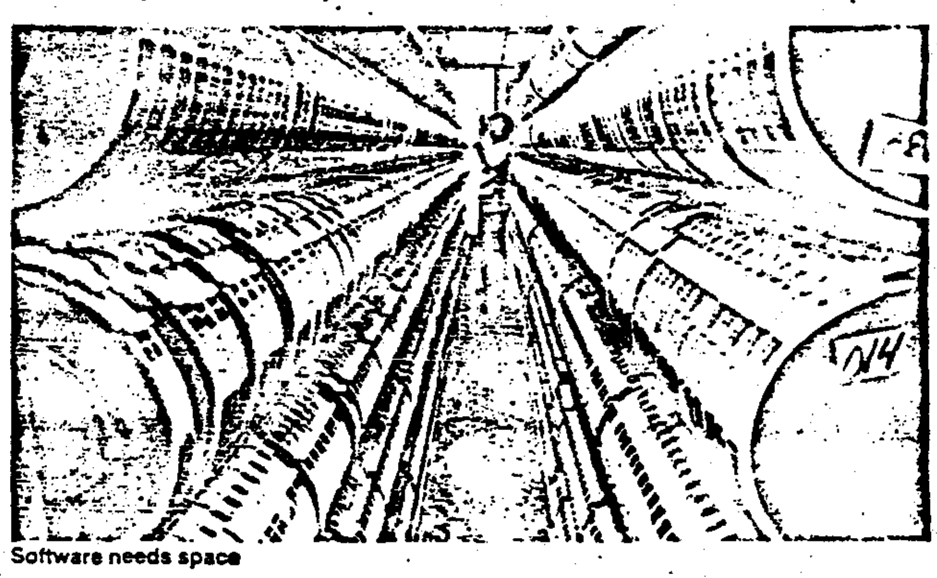
Most of Japan's computer makers came a cropper by riding a bit too blindly on IBM's coat-tails. Lacking the home-grown programming skills, Fujitsu, Hitachi and Mitsubishi made their computers imitate IBM's so they could sell cheaper versions to customers who were already using IBM machines equipped with the necessary software. That worked well until the slumbering giant woke up.

Then, in 1979, IBM introduced its 4300 series computers at a price that shook not just rival Japanese makers, but other American suppliers too. Since then, IBM's aggressive price-cutting and frequent model changes have made life tough for the plug-compatible trade.

Not only is IBM automating vigorously (the company is spending $15 billion over the next four years to achieve lower production costs than anyone in Asia), but it has also begun flexing its technological muscles. Its R&D expenditure is now running at $3.5 billion a year—more than all other computer manufacturers combined. Though for antitrust reasons it will never say so publicly, IBM is nevertheless determined to trample the plug-compatible makers down—both in the personal-computer end of the business as well as among its mainframe competitors.

One of the dodges being adopted is to incorporate more "microcode" in its computers' operating systems (the basic programs that manage a machine's internal housekeeping and support the customers' applications software). Used as an offensive weapon, microcode replaces parts of the computer's electrical circuitry, making it possible to change the whole character of a machine long after it has been installed at a customer's premises. The implication is that IBM can then sell products that can be continuously enhanced—something customers appreciate and will pay a premium for.

Starting with its 3081 series in 1981, IBM caught the competition off guard with a new internal structure called XA ("extended architecture") which allows customers to update their machines with packets of microcode whenever IBM decrees the market needs a shake-up. This



Software needs space

has thrown the plug-compatible makers on the defensive, forcing them to devote more of their development resources than they can afford to trying to anticipate IBM's next round of operating system changes and to try to match them with hurriedly engineered modifications to their hardware. That involves digging ever deeper into their profit margins.

America's other computer firms are also pushing this trend towards replacing hardware with software wherever possible. Writing and "debugging" the programs now accounts for 50-80% of their budgets for developing new computers. Two reasons, then, why American computer executives are smiling:

- At a stroke, the trend towards greater use of software helps neutralise the one great advantage their Japanese competitors have long possessed—namely, the ability to manufacture well-made mechanical components at a modest price.
- And it changes the business of manufacturing computers from being heavily capital-intensive to becoming more brain-intensive. The large pool of experienced programmers and diverse software firms in the United States puts the advantage firmly in American hands.

The Japanese response has been to launch another government-sponsored scheme, this time to help the country's computer makers invent "intelligent" machines for tomorrow. The ten-year fifth-generation project, based largely on "dataflow" concepts pioneered at Massachusetts Institute of Technology, will have cost $450m by the time it is completed in 1992. The aim is to create computers able to infer answers from rough information presented to them visually or orally. Even Japanese scientists working on the project are not sure whether such goals are realistic.

The Americans are not leaving anything to chance. Congress has been persuaded to relax the antitrust rules so that rival manufacturers can collaborate on advanced research without running foul of the law. Two of the first collaborative research institutions to spring up aim to match any challenge the Japanese might offer in computing, software and components for the 1990s. In one, the Semiconductor Research Corporation, 13 microchip companies have clubbed together to form a non-profit consortium for supporting research on advanced integrated circuits at American universities. The consortium is now doling out $35m a year to designers of tomorrow's microchips.

The other institution, the Microelectronics and Computer Technology Corporation (MCC), is an interesting experiment in its own right. Set up as a joint venture in 1983 by initially ten (now 21) rival American computer and semiconductor companies, MCC has 250 scientists carrying out research at its headquarters in Austin, Texas, to the tune of $75m a year. What is for sure, says Mr Bobby Inman, MCC's chief executive and former deputy director of the CIA, "MCC wouldn't have occurred except for MITI."

But the most orchestrated response of all to the Japanese challenge in computing comes not from IBM, Silicon Valley or collaborative consortia of American chip makers and computer firms. Though it is rarely in the public headlines, the Pentagon has been pouring barrels of cash into computing. Its Defence Advanced Research Projects Agency (DARPA) in Washington has been playing busy midwife to some of the most exotic technology of all for computers, communications and electronic equipment generally.

Its VHSIC (very high-speed integrated circuit) project alone has pumped $300m over the past five years into advanced methods for making the superchips needed for radar, missiles, code-breaking and futuristic computers. Also earmarked for DARPA is a reported $1 billion for sponsoring a range of supercomputers which, say insiders, "will outperform anything the Japanese can develop under their super-speed computing project or their fifth-generation programme."

At least a dozen "fifth-generation bashers" have surfaced as research projects around the United States, mainly in university laboratories, but also in small start-up companies founded by academics, entrepreneurs and engineering emigrés from the mainframe computer industry. The latest supercomputer to go public (the prototype was shipped last year to the American navy) is a cluster of boxes a yard square capable of calculating over a billion instructions per second (the Japanese government hopes to have a similar greyhound of a computer by 1992). The group that built it spun off mainly from nearby Massachusetts Institute of Technology to form their own company, Thinking Machines. The firm is now taking orders for a bigger brother with four times the processing power.

If only a handful of the score or so of American groups building advanced computers survives, the United States is going to enlarge its existing technology base in computing over the next decade by as much new engineering talent as its rivals have in totality. And that, not least for the Japanese, is a sobering thought.

Reach out and crush someone

Even more than breakthroughs in telecommunications technology, America's new deregulated freedom to plug in, switch on and sell an information service is breeding a whole new generation of infopreneurs

Americans complain about it, but if truth be told they still have the best and cheapest telephone system in the world. Japan's is a good one too—about as good as the Bell System was in the late 1960s. Which means it is reliable and cheap when making calls within the country, but not particularly good at performing electronic tricks like automatic call-forwarding, call-waiting, short-code dialling, credit-card billing, conference calling—all things Bell users take for granted today.

Americans also take for granted the choice of being able to dial long-distance numbers using alternative carriers who offer cheaper rates. Liberating the phone system from the state monopoly's clutches (so customers may choose what they want instead of what they are given) has barely begun in Japan.

The United States is the world's dominant supplier as well as its most prolific user of telephone equipment. The global market, worth $57 billion in 1982, is expected to grow to $83 billion by 1987. American manufacturers have 42% of it; Japanese firms 8-9%. But that has not prevented Japan from becoming a major exporter of telecoms products. It now sells well over $1 billion worth of telephone equipment abroad, a quarter of it even to the United States. How did that happen?

The main reason is the size of the American market itself. Though the American share of the global telecoms business is five times bigger than Japan's, practically all of it is at home. Some 90% of the domestic market is controlled by the mighty American Telephone and Telegraph ("Ma Bell"); GTE has 10% of the American market, while ITT has traditionally sold its telephone equipment almost exclusively abroad.

Until the deregulation of the American phone system in the wake of AT&T's 1982 consent decree, Ma Bell's manufacturing arm (Western Electric) directed its entire production effort at meeting just the needs of the various Bell phone companies around the country. It got all its inventions and designs from the legendary Bell Laboratories in New Jersey, and neither imported nor exported a single transistor.

Bell Labs has been responsible for a blizzard of innovations (transistor, laser, stored-program control, optical fibres, etc) that have driven down the real cost of communications and raised the quality and availability of telephone service throughout the United States. But because of AT&T's preoccupation in the past with just the domestic market, the best of its technology has had little direct impact on the rest of the world. The door to export sales was thus left ajar for telecoms suppliers elsewhere—from Europe (Siemens, Ericsson, Thomson, GEC and Philips), Canada (Northern Telecom and Mitel) and Japan (NEC, Oki, Fujitsu and Hitachi).

American firms retain their dominant position in supplying switching and transmission equipment. But the Japanese have mounted a serious challenge based on their growing expertise in transmitting messages on the backs of light beams. Made out of cheap silica instead of costly copper, optical fibres can carry three times the telephone traffic of conventional cables, need few repeater stations to boost the signals and send them on their way, are immune to electrical interference and do not corrode like metal wires.

The early American lead in fibre optics, built up by Western Electric and Corning Glass, has been chipped away by scientists at NEC, Sumitomo and Japan's telephone authority (NTT). Apart from learning how to manufacture low-loss fibres, Japanese companies have become superb at making the minute lasers, light-emitting diodes and minuscule receivers used for projecting and catching the messages.

Hand in glove with fibre optics is the growing trend towards digital transmission—sending spoken or picture messages coded as the ones and zeros of computerspeak. The transmission part is easy, but optical switching has presented horrendous headaches and the competition here is fierce.

But American makers have used their knowhow to better commercial ends. In particular, digital transmission has been used to speed the growth in data traffic between big computer systems, especially those owned by airlines, banks, insurance companies and financial institutions. Here, the Federal Communications Commission has taken the initiative, by freeing America's telecommunications networks so anyone can plug in, switch on and sell an information service. Other countries—Britain and West Germany particularly—have been inexplicably making life as difficult as possible for their own infopreneurs.

The lesson has not been wasted on telecommunications mandarins in Japan. They have seen how getting the government off the back of the telephone companies in America has spurred a vibrant free-for-all in "value-added networking", creating numerous jobs in information services and giving local manufacturers a headstart in carving out a piece of a brand new high-tech business for themselves.

This new communications freedom—even more than the changes in digital switching and new transmission technologies—is one of the key driving forces behind the merger between computing, office automation and telecommunications that is beginning to take place within the United States. Last year, computer maker IBM absorbed Rolm, a leading manufacturer of digital private-branch exchanges. At the same time the telephone giant, AT&T, broadened its growing base in computing and office equipment by buying 25% of Olivetti in Italy. The leader of the office-automation pack, Xerox, is still suffering from a surfeit of exotic technology dreamed up by engineering wizards at its PARC laboratories in California.

Japan has no intention of being left behind. The government in Tokyo is pressing on with its plan to privatise as much of its telecommunications services as possible. And while the big names of the Japanese telecoms business (Fujitsu, Hitachi, NEC and Oki) may have deficiencies of their own, each is nevertheless a big name in computing too. And though smaller, all are more horizontally integrated than AT&T, IBM or Xerox.

Will Japan close the technological gap in telecoms with America? Quite possibly. But only through setting up shop in the United States. The reason concerns one missing ingredient, now as essential in telecoms as in computing: ingenious software. Just as Motorola and Texas Instruments have built semiconductor factories in Japan to learn the secrets of quality and cost control, Japanese firms will have to establish telecoms plants in the United States if they are to acquire the necessary software skills. NEC has now done so—for precisely that reason.

Getting smart

Manufacturing is also going high-tech, threatening to turn today's dedicated factories full of automation into relics of the past

Microchips, computers and telecoms equipment will be to the next quarter century what oil, steel and shipbuilding were to the years between Hiroshima and the Yom Kippur war. More than anything else, these three technologies will fuel the engine of economic growth in countries that learn to manage their "smart" machinery properly. This will hasten not so much the trend towards service jobs, but more the revitalisation of manufacturing itself.

Manufacturing? That grimy old metal-bashing business which the more prosperous have been quietly jettisoning for better-paid office jobs in the service sector? It is true that manufacturing jobs in all industrial countries (save Italy and Japan) have been shed continuously since 1973. In the United States, employment in manufacturing industry fell 2.5% last year to less than 20% of the civilian workforce.

But looking at jobs alone is misleading. In terms of manufacturing's contribution to GNP, for instance, little has changed. In fact, manufacturing's share of value added (at current prices) in America was 22% of GNP in both 1947 and 1984, and has wavered narrowly within the 20-25% band for close on 50 years. So much for de-industrialisation.

Manufacturing still means big business in anybody's book. It currently contributes $300 billion and 20m jobs to the American economy; about $350 billion (at today's exchange rate) and 15m jobs in Japan. But manufacturing is really a matter of how you define it. Traditional measures based on Standard Industrial

Classification codes continue to give the impression that making anything in a factory is going the same way as smokestack industry generally—up in smoke. Yet software engineering alone is an explosive new "manufacturing" industry that barely enters the American Treasury Department's calculations of growth, let alone its vision of what constitutes industry.

What is for sure is that the new battle in manufacturing competitiveness and productivity is going to be fought in the fields of process and design technology. Here is what Mr Daniel Roos of Massachusetts Institute of Technology has to say:

> Over the next 25 years, all over the world, semi-skilled labour—whether cheap or expensive—will rapidly give way to smart machinery as the key element in competitiveness. Neither cheap Korean labour nor expensive American labour is our real problem. Rather the challenge lies in rapidly introducing and perfecting the new generations of design and process equipment—and the complex social systems that must accompany them.

It does not require an MIT professor to explain why conventional manufacturing is limping out and new computerised forms of design and fabrication are muscling in. Using the favoured yardstick of productivity (return on investment after discounting for the current cost of money) even back-of-the-envelope calculations show only two factors really count. Energy costs are irrelevant, being typically 3-4% of factory costs. Much the same is true for labour, which now accounts for only 5-15% of total costs.

"The only significant, and controllable, factors are material costs and production volume", preaches Dr Bruce Merrifield of the American Department of Commerce. Thus, with roughly 30% of material costs being in inventory, a "just-in-time" delivery system (like the Japanese *kanban* method for supplying components to motor manufacturers) could improve the real return on investment by as much as 15%.

From smokestack . . .

Getting manufacturing volumes right is trickier. Here high technology is making the whole notion of the special-purpose factory—with its automated equipment purring smoothly along as it churns out millions of identical parts all made to the same high standard of precision—a relic of the smokestack past. The marketplace is much more competitive today, no longer accepting the 10-12 year product life cycles needed to justify the investment of such dedicated plants. The pace of technological change is demanding that manufactured goods be replaced every four or five years: in consumer electronics, every two or three years.

The Japanese factory devoted solely to turning out 10,000 video recorders a day with a handful of operators is the end of the line—not quite yet, but destined shortly to become, a magnificent anachronism and epitaph to the age of mass production. It was a brief and grimy era, spanning just the single lifetime from Henry Ford to Soichiro Toyoda. To take its place, a whole new concept of manufacturing is being hustled out of the laboratory and on to the factory floor. This is the final melding of microchips, computers, software, sensors and telecoms to become in themselves the cutting tools of manufacturing industry.

The retooling of America

Flexible make-anything factories are beginning to sprout across America, bringing back jobs that had slipped offshore

American engineers call it CIM. Computer-integrated manufacturing—hurried into the workplace by a kind of Caesarian section—has arrived before managers have had a chance to find out what they really want or are able to handle. The trouble—and there have been plenty of teething troubles—is that CIM has a grown-up job to do right now. To corporate America, it is the one remaining way of using the country's still considerable clout in high technology to claw back some of the manufacturing advantage Japan has gained through heavy investment, hard work and scrupulous attention to detail.

American companies began pouring big money into high-tech manufacturing around 1980. All told, firms in the United States spent less than $7 billion that year on computerised automation. Today they are spending annually $16 billion, mostly on more sophisticated CIM equipment. By 1990, investment in computer-integrated manufacturing will have doubled to $30 billion or more, forecasts Dataquest of San Jose, California.

General Motors has spent no less than $40 billion over the past five years on factories of the future. Even its suppliers are being hooked into GM's vast computerised information net, allowing them to swap data with the giant motor maker as a first step towards integrating them wholly within its CIM environment. IBM has been spending $3 billion a year on computerising its manufacturing processes. In so doing, it has been able to bring numerous jobs, previously done offshore, back into the United States. Pleased with the results so far, IBM has raised its investment in CIM to an annual $4 billion.

The heart of a CIM plant is a flexible manufacturing shop which can run 24

. . . to robots . . .

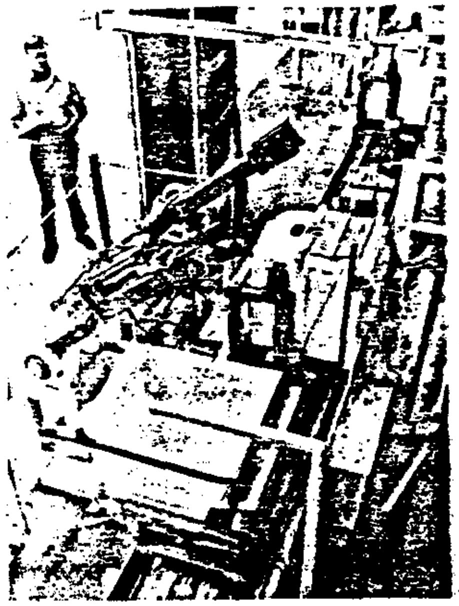
hours a day, but which is capable of being retooled in minutes rather than days, and able to turn out hundreds of different products instead of being dedicated to just one line. The difference between the best of traditional automation (for example, Toyota's Corolla line in Nagoya) and the best of new style CIM plants (for example, General Electric's household-appliance centre in Kentucky) is that the former automates just the flow of material through the factory, while the latter automates the total flow of information needed for managing the enterprise—from ordering the materials to paying the wages and shipping the finished goods out of the front door.

The aim of CIM is not simply to reduce the amount of direct labour involved in manufacturing a product (only 5-15% of the cost). The real savings come instead from applying strict computer and communications controls to slash the amount of waste (typically 30% of the cost) through having up-to-the-minute information on tool wear, while minimising the handling, management and overhead charges (rarely less than 40%) by knowing precisely where items are at any instant during the manufacturing process. The net result is that a CIM factory has a much lower breakeven point than a highly automated conventional plant. The majority of the CIM plants now onstream in the United States break even at half the level of a conventional plant (typically 65-70% of full capacity). And because it does not have to operate flat out from the start to be efficient, a CIM plant makes it easier and cheaper to launch new products. That spells shorter life cycles—and hence more frequent (and more attractive) model updates.

That would be reason enough for enterprising high-tech companies to invest in CIM. But a number of American corporations are being encouraged for other, more strategic, reasons to integrate their computerised manufacturing processes. The Pentagon sees CIM as a nifty way of allowing manufacturing capacity to be sprinkled lightly across the land, instead of being concentrated heavily in targeted areas along the Ohio Valley, parts of Illinois and up through Michigan.

The generals also see CIM plants—with their rapid response and flexible, make-anything nature—as handy standby capacity ready to be instantly reprogrammed to meet the military surge of a national emergency. Apart from its costly military stockpiles, the Pentagon has to underwrite a good deal of redundant and idle capacity among America's defence contractors. That is a political luxury it can no longer afford.

Pressure from other parts of Washington is also helping to usher high-tech



... to CIM

manufacturing into American factories. To government gurus like Dr Bruce Merrifield, the attraction of these flexible manufacturing plants is that they are ideal not just for industrial giants like General Electric, Westinghouse or IBM, but even more so for the tens of thousands of tiny workshops across the country. While Japan has two-thirds of its industrial output within the grasp of broad-based *keiretsu* manufacturing groups, American industry by contrast has always relied heavily on its 100,000 or so independent subcontracting firms. In metal working, for instance, 75% of the parts made in the United States are manufactured by small independent workshops in batches of 50 or less.

The American Commerce Department sees no antitrust reasons why smaller firms should not band together to share a flexible manufacturing centre, making spindles for washing machines one minute, wheel bearings the next, then switching to precision mounts for a microscope maker, crankshafts for diesel engines, microwave cavities for radar equipment, nose-cones for missiles and so on. This would reduce the investment risk for the individual firms, while providing a higher return for the CIM plant as a whole. It could also help rebuild much of the industrial base of rustbowl America.

Let the daisies grow

Bureaucratic guidance is still no match for a fertile economy where anything can take root and flower

Who, then, is better suited to life on the high road of technology—America or Japan? The answer is complicated by the way the two industrial superpowers have honed their separate skills in wholly separate ways (table 3). American technology is overwhelming in big systems, software, computing and aerospace. But nobody can touch Japan in the process technologies that underlie conventional manufacturing. American technology reaches out for the unknown; Japan's bends down to tend the commonplace.

The differences in style mirror the differences in ideals that the two peoples hold dear. The Japanese have a saying: "The nail that stands up will be hammered flat." The Americans say: "Let the daisies grow." So it is hardly surprising that American technology is individualistic, often erratic and always iconoclastic. Japan's, if anything, is pragmatic, geared primarily to problem-solving and hustled along by a herd-instinct.

To date, Japan's high-tech success has been almost exclusively with developments that were predictable—like packing more and more circuits into dynamic RAM chips, or making video recorders smarter and smaller. This is a result of having total mastery of the process technologies. While all the basic breakthroughs for making semiconductors—electron beam lithography, ion implantation, plasma etching, etc—came from the United States, Japanese firms improved the ideas step by step until their equipment was a match for anything made abroad.

By carrying out development continu-

Table 3: Balance of forces

Japanese strengths	American strengths
Applied research and development	Basic research
Incremental improvements	Breakthroughs and inventions
Commercial applications	Military applications
Process and production technology	New product design
Components	Systems integration
Hardware	Software
Predictable technologies	Less predictable technologies
Quality control	New functionalities
Miniaturisation	New architectural designs
Standardised, mass volume	Customisation

Source: "The Positive Sum Strategy", National Academy Press, Washington DC, 1986 ously in small incremental steps (instead of the American way of great quantum leaps every decade or so), Japanese firms have been able to bombard customers with a barrage of new models offering yet better value, quality and reliability. American firms, by contrast, have traditionally made cosmetic improvements every few years, and then brought out complete model overhauls once a decade or so. That has made their products look long in the tooth, then suddenly change dramatically—often for the worse while design bugs and production wrinkles are sorted out.

American technology has also tended to be geared for use mainly at home (for example, telephone systems, motor cars). With its smaller domestic market, Japanese technology has been forced to look farther afield. The Stanford economist, Mr Daniel Okimoto, makes the point that though Japanese firms have excelled at technologies tied closely to commodities with huge export markets (for example, continuous casting in steel, emission-control for motor cars, optical coatings for camera lenses), lately they have begun to do well in technologies for domestic use too. Some examples include gamma interferon and Interleukin II in pharmaceuticals, digital switching and transmission in telecommunications. And with their breakthroughs in gallium arsenide semiconductors, optoelectronics, superceramics and composite materials, the Japanese have shown themselves selectively capable of innovating at the frontier of knowledge as well as anyone.

On the whole, however, Japanese firms have been less successful with technologies that are inherently complex, not particularly predictable and dependent upon ideas springing from basic research. Making jet engines is one such technology. Designing air-traffic-control radars is another. Developing computer-aided design and manufacturing systems is a third. And despite MITI's "targeting" of lasers as a technology to be conquered, little progress has been made here to date—because not enough basic research has been done in the necessary branch of physics.

Such incidents point to serious problems in Japan's educational system. While Japanese youngsters out-perform western school children in all meaningful tests of mathematics and science, their training stresses rote learning rather than critical analysis and creative synthesis. At university, their skills in problem-solving are enhanced at the expense of their abilities to conceptualise.

As faculty members, Japanese academics are civil servants unable to fraternise as paid consultants in industry during the summer vacation. So Japan has none of the cross-fertilisation between basic research and commercial development that characterises MIT and Route 128, Stanford and Silicon Valley and a hundred other campuses across America. Also, because all the leading universities in Japan are state-owned and run rigidly by a conservative central bureaucracy, it is difficult to allocate grants (by peer-review) to the most deserving researchers rather than the most senior.

In the days when Japan could storm the

Lift-off for the airborne economy

Forget about America's underground economy of do-it-yourselfers pushing hamburger carts, paint brushes and illicit drugs. Above the conventional economy, a star-spangled wealth launcher lifted off three or four years ago—to take advantage of the soaring power and plummeting cost of microchips, the breakup of the geriatric telephone monopoly, the chimera of President Reagan's space shield and, above all, the technological collision of computing, communications and office automation. Meet America's exciting new airborne economy.

The first thing to understand is that nobody is quite sure how well even America's conventional economy is performing, let alone its underground or overground components. The only items reported properly seem to be imports and unemployment. The trouble is that the economy is changing so fast—from old-fangled businesses based on metal bashing and carting things around to new-fangled ones that massage, transmit and memorise scraps of information. What is for sure, the leading economic indicators—those monthly headlines that send shockwaves around the world's financial markets—seriously underestimate some of the most important growth sectors within the United States.

Because the statistics have not kept pace with the way American business is becoming internationalised, computerised and more service-oriented, the picture the statisticians paint depicts an economic landscape of a decade or two ago. Here are some examples of lagging statistical response:

- Companies are classified by industrial sectors using definitions last updated in 1972.
- Twenty years after computers swept manual accounting into the dustbin, the first price index for computers has just been introduced—and is still incomplete. Where America's computing costs have been assumed to be fixed, henceforth they will be deemed to fall (as they have actually been doing) by at least 14% a year—adding nearly 1% to GNP.
- An archaic processing system for logging foreign trade, confronted with a 90% increase in imports over the past decade, is ignoring America's growth in foreign sales. A significant proportion (some say 15-20%) of American exports now goes unreported.
- Measures of family income, designed in an age when welfare was a dirty word, omit non-cash components such as company fringe benefits for professionals (pension rights, deferred income plans, health and life insurance, etc) and in-kind government assistance for the poor (food stamps, rent subsidies, etc).
- Poverty is still defined by consumption patterns of the mid-1950s, when a family of three spent a third of its income on food. The same food basket today costs a fifth the equivalent family's income.

Don't snigger. Despite budgetary cuts, the American statistical system is still one of the best in the world. Its only real weakness is that—employment figures aside—the statistics used for determining, say, GNP or growth tend to be by-products of non-statistical agencies (such as the Internal Revenue Service, the Customs Service, Medicare and the Department of Agriculture). As such, they are far from being as clean, complete or timely as the experts would like.

Consider some recent anomalies caused by the quickening pace of technological change. With 70% of Americans being employed in the service sector, you might be tempted to categorise the United States as essentially a service-based economy. It is. But you would not think so from the Standard Industrial Classification (SIC) used in generating the input-output tables for measuring GNP. This has 140 three-digit codes for manufacturing firms, only 66 for services. Moreover, since the SIC system was last revised in 1972, whole new business activities (for example, video rental, computer retailing, software retailing, discount broking, factory-owned retail outlets) have sprung up, while others have withered away.

Nuts and bolts, for instance, are in an SIC category all of their own, employing a grand total of just 46,000 people. Envelope makers, again with their own SIC category, provide fewer than 25,000 jobs. Yet one SIC code in the service sector alone, general medical and surgical hospitals, now covers some 2.3m people. Lots of high-tech service businesses—including computer stores and software publishers and manufacturers—do not even qualify for their own SIC codes yet.

There is no reason why all SIC categories should be the same size. But the imbalance exaggerates the importance of traditional manufacturing at the expense of services in the American economy. Above all, it allows whole sections of America's booming high-tech economy to go unreported.

Back to the future

A glimpse or two at the future will dispel any doubts about Yankee ingenuity as it probes the limits of tomorrow's technology. First, to Silicon Valley where Mr Alan Kay, refugee from such technological hotbeds as DARPA, Stanford, Xerox PARC and Atari, is nowadays visionary-at-large at Apple Computer. Building on the learning theories of John Dewey and Jean Piaget, Mr Kay is trying to create a "fantasy amplifier"—a computer with enough power to outrace the user's senses, enough memory to store library loads of reference material, and enough clever software to couple man's natural desire for exploring fantasies with his innate ability to learn from experiment.

The concept, called "Dynabook", combines the seductive power of both a video game and a graffiti artist's spray-can with the cultural resources of a library, museum, art gallery and concert hall combined. Difficult to make? You bet, especially if the whole gizmo has to fit in a package no bigger than a notepad and be cheap enough for every schoolkid to own.

Smalltalk is the computer language Mr Kay has developed to allow kids to converse with the fantasy amplifier. The rest of the ingredients are all technologically imaginable, just prohibitively expensive and unwieldy for the time being. But a decade ago the first personal computer was just being built at considerable expense. Its functional equivalent today costs less than $50. Still only in his mid-40s, Mr Kay has ample time to put a Dynabook in the hands of millions of youngsters with open minds and a sense of wonder still intact.

Next, meet Mr Ted Nelson, gadfly, prophet and self-confessed computer crackpot, with a lifetime's obsession wrapped up in an enormous program called (after Coleridge's unfinished poem) Xanadu. Boon or boondoggle, nobody is quite sure. But the giant piece of software for steering one's own thought processes (including alternative paths, mental backtracks and intellectual leaps) is hardly lacking in ambition or vision.

Conceived originally by Mr Nelson while a student at Harvard as simply a note-keeping program for preserving his every thought, Xanadu has evolved into a total literary process: creating ideas; organising the thoughts, with traces showing backtracks, alternative versions and jumps to cross-referenced documents, manipulating the text; publishing the results; and logging a share of the royalties to every other author cited.

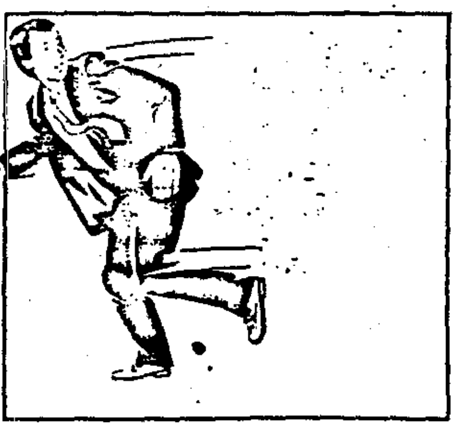
Every document in Xanadu's database has links to its intellectual antecedents and to others covering related topics. The linked references work like footnotes, except that Xanadu offers an electronic "window" through which they can be accessed there and then. Because the whole process works in a non-sequential way, the inventor calls the output "hypertext".

Mr Nelson looks forward to the day when anybody can create what he or she wants—from recipes to research papers, sonnets to songs—and put it into Xanadu's database and quote or cite anybody else. Royalties and sub-royalties, monitored automatically by the host computer, would be paid according to the amount of time a user was on-line and reading a specific document. It sounds pretty wild at the moment, but hypertext could be commonplace before the century is out.

industrial heights with foreign licences, homegrown development and production excellence, the inadequacies of its educational system and academic research hardly mattered. But such shortcomings are becoming increasingly a problem as high-tech competition intensifies.

Nor can Japan call on its little firms to provide the invigorating fillip of innovation such enterprises provide in the United States. And with their lifetime employment practices, Japan's big technology-based corporations rarely get a chance to attract high-flying talent from outside. Technological diffusion between small firms and large corporations, and between companies generally as engineers swap jobs, is one of the more invigorating forces for innovation in the United States.

Nor, also, is there an adequate way in Japan for financing risky innovation outside the big corporations. Since 1978, American equity markets have raised $8 billion for start-ups in electronics alone and a further $3.3 billion for new biotech companies. Over the same period, Japan's venture-capital investments in high-tech have totalled just $100m.



Lacking all these things, the Japanese have sought a substitute. This is one of the main reasons for MITI's special emphasis on collaborative research projects—as in VLSI or fifth-generation computers. To Mr Gary Saxonhouse of the University of Michigan, Japan's lauded industrial policies are little more than a substitute for the ingredients that American companies enjoy from their vibrant capital and labour markets.

As for MITI's infamous industrial targeting, many Japanese (as well as foreigners) have long doubted its effectiveness and believe it is now wholly inappropriate anyway. All technologies have started moving simply too fast to wait upon the whim of bickering bureaucrats. It is not as though Japanese civil servants have shown themselves any better at picking industrial winners than officials elsewhere; and none has bettered the invisible hand of the marketplace.

Apart from possessing vastly greater resources of well-trained brains, more diverse and flexible forms of finance, and a bigger and more acquisitive domestic market, America has one final, decisive factor moving in its favour—the pace of innovation itself.

High-tech products tend to have two things in common: they fall in price rapidly as production builds up (they possess steep learning curves) and they get replaced fairly frequently (they have short life cycles). The trend in high-tech is towards things becoming steeper and shorter. So the competitive advantage of being first to market is going increasingly to outweigh almost everything else.

This spells an end to the traditional low-risk, low-cost approach that Japanese companies have used so successfully to date—coming in second with massive volume and forward prices after others have primed the market. Henceforth, Japanese firms are going to have to take the same technological risks—and pay the same financial penalties—as everyone else. And that puts the advantage decidedly on the side of Yankee ingenuity.

Cossie Phillips

AMERICAN CAN: TSAI GETS THE TOP JOB FOR GETTING THE JOB DONE

When he was younger, Gerald Tsai Jr. tore down and rebuilt five homes. "I liked to see the two-by-fours go up and finally the furnishings put in place," he says. On Apr. 30, in recognition of the solid financial house he's constructed for American Can Co., Tsai was named chief executive, succeeding Chairman William S. Woodside.

American Can's transformation has been remarkable. In 1981, Woodside, who will retire next January, began to shift the company away from can manufacturing and paper operations into less capital-intensive and faster-growing businesses. In only a few years, American Can's financial services business grew to produce 1985 earnings of $200 million on revenues of $1.3 billion. In the same period, the company divested its paper operations, cut back on can manufacturing, trimmed employment, and decentralized management. Return on equity rose from 7% in 1981 to 11% last year. "The challenge now," says Tsai, "is to make sure the company will grow at a faster-than-average rate."

BIGGEST COUP. For the 57-year-old Tsai, who remains vice-chairman for now, the promotion caps a four-year effort. A few years ago, Woodside formed an office of the chairman, putting Tsai in competition for the chief executive spot with President Francis J. Connor. Connor, 56, a 30-year veteran with packaging and retailing expertise, is expected to stay on.

The promotion also marks a comeback for Tsai, who first set Wall Street afire in the 1960s as a "go-go" mutual fund manager. He reappeared in 1982 when he sold Associated Madison Cos., a life insurer, to American Can for $140 million. Associated Madison became the focus of Woodside's financial services strategy, and the chairman gave Tsai the charter to build it. Largely through acquisition, Tsai added specialized insurance, mortgage banking, and real estate syndications. In 1984, financial services contributed 25% of the company's total revenue and 45% of operating income. Last year, financial services accounted for 54% of total profits. And in the quarter ended Mar. 31, while overall aftertax income rose by 20%, financial services' operating income rose by 47%.

American Can's biggest coup came in March, when it sold 15% of its American Capital Management & Research mutual fund subsidiary to the public for $69 million. The Houston-based fund had been acquired less than three years earlier for $38 million, and it produced a special $25 million dividend for American Can before it was sold. Tsai estimates the offering added nearly $10 to American Can's stock price, which hit a new high of 79¾ and closed at 70 on Apr. 30. Other such offerings are under consideration. A likely candidate is Fingerhut Corp., a profitable direct-mail merchandiser.

Other projects include the sale and leaseback of the company's Greenwich (Conn.) headquarters and further reductions of its vast timberlands. American Can is also likely to concentrate on beverage cans and shut its other can plants. Tsai has ambitious plans for the company: He wants to double earnings per share by 1990 and boost return on equity to 18%. He also plans to expand his portfolio of service businesses, probably by buying a health care company. Being a master builder seems to suit Tsai—and American Can.

By Marilyn A. Harris in Greenwich, Conn.

MONSANTO'S SCHNEIDERMAN AND WASHINGTON UNIVERSITY'S MACCORDY: "FASTER SCIENCE"

T. MIKE FLETCHER

MONSANTO'S COLLEGE ALLIANCE IS GETTING HIGH MARKS

While tight research dollars are cramping scientists' style at many universities, researchers at one school are sitting pretty. At Washington University, they can apply to tap into a $52 million research fund bankrolled by Monsanto Co.

Four years ago, the St. Louis university and the chemical giant signed an extensive collaborative industry-university joint research agreement. Monsanto anted up $26 million over four years to fund university research in return for first crack at licenses on any resulting patents. The effort proved so successful that on May 2, Monsanto kicked in another $26 million and extended the partnership until 1990.

Monsanto is convinced that it is getting its money's worth. Indeed, Howard A. Schneiderman, senior vice-president and chief scientist for corporate research and development, says the 1985 acquisition of drugmaker G. D. Searle & Co. might not have happened otherwise. "Through the program we made enough discoveries of potentially interesting pharmaceutical products to justify buying Searle," he says.

The first drug Schneiderman is counting on is a hormone produced by heart cells that plays a key role in regulating blood pressure and kidney function. Several other drugmakers, including Merck & Co., are pursuing the same substance, called atrial natriuretic factor. But Monsanto believes the Washington University group is on the cutting edge of the research: The university won the first U.S. patents for the potential drug, which will enter human clinical tests this summer.

Another dozen or so patents are pending. Monsanto has targeted a group of drugs that dissolve blood clots in heart-attack victims and immune-system regulators that may be useful to treat such diseases as arthritis. To help get those drugs to market, Monsanto has beefed up its internal R&D spending. This year the company expects to spend $520 million on R&D, 57% of it in life sciences, up almost 11% from last year. With that push, "we will deliver to Searle one or two very exciting product candidates in 1986 or 1987," vows Schneiderman. New drugs should be welcome at Searle, which faces hundreds of millions of dollars in liability claims over its Copper 7 intrauterine device.

Initially, the agreement with Monsanto was controversial. Critics, including Representative Albert Gore Jr. (D-Tenn.), feared it would compromise the independence of the university and skew research toward commercial goals. But both parties argued they had developed a committee of Monsanto and university scientists that acted as an on-campus granting agency to prevent conflicts.

'ATYPICAL' The relationship is getting high marks on campus. Last fall, an independent committee of academic leaders gave it a clean bill of health. "Our overall conclusion was that the venture had been extremely successful," says Leroy E. Hood, a committee member and professor of biology at the California Institute of Technology. And academic scientists are finding that the collaborative effort is speeding up their research. "With the collaboration we did faster science than might have been done otherwise," says Philip Needleman, a professor of pharmacology who heads the work on atrial peptides at Washington University Medical School.

Despite the good reviews, the Washington University-Monsanto deal has not become a model. There are fewer than two dozen industry-university collaborations with more than $1 million in funding. Some believe the situation in St. Louis is unique: Monsanto was in the throes of reorienting itself out of commodity-chemical businesses and needed the university for help. "Monsanto was ripe, and the situation was quite atypical," says Edward L. MacCordy, the university's associate vice-chancellor for research. But with cutbacks in federal funds, more universities may try to tie up with corporate backers.

By Emily T. Smith in New York

PATRICE CASE

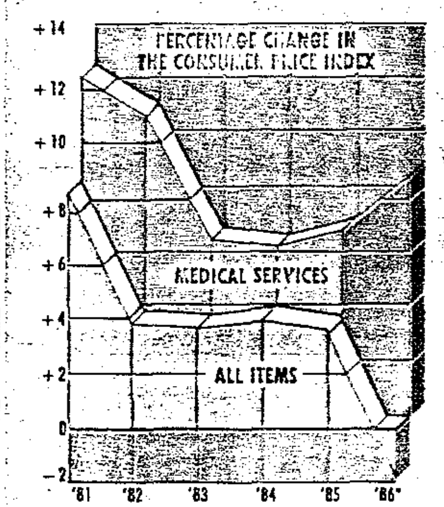
SAFETY & HEALTH

WHY HEALTH CARE COSTS ARE HAVING A RELAPSE

Medical inflation has cooled so dramatically since 1983 that many economists no longer study it as a barometer of rising prices. But if they missed the mid-April release of the consumer price index, they are in for a shock. During the first three months of 1986, the medical component of the CPI rose at an annual rate of 8.7%, while the overall index dropped by 1.9% (chart). With companies and the government battling to contain medical inflation, such price rises "shouldn't be possible," declares Uwe E. Reinhardt, an economist at Princeton University.

What's behind the cost runup? Health care experts suggest the very cost-containment efforts that helped bring increases down to 6.1% in 1984 from a high of 12.5% in 1981 may actually have contributed to the upward spike. Reducing the volume of in-hospital care raised costs per patient. Now, hospital officials contend, significantly higher prices are necessary just to cover costs—which in health care have long outpaced the overall rate of inflation.

MEDICAL COSTS: THE INFLATION GAP GETS WIDER



*FIRST THREE MONTHS AT SEASONALLY ADJUSTED ANNUAL RATE

DATA: BUREAU OF LABOR STATISTICS

HUGE PREMIUMS. The government's program to slash medicare expenditures also may have played a role. Medicare payments to hospitals, which account for 40% of their revenues, have increased by only 4% since 1983, and medicare payments to doctors have been frozen. These actions may have forced rates for private patients to balloon, and they clearly haven't helped doctors facing huge malpractice premiums. "Fees may be rising more rapidly than people like, but that doesn't mean physicians are taking home more net income," says Dr. James S. Todd, senior deputy vice-president of the American Medical Assn.

In the first quarter, hospital-room charges swelled by an annual rate of nearly 10%, prescription-drug prices jumped by more than 12%, and physician fees rose by about 7%. The 8.7% quarterly spurt for the CPI medical component is well above the 6.3% figure for the same period a year earlier.

With oil and commodity prices tumbling, renewed medical inflation poses little immediate threat to the economy. But increases in health prices already are translating into higher health-insurance premiums. Hewlett-Packard Co. has received a handful of proposed contracts calling for increases of about 9%. Arthur J. Young, HP's benefits manager, warns that more hikes of that size would be "cause for significant concern."

'OUT OF THE CLOSET.' Employers clearly will resist. Many already have negotiated discounts for group health plans, and higher rates will prompt more to follow suit. "Employers were getting used to health costs going up only 5% to 7% a year," notes Jeffrey C. Goldsmith, a health care expert for the accounting firm of Ernst & Whinney. "If premiums start increasing by 10% or 12% a year, the club will come out of the closet."

The club already is out in some areas. In Southern California, hospitals in the last year nominally raised room rates from 6% to 10%, estimates Thomas M. Priselac, chief operating officer of Cedars-Sinai Medical Center in Los Angeles. But companies won much lower prices. "The difference between quoted rates and the actual amount paid is growing," Priselac notes. This may mean the CPI itself is a bit inflated.

Because of its deregulatory philosophy, the Reagan Administration is unlikely to try to halt the steep price rise in medical costs. "We've pretty much gotten our own costs under control," says a Health & Human Services Dept. official. "You have to wonder what's going on out there in the private sector."

By Michael A. Pollock, with Vicky Cahan in Washington

THE TAKE AT THE TOP

PAY FOR PROFITS

How the most competitive companies around are "incentivizing" their compensation systems.

BY BRUCE G. POSNER

BACK IN THE LATE 1960s, SHANNON & Luchs Co. was just one of a dozen or so small real estate brokerage businesses in Washington, D.C. Its managers were all paid in accordance with the norms of the industry, and they received the standard merit raises and bonuses at the end of each year. Then, around 1970, the company overhauled its executive compensation system. In addition to their regular salaries, division heads were given the opportunity to earn a percentage (10% to 25%) of the net profits of their respective divisions, adjusted for overhead and other expenses. The result: sales and profits took off. Today, Shannon & Luchs is one of the largest and most profitable real estate companies in the United States. Company president Foster Shannon gives full credit to the compensation system.

Such tales may sound too good to be true, but they are becoming increasingly common as more and more companies turn to incentive pay as a means of achieving strategic objectives. The trend is easily the hottest one to hit the compensation field since the cost-of-living raise. It involves a whole different approach to compensation, one that is geared toward achieving future objectives, rather than rewarding past performance. To date, thousands of businesses have adopted such systems, and those that try it swear by it. Most practitioners will tell you that—in addition to fostering phenomenal results—incentive compensation allows them to recognize the movers and shakers in their organizations, the people who make things happen, and to inject a new sense of vitality and purpose into the company as a whole.

Testimonials aside, the trend reflects important changes in the business environment. As inflation has declined, companies have found it harder to justify the big raises that were common in the 1970s and early '80s, and so they have begun searching for new ways to keep employees motivated. Even more important has been the pressure of increased competition, forcing companies to become ever more efficient and profitable.

Among the first to move in the direction of incentive compensation were the *Fortune* 500 companies. A study by Hewitt Associates, in Lincolnshire, Ill., shows that more than 90% of the nation's largest companies had short-term incentive plans as early as 1980. These plans made it possible for participating managers to earn bonuses totaling 16% to 55% of their base salaries, given the achievement of certain operating or financial targets. Since then, thousands of smaller businesses have set up incentive plans of their own.

On the surface, at least, creating an incentive-pay program doesn't appear to be difficult at all—provided you understand where your company is, and where you want it to be. You have to know, for instance, what you're shooting for, whether it's more profitability, higher sales, better service. As a wise man said, if you don't know where you're going, the odds are you'll wind up somewhere else.

Once you are clear about your objectives, however, the rest falls into place. First, you have to decide who to include in the plan. If you want to increase profitability, for example, and if your business is composed of relatively autonomous operating units or product areas, you may well decide to focus on a handful of key managers—the ones with the leverage to make sure their respective units make money. On the other hand, you may have a company like Riley Gear Inc., in North Tonawanda, N.Y., a $6-million manufacturer of precision gear systems, whose success depends on its ability to deliver quality products on time at competitive prices. Since every employee plays a role in achieving the company's productivity goals, all 90 of them receive a quarterly bonus check when targets are met.

Of course, you also have to choose the performance criteria by which you'll hold people accountable. Here, your decision is almost entirely a function of your goals. Indeed, two identical companies might deliberately choose different performance criteria. One, for example, might decide to reward nothing but sales growth as a way to spur aggressive selling, while the other might target profits or quality control. The latter business would, in effect, be telling people to say no to some business opportunities. But each company, in its own way, would be encouraging the kind of behavior it wanted.

Then again, some companies might want their employees to pay attention to more than one goal at a time. For several years, Nicolet Instrument Corp., a Madison, Wis., manufacturer of medical and chemical testing equipment, calculated its management bonuses using a formula that took into account both sales growth and return on assets. With two important goals to balance, says chief executive officer and president John Krauss, there were no rewards for leaning too far in one direction. Other companies accomplish the same thing by establishing separate incentive pools tied to the achievement of different objectives.

Whatever measures you choose, they must be readily comprehensible to the employees they affect. If employees don't know what kind of performance you are trying to encourage—or why it's important—they aren't likely to respond as you intend. You either have to explain what you are trying to accomplish, or choose other measures. By the same token, the performance criteria must involve aspects of the business that the affected employees can control and monitor. That means providing them with the data—monthly sales figures, production reports, profit statements—that will show them how they are doing.

Within these parameters, however, you have a lot of flexibility, not to mention influence. You can, indeed, attach incentives to almost anything—and thereby determine how managers and employees spend their time and where they focus their attention.

Now, none of this seems particularly difficult. You choose your goals, your people, your performance criteria. What could be simpler? Well, not so fast. The problem is that, at every stage, you have decisions and judgments to make, and any one of them can undermine your plan.

Consider, for example, the choice of performance criteria. Should you establish custom-made targets for individuals, or is it better to tie their incentives to the performance of the company as a whole? Dynamark Security Centers Inc., a $5.5-million franchisor of home security centers and distributor of security equipment, gives

THE INDIVIDUAL INCENTIVE

Tailoring the bonus to the job

ROSEMARIE CERTO

Michael Zisman
President of Soft-Switch Inc.

Establishing incentives for individuals takes time, and many jobs are difficult to measure. But Michael Zisman, chairman and chief executive officer of Soft-Switch Inc., in King of Prussia, Pa., thinks that individual incentives are critical to the success of any compensation program. Last year, his company, an $8-million maker of computer networking software, embarked on a program that provides special rewards for about one-third of Soft-Switch's 70 employees.

The idea, says Zisman, was to encourage key employees to focus on individual objectives that are important to the overall success of the business. To provide the necessary rewards, Soft-Switch established a bonus pool based on its achievement of certain sales and profit targets. If the targets are met in fiscal 1987, for instance, the company will kick in 20% of the combined base salaries of affected employees. How that money gets divided depends partly on each individual's contribution to the company's collective success. Last year, for example, half of the potential bonus for the vice-president of operations was tied to such things as improving customer satisfaction ratings and reducing the time required to install products. (The other half was tied to the overall performance of the business.) Similar criteria are applied to many nonline positions as well. A large chunk of the controller's bonus, for instance, is linked to getting monthly reports in on time.

Zisman admits that it's not always easy to define the right objectives for jobs, but he argues that, without individual goals, some critical tasks will never become priorities. What's more, you'll always have a hard time differentiating between levels of performance, and everyone will wind up with roughly similar rewards.

THE GROUP INCENTIVE

Rewarding a company as a team

PHIL MATT

Tom Lowry
President of Riley Gear Inc.

Suppose you had a company in which each and every employee had the power to undermine your competitive position. That was the problem at Riley Gear Inc., a maker of precision gears, in North Tonawanda, N.Y. The solution was to create a compensation system that gives all 75 manufacturing people and the 15 other employees a significant financial stake in the overall success of the company.

The system is known as gain-sharing, and it is built around monthly productivity targets. Every order that comes in to the $6-million business is broken down into a series of production steps, which are assigned hourly rates related to the capabilities of the equipment and the complexity of the work. These rates are then used to create a "blended" productivity target for the company. The amount that Riley puts into the bonus pool each month depends entirely on the achievement of the companywide target, which in turn depends on the workers meeting, or exceeding, their goals.

In the two years the system has been in effect, Riley's hourly workers have earned 3% to 4% a year in extra compensation—over and above the annual increases of 3.3% provided in their three-year union contract. President Tom Lowry thinks that bonuses of 8% to 10% a year are well within reach "as long as the productivity is there." He's also talking about adding nonfinancial rewards, such as extra vacation time.

Of course, there are trade-offs involved in paying plantwide bonuses. "If you have superb performers, you can't really recognize them," Lowry notes. Nevertheless, he believes the benefits of the system outweigh its liabilities. "There's a lot of peer pressure. People know that if we get the cost reductions, everyone gets something. And they understand it's a competitive market, and we're all in this together."

---

each of its nine key managers and supervisors a different set of performance targets. The marketing and training manager, for instance, gets a small slice (about 1%) of sales up to a given level, and a smaller percentage after that. The head of franchise development, on the other hand, gets a cut of the franchise fees and the inventory ordered by new franchisees. "The structure of the deals is basically the same," says chairman Ed Cusick, "but everyone gets his own report card."

Some businesses go even further, linking an individual's reward to the accomplishment of specific tasks. Thus, at Morris Decision Systems Inc., a computer dealership and maintenance company in New York City, the vice-president of finance has to get a new general-ledger system up and running in order to earn a part of his bonus for 1986.

But there can be problems with this approach. First, it takes time and effort to select the right goals. Then there is the administrative burden of monitoring the performance of many individuals. But perhaps most worrisome is the possibility that what's good for a particular individual, or group of individuals, may be awful for the business as a whole.

In the early '70s, for instance, Nypro Inc., now a $65-million plastic injection molding company in Clinton, Mass., began to reward employees for their own individual output. Some enterprising workers found ways to speed up production equipment during their shifts. They refused to share their secrets with their colleagues, however, and the high-speed work undermined quality. So Nypro was forced to switched from individual to group incentives.

Fearing similar problems, many companies require a certain level of overall results before individual bonuses are paid. "You can say, if we earn so many dollars, or if we get into the World Series, you'll get a reward," notes Peter T. Chingos, who heads the compensation consulting practice at Peat, Marwick, Mitchell & Co. But finding the right balance is not easy.

Nor is it easy to establish performance standards for every job. True, you can set quotas for salespeople and determine efficiency ratios for plant managers. You can even measure performance in such areas as quality control: at Soft-Switch Inc., a King of Prussia, Pa., software company, the quality-control manager is rewarded in part on the basis of results from customer-satisfaction surveys. But what do you do with a human-resources manager? Should you measure employee turnover? In many cases, turnover is totally beyond a manager's control. What's more, if you *do* target turnover, you run the risk of winding up with unambitious employees whose main virtue is that they don't like to change jobs.

To avoid these sorts of decisions, many CEOs prefer to maintain a certain amount of discretion over bonuses. In rewarding vice-presidents and project managers, Joseph Viar takes into account the "degree of difficulty" of the projects they manage. He could pay strictly on the basis of volume of business under management, "but different jobs rely on different mixes of inside people, consultants, and subcontractors," says Viar, president of Viar & Co., an Alexandria, Va.-based consulting company in the data-processing area. Thus they require different amounts of management, and he compensates accordingly.

Then again, you can't use too much

THE PHANTOM STOCK INCENTIVE

Eating your cake and having it, too

TOM SIMON

Al Weatherhead
Weatherchem's founder and CEO

How does a private company get key employees to lose sleep over the business without giving up equity? That was the question confronting Weatherchem Inc., a $6.5-million maker of plastic caps and closures located in Twinsburg, Ohio. Its solution: "phantom stock," an increasingly common technique by which a company **rewards employees for building the business's value, while keeping the stock in the original owner's hands.**

As founder and chief executive officer of the family-owned company, Al Weatherhead knew he wanted to institute some kind of long-term reward system to get his half-dozen key managers focused on "profitable growth." Real equity made him nervous, however. Among other things, he didn't know how long the key people would stay around the 65-employee company, and he didn't look forward to endless battles over stock valuation. Under the phantom program, adopted in May 1982, selected managers will receive a share of the amount by which Weatherchem's value appreciates over a five-year period. The value is calculated according to a formula that takes into account the company's return on assets and return on equity, both adjusted for its cost of capital.

The plan has encouraged managers to focus on Weatherchem's long- and short-term objectives, but Weatherhead is dissatisfied with the formula. "It's too damn complicated, and it isn't something you can pound the table over." So the company is formulating a new, simpler phantom plan to take effect when the first one expires next May. The new formula, he says, will probably be based on cumulative profits over a three-year period. Why three years this time, instead of the five years in the original plan? "Five years," Weatherhead offers, "just seemed a bit too long."

THE REAL EQUITY INCENTIVE

When nothing else will do

RICHARD HOWARD

G. B. Lankton
Nypro's CEO and president

Few owners of small companies relish the idea of taking on their employees as partners and minority shareholders, but that was not the case with Gordon B. Lankton, president and chief executive officer of Nypro Inc., a highly successful plastic injection-molding company in Clinton, Mass. **He inaugurated the company's unusual stock bonus program 17 years ago, and he has never regretted the decision.**

Created in 1969, when Nypro was a struggling $4-million business, the plan was designed to encourage employee commitment and achievement by making equity available to people throughout the company. Eligibility is based on a formula that takes into account three factors: length of service, salary level, and job performance. Every year, employees receive points in each category. If an individual scores 20 points or better, he or she can receive a special equity bonus.

The equity takes the form of real stock. The program is not an employee stock ownership plan and uses none of the tax advantages associated with ESOPs. Nor does Lankton view phantom equity as a viable alternative in a company like his. "I want [the stock] to feel real," he says. "You can explain phantom stock to people who are financially sophisticated, but it can be incredibly confusing to everyone else."

As Nypro has grown—today, it is a $65-million company with 1,200 employees—some 90 employees, about half of them nonmanagers, have become shareholders. Meanwhile, the value of the stock (measured by book value) has shot from $3.50 a share in 1969 to $25 last year. To discourage employees from leaving, Nypro requires departing shareholders to sell their stock back to the company over a period of 5 to 10 years—thereby minimizing the impact on Nypro's cash flow.

discretion in awarding bonuses without undermining your incentive program. If the principal basis for compensation is the boss's whim, the only real incentive is to stay on his good side.

At this point, you still have to decide how much money you should dish out in the form of incentives. It can't be so much as to imperil the business—by getting in the way of meeting debt service payments, for example—yet it has to be enough to attract employees' attention. As a rule of thumb, most compensation experts advise that you make available incentive bonuses of at least 10% to 15% over base salaries. Employees will tend to regard smaller bonuses as "tips," which may motivate them to work a little harder and "smarter," but not enough to justify the effort and expense of establishing an elaborate incentive system.

Then there's the related issue of selecting the right performance levels—a critical part of the process. If the targets are too high, people may give up. If they're too low, you may encourage people to take it easy. What happens, for example, if you surpass the target midway through the year?

And what if you set target levels that inadvertently wind up *penalizing* your best employees? That's more or less what happened at The Myers Group Inc., a freight forwarder with 65 offices around the country. For several years, the company paid out bonuses according to a formula that rewarded people annually for profit improvements at their individual branches. The formula was designed to motivate those who worked at the least efficient locations, and that it did. But it provided little incentive for employees assigned to the most profitable branches. Moreover, the system became less and less effective over time. The better an office did one year, the harder it was to receive a bonus the next. People grumbled, and so the company, based in Rouses Point, N.Y., eventually scrapped the formula. Now incentives are tied to the overall profitability of each office and of the company.

Once you have settled on performance levels and criteria, you still have to decide how often people will be rewarded—an aspect of incentive compensation that is often overlooked. After all, the real test of any incentive program is its ability to keep people focused on company objectives. Annual bonuses are traditional, and relatively easy to administer, but can employees stay focused on targets for a whole year? Gordon Lankton of Nypro, the plastic molding company, doesn't think so. His company pays its productivity bonuses on a quarterly basis because "a year can feel like a long time," he says. To make sure that everyone notices, Nypro even uses special profit-sharing checks with a picture of George Washington in the center and "profit-sharing" printed across the top.

On the other hand, quarterly bonuses can be extremely impractical from a company's perspective. Not only does it take administrative effort, but it demands an ability to forecast with precision and to anticipate cash-flow needs. Recently, an air-freight company paid out substantial incentive bonuses at the end of one quarter, only to hit a dry period the next. It hastily revamped its quarterly incentive program. Now nonmanagers get bonus checks after each profitable quarter, but managers don't receive theirs until annual results are in.

So, if you look hard enough, there are solutions to all these potential problems. The bad news is that, once you've come up with a viable short-term incentive plan, you

STRATEGIES FOR INCENTIVE COMPENSATION

You can look outside for help and inspiration. but the answers are all close to home.

There are no real shortcuts to creating an effective incentive compensation system. No matter how you approach it, you still have to ask, and answer, dozens of difficult questions about your goals, your people, and your business. It helps, however, to have a strategy for dealing with these questions. There are essentially three to choose from:

THE COPYCAT METHOD

One strategy is to adapt somebody else's plan to your own circumstances and needs. It's particularly appealing if the other company is similar to yours, and if its system has worked well.

That was the case with Nicolet Instrument Corp., which developed its plan back in 1981 after chief executive officer John Krauss saw an article in the *Harvard Business Review* about the incentive compensation program at Analog Devices Inc. As it happened, Analog had management and operating structures strikingly similar to Nicolet's. So Krauss copied Analog's incentive compensation program, and it worked effectively for several years.

There are pitfalls in the copycat approach, however. To begin with, no two companies have identical cost structures: if your costs are higher than those of the company you're copying, you may be stimulating behavior that you can't afford. Nor can you assume that the other company's market position or goals are the same as yours. If they aren't, the performance criteria are liable to be off as well. "Copying another incentive plan," says one consultant, "is like trying to learn Jimmy Connors's backhand when you don't have his serve." It may work: then again, it may throw everything out of whack.

THE CONSULTANT ROUTE

Another strategy is to hire a specialist to design your compensation program for you. That's a natural impulse, and consultants do have much to offer in the way of advice and experience. But many have worked only with large companies, which does not help them in understanding and solving the compensation problems of smaller companies.

James Bernstein learned that lesson the hard way when he brought in a well-known consulting firm to design an incentive plan for his $4.5-million health risk-management firm, General Health Inc., based in Washington, D.C. He wanted a compensation system that would encourage employees to focus on sales volume and building market share. With that mandate, the consultant produced an elaborate plan under which all 80 employees could earn handsome bonuses by meeting individual and company objectives. "The consultant gave me his best advice," says Bernstein. "It sounded just terrific." Unfortunately, it wasn't. Not only did the system demand hours upon hours of management time to review each employee's objectives, but it also completely overlooked the company's need to change direction and shift people around on short notice. Objectives that made perfect sense one week were outdated the next.

Within a year, General Health scrapped the consultant's incentive program and installed a simpler one designed by Bernstein himself. Dispensing with individual goals for everyone but salespeople, the new system rewards employees for meeting quarterly profit objectives. It takes a lot less time to administer, notes Bernstein, and yet it's enough to send the message that "everyone needs to put their shoulder to the wheel."

THE TAKE-YOUR-LUMPS APPROACH

Bernstein's experience illustrates a fundamental fact of incentive compensation: sooner or later, you have to develop your own system. There are no blueprints, and there are no outside cures. You may discover some interesting features in other companies' programs. You may also find consultants who can help you think through your company's needs. But don't expect anyone to understand your company as well as you do.

"There's no substitute for sitting down, locking yourself in a room, and thinking about what's really important to your business," says Bernstein. "Otherwise you'll end up with a cookie-cutter approach that was designed for the company next door." So, in the end, most companies wind up developing their compensation programs the old-fashioned way—by doing it themselves.

---

still have to confront the issue of *long-term* incentives—the kinds of rewards that ensure employees stay focused on a company's objectives over the long haul. Those kinds of incentives can be just as important as the quarterly and annual ones, maybe more so, and the issues involved are no less thorny. Should you give people real stock, or stock options, or some sort of substitute, such as "phantom equity"? In a private company, how much information should you reveal? How should the value be determined? Who should you include in the plan? How often should you make awards, and at what level? Should you pay dividends? How can people cash out? The list goes on and on. In effect, you have to start all over again, deciding what kind of behavior you want to encourage, and why.

And, as they say on late-night television, THAT'S NOT ALL! You also have to be prepared to change your plan (or plans) at least every couple of years. Why? Because companies change, markets change, people change, objectives change. Even the best plans aren't good forever. Some need to be rejiggered every year—adjusting the performance criteria, including other people, and so on. From time to time, moreover, you may have to scrap the whole system and start again.

Consider Nicolet Instruments, which recently has been forced to restructure its program in response to a slowdown in its market. The original system rewarded managers according to the performance of individual product groups. It worked fine, says CEO Krauss, when the company was smaller, and growing at 25% to 30% a year. But now the growth has leveled off, and the old rules don't apply.

Incentive compensation takes an enormous amount of time and effort. It also requires that you think strategically about your business, that you provide significant rewards for performance, and that you be willing to share a lot of information with your employees. The systems that work best are the ones with clear objectives that people can understand and clear incentives that they can follow. If you can't provide those things, or don't want to, you might as well save yourself the trouble. Incentive compensation is not for you.

There's only one problem with that attitude. The evidence is overwhelming that a well-designed incentive system can have a major impact on a company's performance, giving it a new competitive edge. So if you don't set one up, you run the risk that your competitors will.

In fact, it could be that the company passing you on the right already has one. □

THE TAKE AT THE TOP

PAY FOR PROFITS

How the most competitive companies around are "incentivizing" their compensation systems.

BY BRUCE G. POSNER

BACK IN THE LATE 1960s, SHANNON & Luchs Co. was just one of a dozen or so small real estate brokerage businesses in Washington, D.C. Its managers were all paid in accordance with the norms of the industry, and they received the standard merit raises and bonuses at the end of each year. Then, around 1970, the company overhauled its executive compensation system. In addition to their regular salaries, division heads were given the opportunity to earn a percentage (10% to 25%) of the net profits of their respective divisions, adjusted for overhead and other expenses. The result: sales and profits took off. Today, Shannon & Luchs is one of the largest and most profitable real estate companies in the United States. Company president Foster Shannon gives full credit to the compensation system.

Such tales may sound too good to be true, but they are becoming increasingly common as more and more companies turn to incentive pay as a means of achieving strategic objectives. The trend is easily the hottest one to hit the compensation field since the cost-of-living raise. It involves a whole different approach to compensation, one that is geared toward achieving future objectives, rather than rewarding past performance. To date, thousands of businesses have adopted such systems, and those that try it swear by it. Most practitioners will tell you that—in addition to fostering phenomenal results—incentive compensation allows them to recognize the movers and shakers in their organizations, the people who make things happen, and to inject a new sense of vitality and purpose into the company as a whole.

Testimonials aside, the trend reflects important changes in the business environment. As inflation has declined, companies have found it harder to justify the big raises that were common in the 1970s and early '80s, and so they have begun searching for new ways to keep employees motivated. Even more important has been the pressure of increased competition, forcing companies to become ever more efficient and profitable.

Among the first to move in the direction of incentive compensation were the *Fortune* 500 companies. A study by Hewitt Associates, in Lincolnshire, Ill., shows that more than 90% of the nation's largest companies had short-term incentive plans as early as 1980. These plans made it possible for participating managers to earn bonuses totaling 16% to 55% of their base salaries, given the achievement of certain operating or financial targets. Since then, thousands of smaller businesses have set up incentive plans of their own.

On the surface, at least, creating an incentive-pay program doesn't appear to be difficult at all—provided you understand where your company is, and where you want it to be. You have to know, for instance, what you're shooting for, whether it's more profitability, higher sales, better service. As a wise man said, if you don't know where you're going, the odds are you'll wind up somewhere else.

Once you are clear about your objectives, however, the rest falls into place. First, you have to decide who to include in the plan. If you want to increase profitability, for example, and if your business is composed of relatively autonomous operating units or product areas, you may well decide to focus on a handful of key managers—the ones with the leverage to make sure their respective units make money. On the other hand, you may have a company like Riley Gear Inc., in North Tonawanda, N.Y., a $6-million manufacturer of precision gear systems, whose success depends on its ability to deliver quality products on time at competitive prices. Since every employee plays a role in achieving the company's productivity goals, all 90 of them receive a quarterly bonus check when targets are met.

Of course, you also have to choose the performance criteria by which you'll hold people accountable. Here, your decision is almost entirely a function of your goals. Indeed, two identical companies might deliberately choose different performance criteria. One, for example, might decide to reward nothing but sales growth as a way to spur aggressive selling, while the other might target profits or quality control. The latter business would, in effect, be telling people to say no to some business opportunities. But each company, in its own way, would be encouraging the kind of behavior it wanted.

Then again, some companies might want their employees to pay attention to more than one goal at a time. For several years, Nicolet Instrument Corp., a Madison, Wis., manufacturer of medical and chemical testing equipment, calculated its management bonuses using a formula that took into account both sales growth and return on assets. With two important goals to balance, says chief executive officer and president John Krauss, there were no rewards for leaning too far in one direction. Other companies accomplish the same thing by establishing separate incentive pools tied to the achievement of different objectives.

Whatever measures you choose, they must be readily comprehensible to the employees they affect. If employees don't know what kind of performance you are trying to encourage—or why it's important—they aren't likely to respond as you intend. You either have to explain what you are trying to accomplish, or choose other measures. By the same token, the performance criteria must involve aspects of the business that the affected employees can control and monitor. That means providing them with the data—monthly sales figures, production reports, profit statements—that will show them how they are doing.

Within these parameters, however, you have a lot of flexibility, not to mention influence. You can, indeed, attach incentives to almost anything—and thereby determine how managers and employees spend their time and where they focus their attention.

Now, none of this seems particularly difficult. You choose your goals, your people, your performance criteria. What could be simpler? Well, not so fast. The problem is that, at every stage, you have decisions and judgments to make, and any one of them can undermine your plan.

Consider, for example, the choice of performance criteria. Should you establish custom-made targets for individuals, or is it better to tie their incentives to the performance of the company as a whole? Dynamark Security Centers Inc., a $5.5-million franchisor of home security centers and distributor of security equipment, gives

THE INDIVIDUAL INCENTIVE
Tailoring the bonus to the job

ROSEMARIE CEPRO

Michael Zisman
President of Soft-Switch Inc.

Establishing incentives for individuals takes time, and many jobs are difficult to measure. But Michael Zisman, chairman and chief executive officer of Soft-Switch Inc., in King of Prussia, Pa., thinks that individual incentives are critical to the success of any compensation program. Last year, his company, an $8-million maker of computer networking software, embarked on a program that provides special rewards for about one-third of Soft-Switch's 70 employees.

The idea, says Zisman, was to encourage key employees to focus on individual objectives that are important to the overall success of the business. To provide the necessary rewards, Soft-Switch established a bonus pool based on its achievement of certain sales and profit targets. If the targets are met in fiscal 1987, for instance, the company will kick in 20% of the combined base salaries of affected employees. How that money gets divided depends partly on each individual's contribution to the company's collective success. Last year, for example, half of the potential bonus for the vice-president of operations was tied to such things as improving customer satisfaction ratings and reducing the time required to install products. (The other half was tied to the overall performance of the business.) Similar criteria are applied to many nonline positions as well. A large chunk of the controller's bonus, for instance, is linked to getting monthly reports in on time.

Zisman admits that it's not always easy to define the right objectives for jobs, but he argues that, without individual goals, some critical tasks will never become priorities. What's more, you'll always have a hard time differentiating between levels of performance, and everyone will wind up with roughly similar rewards.

THE GROUP INCENTIVE
Rewarding a company as a team

PHIL MATT

Tom Lowry
President of Riley Gear Inc.

Suppose you had a company in which each and every employee had the power to undermine your competitive position. That was the problem at Riley Gear Inc., a maker of precision gears, in North Tonawanda, N.Y. The solution was to create a compensation system that gives all 75 manufacturing people and the 15 other employees a significant financial stake in the overall success of the company.

The system is known as gain-sharing, and it is built around monthly productivity targets. Every order that comes in to the $6-million business is broken down into a series of production steps, which are assigned hourly rates related to the capabilities of the equipment and the complexity of the work. These rates are then used to create a "blended" productivity target for the company. The amount that Riley puts into the bonus pool each month depends entirely on the achievement of the companywide target, which in turn depends on the workers meeting, or exceeding, their goals.

In the two years the system has been in effect, Riley's hourly workers have earned 3% to 4% a year in extra compensation—over and above the annual increases of 3.3% provided in their three-year union contract. President Tom Lowry thinks that bonuses of 8% to 10% a year are well within reach "as long as the productivity is there." He's also talking about adding nonfinancial rewards, such as extra vacation time.

Of course, there are trade-offs involved in paying plantwide bonuses. "If you have superb performers, you can't really recognize them," Lowry notes. Nevertheless, he believes the benefits of the system outweigh its liabilities. "There's a lot of peer pressure. People know that if we get the cost reductions, everyone gets something. And they understand it's a competitive market, and we're all in this together."

each of its nine key managers and supervisors a different set of performance targets. The marketing and training manager, for instance, gets a small slice (about 1%) of sales up to a given level and a smaller percentage after that. The head of franchise development, on the other hand, gets a cut of the franchise fees and the inventory ordered by new franchisees. "The structure of the deals is basically the same," says chairman Ed Cusick, "but everyone gets his own report card."

Some businesses go even further, linking an individual's reward to the accomplishment of specific tasks. Thus, at Morris Decision Systems Inc., a computer dealership and maintenance company in New York City, the vice-president of finance has to get a new general-ledger system up and running in order to earn a part of his bonus for 1986.

But there can be problems with this approach. First, it takes time and effort to select the right goals. Then there is the administrative burden of monitoring the performance of many individuals. But perhaps most worrisome is the possibility that what's good for a particular individual, or group of individuals, may be awful for the business as a whole.

In the early '70s, for instance, Nypro Inc., now a $65-million plastic injection molding company in Clinton, Mass., began to reward employees for their own individual output. Some enterprising workers found ways to speed up production equipment during their shifts. They refused to share their secrets with their colleagues, however, and the high-speed work undermined quality. So Nypro was forced to switched from individual to group incentives.

Fearing similar problems, many companies require a certain level of overall results before individual bonuses are paid. "You can say, if we earn so many dollars, or if we get into the World Series, you'll get a reward," notes Peter T. Chingos, who heads the compensation consulting practice at Peat, Marwick, Mitchell & Co. But finding the right balance is not easy.

Nor is it easy to establish performance standards for every job. True, you can set quotas for salespeople and determine efficiency ratios for plant managers. You can even measure performance in such areas as quality control: at Soft-Switch Inc., a King of Prussia, Pa., software company, the quality-control manager is rewarded in part on the basis of results from customer-satisfaction surveys. But what do you do with a human-resources manager? Should you measure employee turnover? In many cases, turnover is totally beyond a manager's control. What's more, if you *do* target turnover, you run the risk of winding up with unambitious employees whose main virtue is that they don't like to change jobs.

To avoid these sorts of decisions, many CEOs prefer to maintain a certain amount of discretion over bonuses. In rewarding vice-presidents and project managers, Joseph Viar takes into account the "degree of difficulty" of the projects they manage. He could pay strictly on the basis of volume of business under management, "but different jobs rely on different mixes of inside people, consultants, and subcontractors," says Viar, president of Viar & Co., an Alexandria, Va.-based consulting company in the data-processing area. Thus they require different amounts of management, and he compensates accordingly.

Then again, you can't use too much

THE PHANTOM STOCK INCENTIVE

Eating your cake and having it, too

TOM SIMON

Al Weatherhead
Weatherchem's founder and CEO

How does a private company get key employees to lose sleep over the business without giving up equity? That was the question confronting Weatherchem Inc., a $6.5-million maker of plastic caps and closures located in Twinsburg, Ohio. Its solution: "phantom stock," an increasingly common technique by which a company rewards employees for building the business's value, while keeping the stock in the original owner's hands.

As founder and chief executive officer of the family-owned company, Al Weatherhead knew he wanted to institute some kind of long-term reward system to get his half-dozen key managers focused on "profitable growth." Real equity made him nervous, however. Among other things, he didn't know how long the key people would stay around the 65-employee company, and he didn't look forward to endless battles over stock valuation. Under the phantom program, adopted in May 1982, selected managers will receive a share of the amount by which Weatherchem's value appreciates over a five-year period. The value is calculated according to a formula that takes into account the company's return on assets and return on equity, both adjusted for its cost of capital.

The plan has encouraged managers to focus on Weatherchem's long- and short-term objectives, but Weatherhead is dissatisfied with the formula. "It's too damn complicated, and it isn't something you can pound the table over." So the company is formulating a new, simpler phantom plan to take effect when the first one expires next May. The new formula, he says, will probably be based on cumulative profits over a three-year period. Why three years this time, instead of the five years in the original plan? "Five years," Weatherhead offers, "just seemed a bit too long."

THE REAL EQUITY INCENTIVE

When nothing else will do

RICHARD HOWARD

G. B. Lankton
Nypro's CEO and president

Few owners of small companies relish the idea of taking on their employees as partners and minority shareholders, but that was not the case with Gordon B. Lankton, president and chief executive officer of Nypro Inc., a highly successful plastic injection-molding company in Clinton, Mass. He inaugurated the company's unusual stock bonus program 17 years ago, and he has never regretted the decision.

Created in 1969, when Nypro was a struggling $4-million business, the plan was designed to encourage employee commitment and achievement by making equity available to people throughout the company. Eligibility is based on a formula that takes into account three factors: length of service, salary level, and job performance. Every year, employees receive points in each category. If an individual scores 20 points or better, he or she can receive a special equity bonus.

The equity takes the form of real stock. The program is not an employee stock ownership plan and uses none of the tax advantages associated with ESOPs. Nor does Lankton view phantom equity as a viable alternative in a company like his. "I want [the stock] to feel real," he says. "You can explain phantom stock to people who are financially sophisticated, but it can be incredibly confusing to everyone else."

As Nypro has grown—today, it is a $65-million company with 1,200 employees—some 90 employees, about half of them nonmanagers, have become shareholders. Meanwhile, the value of the stock (measured by book value) has shot from $3.50 a share in 1969 to $25 last year. To discourage employees from leaving, Nypro requires departing shareholders to sell their stock back to the company over a period of 5 to 10 years—thereby minimizing the impact on Nypro's cash flow.

---

discretion in awarding bonuses without undermining your incentive program. If the principal basis for compensation is the boss's whim, the only real incentive is to stay on his good side.

At this point, you still have to decide how much money you should dish out in the form of incentives. It can't be so much as to imperil the business—by getting in the way of meeting debt service payments, for example—yet it has to be enough to attract employees' attention. As a rule of thumb, most compensation experts advise that you make available incentive bonuses of at least 10% to 15% over base salaries. Employees will tend to regard smaller bonuses as "tips," which may motivate them to work a little harder and "smarter," but not enough to justify the effort and expense of establishing an elaborate incentive system.

Then there's the related issue of selecting the right performance levels—a critical part of the process. If the targets are too high, people may give up. If they're too low, you may encourage people to take it easy. What happens, for example, if you surpass the target midway through the year?

And what if you set target levels that inadvertently wind up *penalizing* your best employees? That's more or less what happened at The Myers Group Inc., a freight forwarder with 65 offices around the country. For several years, the company paid out bonuses according to a formula that rewarded people annually for profit improvements at their individual branches. The formula was designed to motivate those who worked at the least efficient locations, and that it did. But it provided little incentive for employees assigned to the most profitable branches. Moreover, the system became less and less effective over time. The better an office did one year, the harder it was to receive a bonus the next. People grumbled, and so the company, based in Rouses Point, N.Y., eventually scrapped the formula. Now incentives are tied to the overall profitability of each office and of the company.

Once you have settled on performance levels and criteria, you still have to decide how often people will be rewarded—an aspect of incentive compensation that is often overlooked. After all, the real test of any incentive program is its ability to keep people focused on company objectives. Annual bonuses are traditional, and relatively easy to administer, but can employees stay focused on targets for a whole year? Gordon Lankton of Nypro, the plastic molding company, doesn't think so. His company pays its productivity bonuses on a quarterly basis because "a year can feel like a long time," he says. To make sure that everyone notices, Nypro even uses special profit-sharing checks with a picture of George Washington in the center and "profit-sharing" printed across the top.

On the other hand, quarterly bonuses can be extremely impractical from a company's perspective. Not only does it take administrative effort, but it demands an ability to forecast with precision and to anticipate cash-flow needs. Recently, an air-freight company paid out substantial incentive bonuses at the end of one quarter, only to hit a dry period the next. It hastily revamped its quarterly incentive program. Now nonmanagers get bonus checks after each profitable quarter, but managers don't receive theirs until annual results are in.

So, if you look hard enough, there are solutions to all these potential problems. The bad news is that, once you've come up with a viable short-term incentive plan, you

STRATEGIES FOR INCENTIVE COMPENSATION

You can look outside for help and inspiration, but the answers are all close to home.

There are no real shortcuts to creating an effective incentive compensation system. No matter how you approach it, you still have to ask, and answer, dozens of difficult questions about your goals, your people, and your business. It helps, however, to have a strategy for dealing with these questions. There are essentially three to choose from:

THE COPYCAT METHOD

One strategy is to adapt somebody else's plan to your own circumstances and needs. It's particularly appealing if the other company is similar to yours, and if its system has worked well.

That was the case with Nicolet Instrument Corp., which developed its plan back in 1981 after chief executive officer John Krauss saw an article in the *Harvard Business Review* about the incentive compensation program at Analog Devices Inc. As it happened, Analog had management and operating structures strikingly similar to Nicolet's. So Krauss copied Analog's incentive compensation program, and it worked effectively for several years.

There are pitfalls in the copycat approach, however. To begin with, no two companies have identical cost structures: if your costs are higher than those of the company you're copying, you may be stimulating behavior that you can't afford. Nor can you assume that the other company's market position or goals are the same as yours. If they aren't, the performance criteria are liable to be off as well. "Copying another incentive plan," says one consultant, "is like trying to learn Jimmy Connors's backhand when you don't have his serve." It may work; then again, it may throw everything out of whack.

THE CONSULTANT ROUTE

Another strategy is to hire a specialist to design your compensation program for you. That's a natural impulse, and consultants do have much to offer in the way of advice and experience. But many have worked only with large companies, which does not help them in understanding and solving the compensation problems of smaller companies.

James Bernstein learned that lesson the hard way when he brought in a well-known consulting firm to design an incentive plan for his $4.5-million health risk-management firm, General Health Inc., based in Washington, D.C. He wanted a compensation system that would encourage employees to focus on sales volume and building market share. With that mandate, the consultant produced an elaborate plan under which all 80 employees could earn handsome bonuses by meeting individual and company objectives. "The consultant gave me his best advice," says Bernstein. "It sounded just terrific." Unfortunately, it wasn't. Not only did the system demand hours upon hours of management time to review each employee's objectives, but it also completely overlooked the company's need to change direction and shift people around on short notice. Objectives that made perfect sense one week were outdated the next.

Within a year, General Health scrapped the consultant's incentive program and installed a simpler one designed by Bernstein himself. Dispensing with individual goals for everyone but salespeople, the new system rewards employees for meeting quarterly profit objectives. It takes a lot less time to administer, notes Bernstein, and yet it's enough to send the message that "everyone needs to put their shoulder to the wheel."

THE TAKE-YOUR-LUMPS APPROACH

Bernstein's experience illustrates a fundamental fact of incentive compensation: sooner or later, you have to develop your own system. There are no blueprints, and there are no outside cures. You may discover some interesting features in other companies' programs. You may also find consultants who can help you think through your company's needs. But don't expect anyone to understand your company as well as you do.

"There's no substitute for sitting down, locking yourself in a room, and thinking about what's really important to your business," says Bernstein. "Otherwise you'll end up with a cookie-cutter approach that was designed for the company next door." So, in the end, most companies wind up developing their compensation programs the old-fashioned way—by doing it themselves.

still have to confront the issue of *long-term* incentives—the kinds of rewards that ensure employees stay focused on a company's objectives over the long haul. Those kinds of incentives can be just as important as the quarterly and annual ones, maybe more so, and the issues involved are no less thorny. Should you give people real stock, or stock options, or some sort of substitute, such as "phantom equity"? In a private company, how much information should you reveal? How should the value be determined? Who should you include in the plan? How often should you make awards, and at what level? Should you pay dividends? How can people cash out? The list goes on and on. In effect, you have to start all over again, deciding what kind of behavior you want to encourage, and why.

And, as they say on late-night television, THAT'S NOT ALL! You also have to be prepared to change your plan (or plans) at least every couple of years. Why? Because companies change, markets change, people change, objectives change. Even the best plans aren't good forever. Some need to be rejiggered every year—adjusting the performance criteria, including other people, and so on. From time to time, moreover, you may have to scrap the whole system and start again.

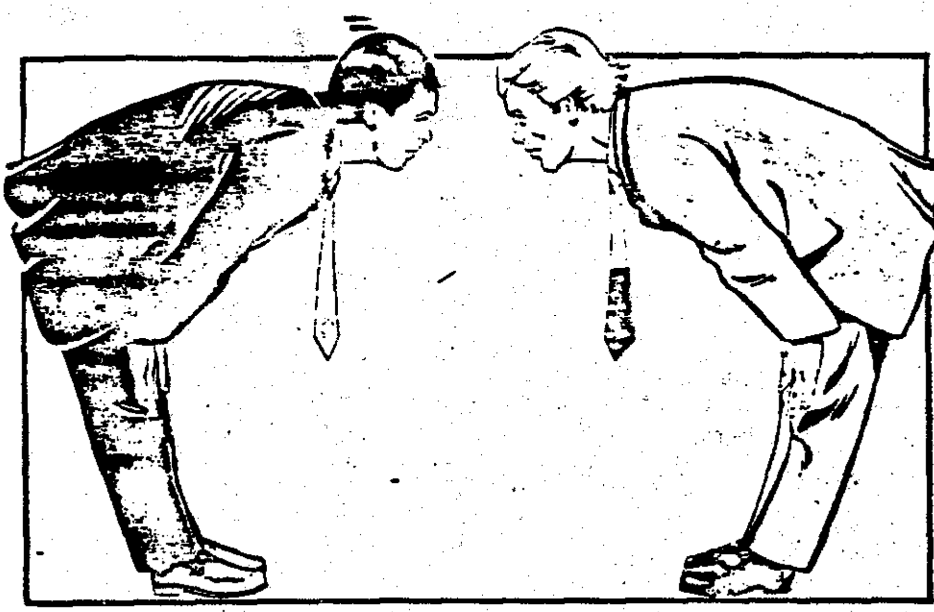
Consider Nicolet Instruments, which recently has been forced to restructure its program in response to a slowdown in its market. The original system rewarded managers according to the performance of individual product groups. It worked fine, says CEO Krauss, when the company was smaller, and growing at 25% to 30% a year. But now the growth has leveled off, and the old rules don't apply.

Incentive compensation takes an enormous amount of time and effort. It also requires that you think strategically about your business, that you provide significant rewards for performance, and that you be willing to share a lot of information with your employees. The systems that work best are the ones with clear objectives that people can understand and clear incentives that they can follow. If you can't provide those things, or don't want to, you might as well save yourself the trouble. Incentive compensation is not for you.

There's only one problem with that attitude. The evidence is overwhelming that a well-designed incentive system can have a major impact on a company's performance, giving it a new competitive edge. So if you don't set one up, you run the risk that your competitors will.

In fact, it could be that the company passing you on the right already has one. □

HIGH TECHNOLOGY



Clash of the titans

After steel, motor cars, consumer electronics and cheap micro-chips, Japan has begun to challenge American pre-eminence in the one industrial area the United States has long cherished as its own: high technology. The two are girding up for a trade war in high-tech that threatens to be bloodier than anything yet. Nicholas Valéry reports on the strengths and weaknesses of the two technological superpowers

The recent movie "Gung Ho" gets a lot of laughs out of the many misunderstandings that ensue when a Japanese car firm moves into a sad little town in Pennsylvania. Stereotypes abound: dedicated Japanese managers putting in double shifts, lazy American loudmouths slowing down the assembly line—with the locals winning a baseball match between the two sides only through brute force and intimidation.

All good clean fun. In real life, however, American workers—despite the popular myth—remain the most productive in the world (see the feature on the next page). In terms of real gross domestic product (GDP) generated per employed person, the United States outstrips all major industrial countries, Japan included (chart 1). The problem for Americans is that the rest of the world has been catching up. In the decade from the first oil shock to 1983, increases in annual productivity in the United States had been roughly a seventh of those of its major trading partners.

In the 1960s, American companies held all the technological high cards and dominated the world's markets for manufactured goods. The United States supplied over three-quarters of the television sets, half the motor cars and a quarter of the steel used around the world. Yet, a mere two decades later, Japan had taken America's place as the dominant supplier of such products.

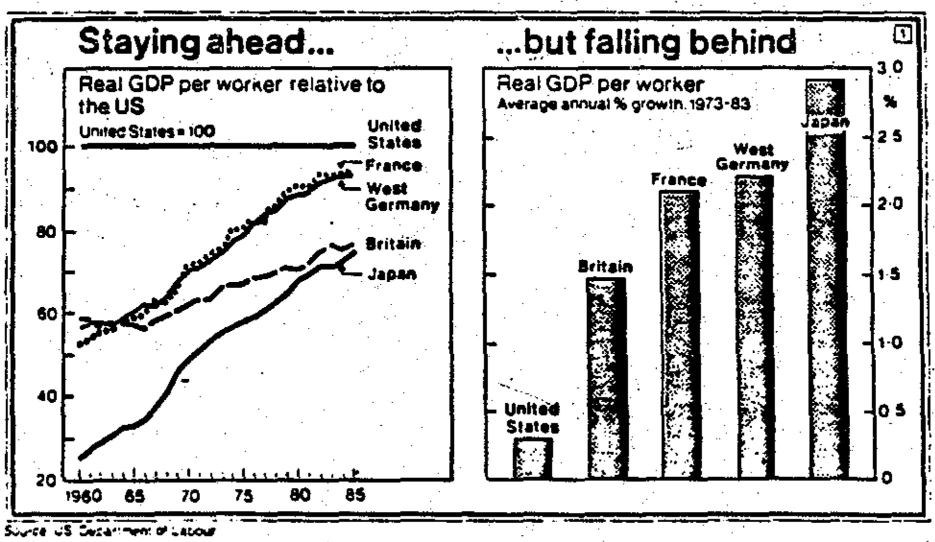
The agony for Americans does not end there. Over the past 25 years they have seen:

- Their share of world trade fall from 21% in 1960 to 14% in 1985.
- The American trade balance go from a surplus of $5 billion in 1960 to a deficit of $150 billion last year.
- More worryingly still, the country's trade balance in manufactured goods slip from a healthy surplus of $11 billion as recently as 1981 to a deficit of $32 billion last year—approaching 1% of America's total output.
- The volume of its manufacturing exports tumble 32% over the past five years—with every $1 billion of exports lost costing an estimated 25,000 American jobs.

Angry and confused, businessmen in the United States have had to stand by and watch as "smokestack" industry all around them has been snuffed out. Then came the unthinkable: if the Japanese could thrash them in mainstream manufacturing, would they give them a mauling in high technology, too?

By the beginning of the 1980s, it began to look as if they would. It became clear that the Ministry of International Trade and Industry (MITI) in Tokyo had "targeted" not just semiconductors and computers but all of America's high technology industries—from aerospace to synthetic materials—for a blitzkrieg attack.

Six years on, Japan has scored some



Source: US Department of Labour

Power to the elbow

Americans work every bit as hard as (and often a lot harder than) the Japanese—and generate proportionately more wealth in the process. The average output of American workers last year was $36,800. The Japanese equivalent was $22,500 (at an average 1985 exchange rate of Y220 to the dollar).

But labour productivity is only half the story. The amount of capital applied to a worker's elbow is crucial, too. The traditional definition of productivity (output per hour of all workers) makes it difficult to measure these inputs separately. True, the definition reflects all the factors that contribute to rising output—from advances in technology, better utilisation of capacity, improvements in the way production is organised and sharper management, to harder efforts by the workers themselves as well as the impact of changes in the amount of capital employed.

In 1983, the American Bureau of Labour Statistics introduced a yardstick called multifactor productivity. This shows the changes in the amount of capital as well as labour used in production. Reworking its data for 1950-83, the bureau found that multifactor productivity in the United States increased at an average annual rate of 1.7% for the period. As output per hour over the same period increased by an annual 2.5%, capital productivity inched up by only a modest 0.8% a year.

Overall, America's multifactor productivity has shown two distinct trends over the past 35 years. Up till the first oil shock of 1973, the country experienced an annual 2% multifactor growth: then an annual average of only 0.1% from 1973 to 1981. The post-OPEC slowdown seems to have resulted from high interest rates keeping the brakes on capital spending, while more people were having to work longer hours to hang on to their jobs.

How did the Japanese fare? The driving force behind the Japanese economy over the past 25 years has been the high growth in capital input. Mr Dale Jorgenson and his colleagues at Harvard University reckon it has been roughly double that in the United States. Growth rates in labour productivity have been much the same for the two countries. All told, the growth in Japanese productivity outstripped that in the United States until 1970, when productivity growth began to slow dramatically in Japan. Thereafter, with Vietnam behind it and two oil shocks ahead, the American economy flexed its muscles and coped more effectively. Then the competitive advantage started to move back in America's favour.

The interesting thing is what has happened since the last recession. Multifactor productivity in the United States has been running at an average of 5% a year, while the growth in labour productivity is now averaging nearly 4% a year. That means that productivity of capital employed is now growing at well over 6% a year.

Could this be the first signs of the productivity pay-off from the $80 billion that Detroit spent on new plant and equipment over the past half dozen years; the combined (additional) $180 billion invested by the airlines since deregulation, telecommunications firms since the AT&T consent decree and the Pentagon since President Reagan's defence build-up began in 1980? It looks remarkably like it.

notable hits. A group of American economists and engineers met for three days at Stanford University, California, last year to assess the damage*. They concluded that Japanese manufacturers were already ahead in consumer electronics, advanced materials and robotics, and were emerging as America's fiercest competitors in such lucrative areas as computers, telecommunications, home and office automation, biotechnology and medical instruments. "In other areas in which Americans still hold the lead, such as semiconductors and optoelectronics, American companies are hearing the footsteps of the Japanese", commented the Stanford economist Mr Daniel Okimoto.

How loud will those footsteps become? American industry may have been deaf in the past, but it certainly isn't any more. And never forget that Americans are a proud and energetic people. More to the point, they are prone to periodic bouts of honest self-reflection—as if, throughout their two centuries of nationhood, they have been impelled forward by a "kick up the backside" theory of history.

Once every couple of decades, America has received a short and painful blow to its self-esteem; Pearl Harbour, Sputnik, Vietnam are recent examples. What follows then is usually a brief and heart-searching debate along with a detailed analysis of the problem, then an awesome display of industrial muscle coupled with unexpected consensus between old adversaries—most notably between Congress, business and labour.

With its ceaseless shipments of cameras, cars, television sets, video recorders, photocopiers, computers and microchips, Japan unwittingly supplied the latest kick up the broad American buttocks. After witnessing Japanese exporters almost single-handedly reduce Pittsburgh's steel industry to a smouldering heap, drive Detroit into a ditch, butcher some of the weaker commodity microchip makers of Silicon Valley, and threaten America's remaining bastions of technological clout—aircraft and computers—then, and finally then, American lethargy ceased.

This survey tries to assess the strengths and weaknesses of the world's two technological superpowers. For if the past decade has seen some of the ugliest recrimination between Washington and Tokyo over trade issues generally, imagine what the coming decade must have in store. Henceforth, industrial competition between America and Japan is going to range fiercely along the high-tech frontier—where both countries take a special pride in their industrial skills and cherish sacred beliefs about their innate abilities.

The question that ultimately has to be answered is whether America is going to allow the Japanese to carry on nibbling away at its industrial base without let, hindrance or concession? Or are the Americans (as some bystanders have begun to suspect) "about to take the Japanese apart"?

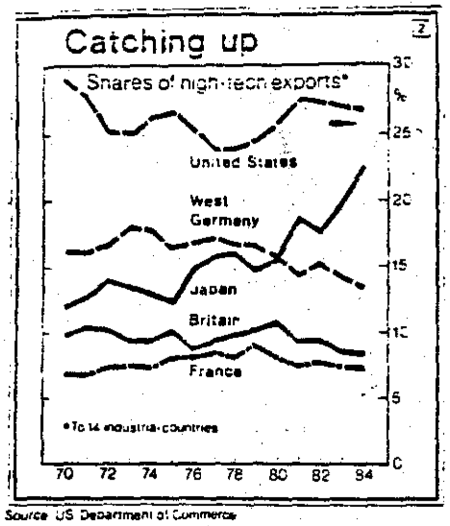
With the gloves now off, which of the two technological heavyweights should one put some money on? In the blue corner, Yankee ingenuity? In the red, Japanese production savvy?

*Symposium on Economics and Technology held at Stanford University, March 17-19 1985. Now published as "The Positive Sum Strategy: Harnessing Technology for Economic Growth" by National Academy Press, Washington, DC.

Copycat turns leader?

Is Japan still a technological free-loader—or has it become a pacesetter in high-tech?

America may still have the largest share of high technology exports, but Japan is catching up fast. It skipped smartly past West Germany to become the second largest supplier of high-tech goods in 1980 (chart 2 on next page). Only in three high-tech industries—communications and electronics, office automation, and ordnance—have American companies increased their market share.



Catching up

Source: US Department of Commerce

The Japanese know they do not have a chance in fields that are either defence-related (for example, weapons, aircraft, satellites and avionics) or too dependent on imported energy or raw materials (like petrochemicals). But they see everything else as up for grabs. Even in lasers, software and computer-integrated engineering—where American pre-eminence was long thought unassailable—the Japanese have begun to make inroads.

Who would have thought it possible a decade ago? Of the 500 breakthroughs in technology considered seminal during the two decades between 1953 and 1973, only 5% (some 34 inventions) were made in Japan compared with 63% (315 inventions) in the United States. Despite its large, well-educated population, Japan has won only four Nobel prizes in science: American researchers have won 158. It is not hard to see why Japan has been considered more an imitator than innovator.

Stanford University's Mr Daniel Okimoto lists half a dozen reasons for Japan's lack of technological originality in the past:

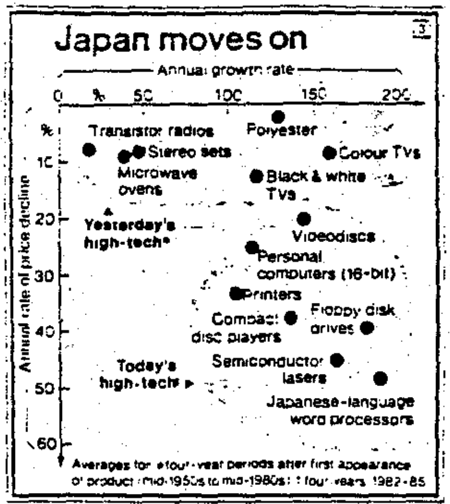
- As an industrial latecomer, it has always been trying to catch up.
- The Japanese tendency towards group conformity has made it difficult to win a hearing at home for radical ideas.
- Research in Japanese universities is bureaucratic, starved of cash and dominated by old men.
- The venture-capital market is almost non-existent.
- Lifetime employment, along with a rigid seniority system, stifles innovation inside industry.
- And the traditional heavy gearing (high debt-to-equity ratio) of much of Japanese industry has made firms think twice about taking risks.

All these things—and more—have been true to some extent in the past; but all are also changing. The deregulation of Tokyo's financial markets, for instance, is forcing Japanese companies to reduce their levels of debt (see accompanying feature on next page). This, in turn, is making them more adventurous, while at the same time helping ferment a number of venture-capital funds.

Japan's "invisible" balance of technological trade (its receipts compared with payments for patent royalties, licences, etc) which had a ratio of 1:47 a couple of decades ago came within a whisker of being in balance last year. That said, Japan still buys its high-tech goods and knowhow predominantly in the West and sells them mainly to the developing world.

In certain industries, however, Japanese manufacturers have already started bumping their heads against the ceiling of current knowhow. There are no more high-tech secrets to be garnered from abroad in fibre optics for telecommunications, gallium arsenide memory chips for superfast computers, numerically-controlled machine tools and robots, and computer disk-drives, printers and magnetic storage media. In all these, Japan now leads the world. Today, Japanese-language word processors represent the cutting edge of high-tech in Japan—taking over the technological (but hardly export-leading) role that colour television played earlier (chart 3).

Although it is no longer quite the technological free-loader it was in the past, is Japan's new reputation as a pace-setter in high-tech justified? A new image has certainly emerged over the past few years of Japan as an invincible Goliath, capable of vanquishing any rival, whatever the field. Yesterday, the smokestack



Japan moves on

Source: Mitsubishi Bank

sectors. Today, high technology. Tomorrow, services. . . "Which is the 'real' Japan?" asks Mr Okimoto:

> Is it a technological imitator and industrial over-achiever? Or is Japan an astute learner and unbeatable colossus? Will Japan dislodge the United States from its current position of dominance in high technology as convincingly as it did in the smokestack sectors? Or has it reached the limits of its phenomenal postwar growth?

Japan is all these things and more. And to understand what the future holds, and whether America is up against a David or a Goliath, means looking closely at the frontiers of modern electronics. For the country that commands the three most crucial technologies of all—semiconductors, computing and communications—will most assuredly command the mightiest industrial bandwagon of the twenty-first century.

Made in the USA

Just as Japan has begun to muscle into high-tech, America has raised the technological stakes. The name of the game now is ultra-tech

High technology is an American invention. Despite the near meltdown at Three Mile Island, broken helicopters in the Iranian desert and recent disasters on the launch pad, Americans remain the supreme practitioners of this demanding and arcane art. And while the United States has racked up large deficits on its international trading account, it has enjoyed growing surpluses in its worldwide sales of high-tech goods. Or, rather, it did so until recently. Once again, blame the Japanese.

Five years ago, America sold the world $23.6 billion more technological widgets than it bought. That handy surplus had dwindled, says America's Department of Commerce, to a token $5 billion by 1984 (chart 7 on later page). Meanwhile, foreigners had grabbed three-quarters of the world's current $300 billion in high-tech trade. In the process, Japan has gone from being a small-time tinkerer in the 1960s to becoming (as in everything else) the Avis of high technology to America's Hertz.

Even so, trade in high-technology goods remains a crucial breadwinner for the United States. Since the mid-1960s, high-tech's share of American manufactured goods sold around the world has gone from a little over a quarter to close to a half.

Office automation is now America's most competitive high-tech industry as well as its biggest revenue-earner abroad. Selling its trading partners computers, copiers and word processors brought in

Crying all the way to the bank

One thing Americans have learned is that having the world's most productive labour force does not guarantee industrial competitiveness. At least three other things are needed. The first is to keep a lid on wages. The second concerns exchange rates. The third involves the return on capital employed. All three have been seen lately as spanners in the American works.

Take wages. During the ten years before 1973, real wages for American workers had increased steadily at an average rate of 2.6% a year. But ever since the first oil shock, real wages in the United States have stagnated. So American labour is becoming more competitive, yes?

Unfortunately no. When fringe benefits are included, hourly compensation for blue-collar workers in the United States has continued to rise. American labour has sensibly been taking raises less in cash than kind. Total compensation for American industrial workers—a modest $6.30 an hour in 1975—had climbed to $9.80 an hour by 1980 and to $12.40 by 1983.

Compared with Japan, hourly labour costs in America went from being on average a little over $3 more expensive in 1975 to becoming nearly $6 more so by 1983 (chart 4). So much for narrowing the $1,900 gap between making a motor car in Nagoya compared with Detroit.

Ah, yes, but hasn't the dollar tumbled dramatically? It has indeed—from a 1985 high of over Y260 to the dollar to a low this year of Y150 or so. In trade-weighted terms, that represents a drop for the dollar of 28% in 15 months. Meanwhile, the trade-weighted value of the yen has appreciated by over 40%.

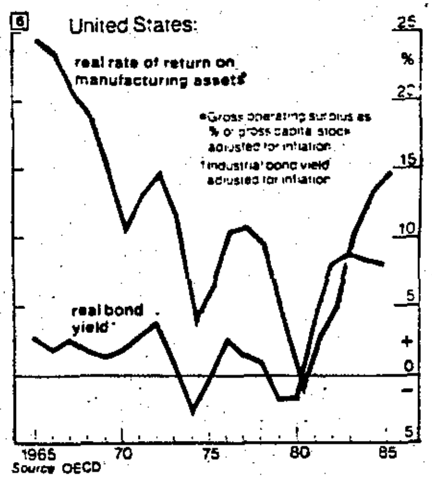
What about differences between America and Japan in terms of return on capital? Here things are actually better than most American businessmen imagine. True, real rates of return earned by American manufacturing assets in the 1960s were substantially higher than investments in financial instruments, while things were briefly the other way round during the early 1980s (chart 6). On the face of it, capital for buying equipment or building factories seems twice as expensive in America as in Japan.

Today's most cited account comes from Mr George Hatsopoulos of Thermo Electron Corporation in Massachusetts. Comparing the cost of (non-financial) capital in the two countries between 1961 and 1983, Mr Hatsopoulos found real pre-tax rates ranged between 6% and 10% for Japanese firms and anything from 13% to 20% for their American counterparts.

The conventional explanation for this difference is that Japanese firms are more highly geared (leveraged) and thus benefit because debt generally costs less than equity—interest payments being deducted from pre-tax profits, while dividends come out of taxed earnings.

Then there is Japan's two-tier interest rate structure, which is carefully regulated to favour business debt at the expense of consumer credit. Throw in a banking system that is bursting at the seams with yen being squirrelled away by housewives worried about school fees, rainy days and the ever-present threat of their husband's early (and often unpensioned) retirement. All of which, say American trade officials, adds up to a financial advantage that makes it tough for American firms to compete.

What is studiously ignored in the financial folklore about Japan Inc is the fact that, over the past decade, Japanese manufacturers have been getting out of debt as fast as decently possible (see the survey on corporate finance in *The Economist*, June 7 1986). The most compelling reason right now is because Tokyo's financial markets have joined the fashionable trend towards liberalisation. With old controls over the movement of capital going out of the window, Japanese interest rates are destined to become more volatile. So who wants to be highly geared when interest rates are rising or (worse) becoming less predictable?



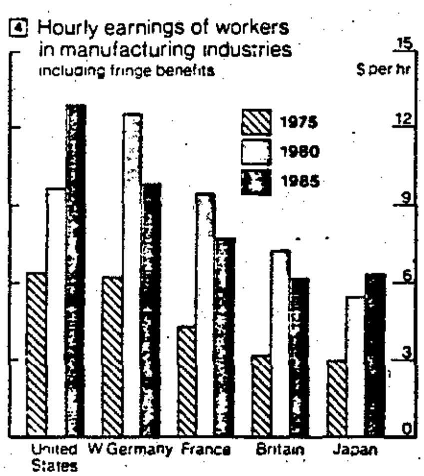
Source: OECD

Another thing Japanese manufacturers resent about some of these allegedly cheap industrial loans are the strings and hidden costs involved. The most punishing are the so-called "compensating balances" which a borrower has to deposit (at a considerably lower interest rate) with the bank offering the industrial loan. And so he has to borrow more money—at higher cost and with greater restrictions—than he actually needs.

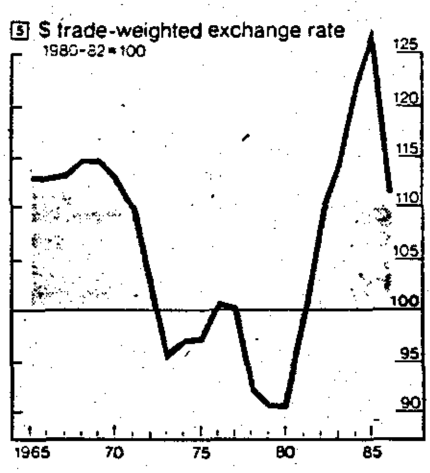
Yet another thing that muddies the water is the way debt in Japanese balance sheets is grossly overstated by western standards. For one thing, the compensating balances, though they are actually deposits, are recorded as borrowings. Then there is the habit Japanese companies have of doing much of their business on credit, especially with suppliers and subsidiaries. This makes their accounts payable and receivable look huge—in fact, twice as large as in America.

Other factors inflating debt among at least the bigger Japanese companies are things like non-taxable reserves for special contingencies and (if they pay them) pensions. The last time figures were collected in Japan (in 1981), employees in large corporations with established retirement plans were divvying up 15-20% of their companies' capital through their pension contributions. All of which showed up in their corporate accounts as debt.

All that said, Japanese companies are on balance more highly geared than American corporations; and, overall, the cost of financing industry has been lower in Japan than in the United States. But at most only 20% lower, and nothing like the 50% lower claimed by lobbyists in America.



Source: US Department of Labour, Bureau of Labour Statistics, 1984



Source: DRI

Technology's top ten

How high is the high in high-tech? Difficult to say. Most economists at least agree that high technology products embody an "above average" concentration of scientific and engineering skills. As far as the National Science Foundation in Washington is concerned, this means anything produced by organisations employing 25 or more scientists and engineers per 1,000 employees and spending over 3.5% of net sales on R&D.

The American Department of Commerce is a bit more scientific. Its definition of high-tech is derived from input-output analyses of the total R&D spent on a spectrum of individual products. Thus an aircraft gets credit for not only the R&D done in developing the airframe, but also the relevant contribution of the avionics supplier and even the tyre maker. Using this definition, high-tech industry is a ranking of the ten most "research-intensive" sectors, where the tenth has at least double the R&D intensity of manufacturing generally (table 1).

A laudable effort, but not without criticism. First, such a definition focuses entirely on products, ignoring the booming business in high-tech processes—and, increasingly, high-tech services as well. Second, it favours systems (that is, collections of interdependent components) over individual widgets, as well as products manufactured by large companies rather than small firms.

Third, because the data come of necessity from broad industrial categories, anomalies crop up—like cuckoo clocks being labelled high-tech because they fall within the eighth-ranking group, professional instruments.

Fourth, and perhaps most damning, the Commerce Department's definition is based on Standard Industrial Classification (SIC) codes—many of which have been rendered irrelevant by technological changes that have occurred since the SIC codes were last overhauled in 1972.

Table 1: Product range

	HIGH-TECH SECTOR	EXAMPLES OF PRODUCTS
1	Missiles and spacecraft	Rocket engines; satellites and parts
2	Electronics and telecoms	Telephone and telegraph apparatus, radio and TV receiving and broadcast equipment, telecoms equipment, sonar and other instruments, semiconductors, tape recorders
3	Aircraft and parts	Commercial aircraft, fighters, bombers, helicopters, aircraft engines, parts
4	Office automation	Computers, input-output devices, storage devices, desk calculators, duplicating machines, parts
5	Ordnance and accessories	Non-military arms, hunting and sporting ammunition, blasting and percussion caps
6	Drugs and medicines	Vitamins, antibiotics, hormones, vaccines
7	Inorganic chemicals	Nitrogen, sodium hydroxide, rare gases, inorganic pigments, radioactive isotopes and compounds, special nuclear materials
8	Professional and scientific instruments	Industrial process controls, optical instruments and lenses, navigational instruments, medical instruments, photographic equipment
9	Engines, turbines and parts	Generator sets, diesel engines, non-automotive petrol engines, gas turbines, water turbines
10	Plastics, rubber and synthetic fibres	Various chemicals derived from condensation, polycondensation, polyaddition, polymerisation and copolymerisation; synthetic resins and fibres

$20 billion in 1984. Along with aircraft, electronics and professional instruments, these "big four" account for more than three-quarters of the United States' exports of high technology (table 2). Despite the popular myth, America exports only modest amounts of missiles and aerospace products. But fears that foreigners may eventually storm even the high frontier of aerospace keep Washington officials awake at night.

Of the ten industrial sectors designated high-tech (see feature above), America has managed to increase its share of the global market in only two: office automation and electronics. For which, it should thank the likes of IBM, Hewlett-Packard, Digital Equipment, Xerox, ITT, RCA, General Electric, Texas Instruments and a host of brainy technological-based businesses scattered around the West Coast, Rockies, Sunbelt, Mid-Atlantic and New England.

A common cry in Washington is that this "narrowing" of America's high-tech base is one of the most disturbing problems facing the United States today. Others see this trend as more or less inevitable—and perhaps even to be encouraged. Trade ministers in Western Europe, for instance, only wish they had such "problems"; Japanese bureaucrats are doing all they can to create similar "problems" back home.

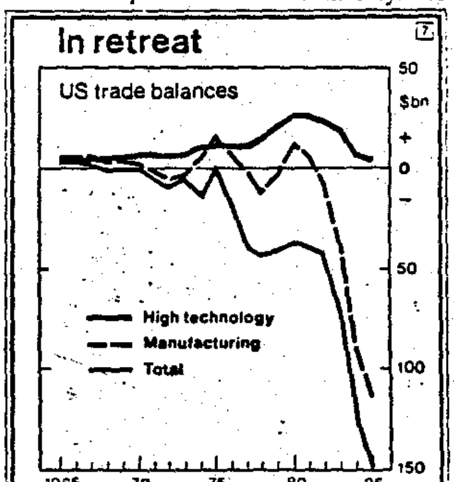
The reason is simple. These so-called "problems" concern a focusing of all the underlying technologies that have come to drive the computing, office automation and communications industries. All three provide the tools for handling information; and information—its collation, storage, processing, transmission and use elsewhere—will, quite literally, be the oil of the twenty-first century (see the survey on information technology in *The Economist*, July 12 1986).

All that noisy jostling going on right now between the IBMs, Xeroxs and AT&Ts of the corporate world is merely the

Table 2: High-tech exports in 1984

High-tech sector	American exports		Others' exports*	
	Value	% of total	Value	% of total
Office automation	$19.7bn	22.4	$6.5bn	14.5
Electronics & telecoms	$14.4bn	22.0	$53.8bn	29.4
Aircraft and parts	$13.5bn	20.7	$15.4bn	8.4
Profess'l instruments	$7.2bn	11.0	$27.0bn	14.7
Plastics, rubber, etc.	$4.4bn	6.7	$26.5bn	14.5
Inorganic chemicals	$3.5bn	5.4	$10.9bn	6.0
Engines and turbines	$3.2bn	4.9	$10.7bn	5.9
Drugs and medicines	$2.7bn	4.1	$10.7bn	5.9
Missiles and spacecraft	$1.0bn	1.5	$0.6bn	0.3
Ordnance	$0.8bn	1.3	$0.7bn	0.4

*Of the 14 other countries (apart from America) exporting high-tech goods, France, West Germany, Japan and Britain accounted for three-quarters of total trade.
Source: US Department of Commerce.



Source: US Department of Commerce

clatter of these three industrial sectors (each with its own distinctive style of manufacturing, procurement and customer support) being forged together by their underlying technologies into a single, ultra-tech activity called information services.

Yes, beyond high-tech in the industrial spectrum lies ultra-tech—today a mere multi-billion-dollar stripling of a business, but by the year 2000 potentially a trillion-dollar leviathan. As such, ultra-tech alone will come to dwarf all manufacturing sectors before the century is out. America is well on the way to making that happen. A lap or two behind, Japan at least is getting up speed. Europe is barely in the race.

Chips with everything

Gone are the days when American semiconductor firms short-sightedly sold their licences and knowhow to Japanese microchip makers

America's electronics firms have maintained their global leadership in all branches of their business save one. They kissed goodbye to consumer electronics (television, hi-fi, video recorders, etc) as customers across the country voted with their pockets for shiny boxes with flashing lights and labels like Panasonic, Technics, JVC and Sony.

The American electronics industry came close to allowing much the same to happen in microchips. In 1982, Silicon Valley took a caning when the Japanese started flooding the market with cheap 64k RAMS (random-access memory chips capable of storing over 64,000 bits of computer data). Most beat a hasty retreat up or out of the market.

From having a dozen mass producers of dynamic-RAMS in 1980, only five American chip makers were still in the high-volume memory business by 1983. Today, there are effectively only two or three with the capacity to produce the latest generation of memory chips (1 megabit RAMS) in anything like economic volumes. Meanwhile, the six Japanese firms that plunged into the memory-chip business back in the early 1970s are still around—and now have a 70% share of the dynamic-RAM market in America.

Microchips have been the engine powering Japan's drive into high-tech generally. But before it could join the microchip generation, Japan had to find a way of disseminating this vital American technology throughout its fledgling semiconductor industry. The trick adopted was, first, to protect the home market, and then to bully abler firms into joining government-sponsored research schemes—one run by the Japanese telephone authority NTT and the other by the Ministry of International Trade and Industry—to develop the knowhow for making their own very large-scale integrated (VLSI) circuits.

Next, by "blessing" VLSI as the wave of the future and crucial to Japan's survival, the government triggered a scramble among the country's electronics firms (encouraged by their long-term investment banks) to build VLSI plants. The net result was massive over-capacity (first in 64k RAMS and then in 256k versions), abundant local supply for the domestic consumer electronics makers and an impelling urgency to export (or dump) surplus microchips abroad.

This targeting ploy had been tried before. Japanese manufacturers found it worked moderately well with steel, much better with motorcycles, better still with consumer electronics and best of all with semiconductors. The only requirement was a steeply falling "learning curve" (that is, rapidly reducing unit costs as production volume builds up and manufacturers learn how to squeeze waste out of the process).

The trick was simply to devise a forward-pricing strategy that allowed Japanese manufacturers to capture all the new growth that their below-cost pricing created in export markets, while underwriting the negative cashflow by cross-subsidies and higher prices back home.

The Americans finally lost their patience when the Japanese tried to do a repeat performance with pricier memory chips called EPROMS. The price fell from $17 each when the Japanese first entered the American market with their EPROM chips early in 1985 to less than $4 six months later. Intel, National Semiconductor and Advanced Micro Devices promptly filed a joint petition, accusing the Japanese of dumping EPROMS on the American market at below their manufacturing costs in Japan (then estimated to be $6.30 apiece). The issue is currently being used by Washington as a battering ram to breach the wall Japan has erected around its own $8 billion semiconductor market back home.

For America, this get-tough policy has come only just in time. Japan now enjoys a 27% share (to America's 64%) of the world's $42 billion semiconductor market. And while cut-throat competition may make memory chips a loss-leader, acquiring the technology for producing RAMS has given Japan's microcircuit makers a leg-up in getting to grips with more complex semiconductors used in computer graphics, communications and video equipment.

So far, however, it has not helped Japanese chip makers to loosen the stranglehold that American semiconductor firms have on the lucrative microprocessor business. Where 256k RAMS have become commodity products that sell wholesale for $1 or so each, 32-bit microprocessors from the likes of Motorola, Intel, National Semiconductor, Texas Instruments, AT&T and Zilog cost hundreds of dollars apiece. Between them, these six American chip makers control 90% of the world market for the latest generation of microprocessors, leaving just 10% for the rest of the American semiconductor industry, Europe and Japan.

Fortunately for the Americans, micro-

Street map for a microchip circuit

processors are not like memory chips. Being literally a "computer-on-a-chip", they are vastly more complex and cannot be designed in any routine manner. Sweat, insight and inspiration are needed every step of the way. And they have to be designed with their software applications in mind. Americans have been doing this longer, and are better at it, than anyone else.

More to the point, American firms are not parting with their patents as readily as they did in the past. Hitachi has been trying (with little luck) to persuade Motorola to sell it a licence for making its advanced 68020 microprocessor. Meanwhile, Japan's leading electronics firm, NEC, is having to defend itself in the American courts for infringing one of Intel's microprocessor patents.

With America's new, stricter copyright laws making it difficult to imitate American designs, Japanese chip makers are being shut out of all the major markets for microprocessors. Fujitsu, Matsushita, Mitsubishi and Toshiba are all gambling on a microprocessor design called TRON developed at the University of Tokyo. But nobody, least of all NEC or Hitachi, holds out much hope for the TRON design winning a big enough share of the market in its own right to be economic—at least, not until the mid-1990s. And, by then, Silicon Valley will have upped the technological stakes again.

When, late at night, the conversation gets down to *honne* (brass tacks), even Japan's ablest microchip wizards despair at ever matching Silicon Valley's mix of entrepreneurial and innovative flair. "Japan is powerful in only one sub-field of a single application of semiconductors tied to a specific line of products", bemoans Mr Atsushi Asada of Sharp Corporation.

Calculus of competition

Aping IBM has given Japan's computer makers a toe-hold in the market—but largely on Big Blue's terms

America's response to Japan's challenge in microchips is being repeated in computers. Here, Japan's specialty has been making workalike copies of IBM's big office machines (mainframes). The most one can say about these "plug-compatible" computers is that they have managed to prevent IBM from swamping the Japanese home market completely. Big Blue has to put up with being number two in Japan. Overall, however, Japanese compatibles have had only a marginal impact on the $150 billion computer business worldwide.

American manufacturers have established an almost impregnable position in mainframes and minicomputers—the stuff of corporate sales and accounting departments. And in the push to put a microcomputer on every desk, a handful of American firms (IBM, Compaq, Apple, Atari and Commodore) have been feeding the market a feast of cleverer, faster and (in many cases) cheaper machines that have left Japan's "IBMulators" nibbling on the leftovers of yesterday's lunch. In the personal-computer market, the IBM clone makers having the most impact come mainly from low-cost South Korea and Taiwan rather than Japan.

Meanwhile, in developing the programs that make computers tick, American software engineers have been every bit as clever as their chip-designing colleagues in Silicon Valley. In the process, they have increased their share of the world's software market (worth $40 billion a year) from under 65% a decade ago to over 75% today.

All this does not mean Japan's computer industry is a write-off. Its component suppliers have quietly established a significant position for themselves in the United States and elsewhere. In personal computers, for instance, Japanese machines account for less than 2% of the $14 billion annual sales of PCs in America. But Japanese components and peripherals (chips, disk-drives, keyboards, monitors, printers, etc) account for nearly 30% of the market's wholesale value.

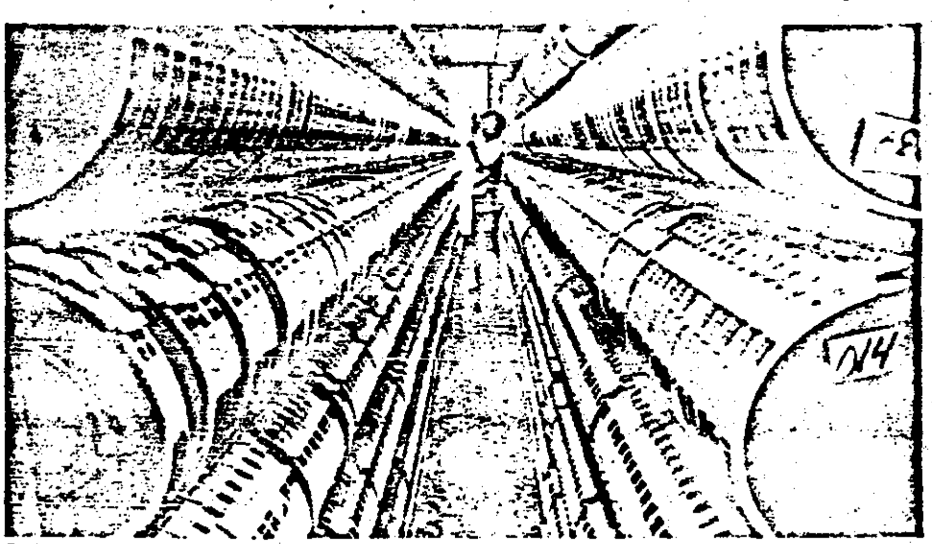
Most of Japan's computer makers came a cropper by riding a bit too blindly on IBM's coat-tails. Lacking the home-grown programming skills, Fujitsu, Hitachi and Mitsubishi made their computers imitate IBM's so they could sell cheaper versions to customers who were already using IBM machines equipped with the necessary software. That worked well until the slumbering giant woke up.

Then, in 1979, IBM introduced its 4300 series computers at a price that shook not just rival Japanese makers, but other American suppliers too. Since then, IBM's aggressive price-cutting and frequent model changes have made life tough for the plug-compatible trade.

Not only is IBM automating vigorously (the company is spending $15 billion over the next four years to achieve lower production costs than anyone in Asia), but it has also begun flexing its technological muscles. Its R&D expenditure is now running at $3.5 billion a year—more than all other computer manufacturers combined. Though for antitrust reasons it will never say so publicly, IBM is nevertheless determined to trample the plug-compatible makers down—both in the personal-computer end of the business as well as among its mainframe competitors.

One of the dodges being adopted is to incorporate more "microcode" in its computers' operating systems (the basic programs that manage a machine's internal housekeeping and support the customers' applications software). Used as an offensive weapon, microcode replaces parts of the computer's electrical circuitry, making it possible to change the whole character of a machine long after it has been installed at a customer's premises. The implication is that IBM can then sell products that can be continuously enhanced—something customers appreciate and will pay a premium for.

Starting with its 3081 series in 1981, IBM caught the competition off guard with a new internal structure called XA ("extended architecture") which allows customers to update their machines with packets of microcode whenever IBM decrees the market needs a shake-up. This


Software needs space

has thrown the plug-compatible makers on the defensive, forcing them to devote more of their development resources than they can afford to trying to anticipate IBM's next round of operating system changes and to try to match them with hurriedly engineered modifications to their hardware. That involves digging ever deeper into their profit margins.

America's other computer firms are also pushing this trend towards replacing hardware with software wherever possible. Writing and "debugging" the programs now accounts for 50-80% of their budgets for developing new computers. Two reasons, then, why American computer executives are smiling:

- At a stroke, the trend towards greater use of software helps neutralise the one great advantage their Japanese competitors have long possessed—namely, the ability to manufacture well-made mechanical components at a modest price.
- And it changes the business of manufacturing computers from being heavily capital-intensive to becoming more brain-intensive. The large pool of experienced programmers and diverse software firms in the United States puts the advantage firmly in American hands.

The Japanese response has been to launch another government-sponsored scheme, this time to help the country's computer makers invent "intelligent" machines for tomorrow. The ten-year fifth-generation project, based largely on "dataflow" concepts pioneered at Massachusetts Institute of Technology, will have cost $450m by the time it is completed in 1992. The aim is to create computers able to infer answers from rough information presented to them visually or orally. Even Japanese scientists working on the project are not sure whether such goals are realistic.

The Americans are not leaving anything to chance. Congress has been persuaded to relax the antitrust rules so that rival manufacturers can collaborate on advanced research without running foul of the law. Two of the first collaborative research institutions to spring up aim to match any challenge the Japanese might offer in computing, software and components for the 1990s. In one, the Semiconductor Research Corporation, 13 microchip companies have clubbed together to form a non-profit consortium for supporting research on advanced integrated circuits at American universities. The consortium is now doling out $35m a year to designers of tomorrow's microchips.

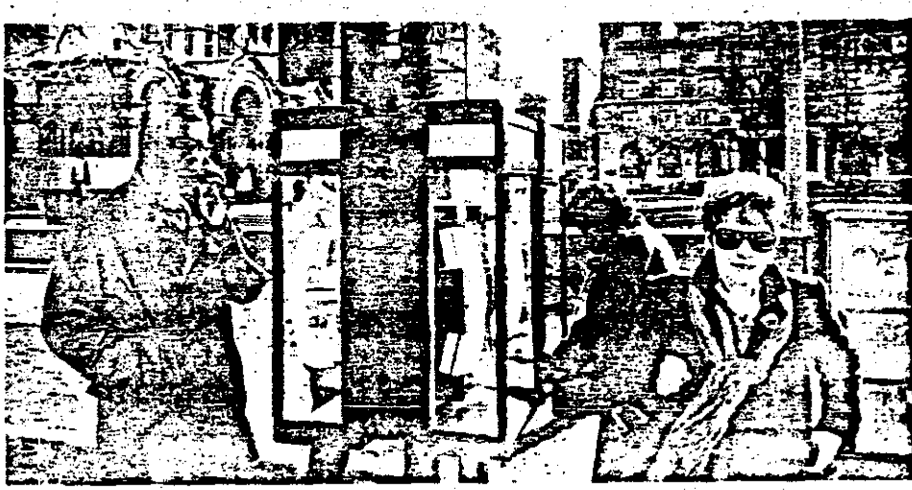
The other institution, the Microelectronics and Computer Technology Corporation (MCC), is an interesting experiment in its own right. Set up as a joint venture in 1983 by initially ten (now 21) rival American computer and semiconductor companies, MCC has 250 scientists carrying out research at its headquarters in Austin, Texas, to the tune of $75m a year. What is for sure, says Mr Bobby Inman, MCC's chief executive and former deputy director of the CIA, "MCC wouldn't have occurred except for MITI."

But the most orchestrated response of all to the Japanese challenge in computing comes not from IBM, Silicon Valley or collaborative consortia of American chip makers and computer firms. Though it is rarely in the public headlines, the Pentagon has been pouring barrels of cash into computing. Its Defence Advanced Research Projects Agency (DARPA) in Washington has been playing busy midwife to some of the most exotic technology of all for computers, communications and electronic equipment generally.

Its VHSIC (very high-speed integrated circuit) project alone has pumped $300m over the past five years into advanced methods for making the superchips needed for radar, missiles, code-breaking and futuristic computers. Also earmarked for DARPA is a reported $1 billion for sponsoring a range of supercomputers which, say insiders, "will outperform anything the Japanese can develop under their super-speed computing project or their fifth-generation programme."

At least a dozen "fifth-generation bashers" have surfaced as research projects around the United States, mainly in university laboratories, but also in small start-up companies founded by academics, entrepreneurs and engineering emigrés from the mainframe computer industry. The latest supercomputer to go public (the prototype was shipped last year to the American navy) is a cluster of boxes a yard square capable of calculating over a billion instructions per second (the Japanese government hopes to have a similar greyhound of a computer by 1992). The group that built it spun off mainly from nearby Massachusetts Institute of Technology to form their own company, Thinking Machines. The firm is now taking orders for a bigger brother with four times the processing power.

If only a handful of the score or so of American groups building advanced computers survives, the United States is going to enlarge its existing technology base in computing over the next decade by as much new engineering talent as its rivals have in totality. And that, not least for the Japanese, is a sobering thought.



Reach out and crush someone

Even more than breakthroughs in telecommunications technology, America's new deregulated freedom to plug in, switch on and sell an information service is breeding a whole new generation of infopreneurs

Americans complain about it, but if truth be told they still have the best and cheapest telephone system in the world. Japan's is a good one too—about as good as the Bell System was in the late 1960s. Which means it is reliable and cheap when making calls within the country, but not particularly good at performing electronic tricks like automatic call-forwarding, call-waiting, short-code dialling, credit-card billing, conference calling—all things Bell users take for granted today.

Americans also take for granted the choice of being able to dial long-distance numbers using alternative carriers who offer cheaper rates. Liberating the phone system from the state monopoly's clutches (so customers may choose what they want instead of what they are given) has barely begun in Japan.

The United States is the world's dominant supplier as well as its most prolific user of telephone equipment. The global market, worth $57 billion in 1982, is expected to grow to $88 billion by 1987. American manufacturers have 42% of it; Japanese firms 8-9%. But that has not prevented Japan from becoming a major exporter of telecoms products. It now sells well over $1 billion worth of telephone equipment abroad, a quarter of it even to the United States. How did that happen?

The main reason is the size of the American market itself. Though the American share of the global telecoms business is five times bigger than Japan's, practically all of it is at home. Some 90% of the domestic market is controlled by the mighty American Telephone and Telegraph ("Ma Bell"); GTE has 10% of the American market, while ITT has traditionally sold its telephone equipment almost exclusively abroad.

Until the deregulation of the American phone system in the wake of AT&T's 1982 consent decree, Ma Bell's manufacturing arm (Western Electric) directed its entire production effort at meeting just the needs of the various Bell phone companies around the country. It got all its inventions and designs from the legendary Bell Laboratories in New Jersey, and neither imported nor exported a single transistor.

Bell Labs has been responsible for a blizzard of innovations (transistor, laser, stored-program control, optical fibres, etc) that have driven down the real cost of communications and raised the quality and availability of telephone service throughout the United States. But because of AT&T's preoccupation in the past with just the domestic market, the best of its technology has had little direct impact on the rest of the world. The door to export sales was thus left ajar for telecoms suppliers elsewhere—from Europe (Siemens, Ericsson, Thomson, GEC and Philips), Canada (Northern Telecom and Mitel) and Japan (NEC, Oki, Fujitsu and Hitachi).

American firms retain their dominant position in supplying switching and transmission equipment. But the Japanese have mounted a serious challenge based on their growing expertise in transmitting messages on the backs of light beams. Made out of cheap silica instead of costly copper, optical fibres can carry three times the telephone traffic of conventional cables, need few repeater stations to boost the signals and send them on their way, are immune to electrical interference and do not corrode like metal wires.

The early American lead in fibre optics, built up by Western Electric and Corning Glass, has been chipped away by scientists at NEC, Sumitomo and Japan's telephone authority (NTT). Apart from learning how to manufacture low-loss fibres, Japanese companies have become superb at making the minute lasers, light-emitting diodes and minuscule receivers used for projecting and catching the messages.

Hand in glove with fibre optics is the growing trend towards digital transmission—sending spoken or picture messages coded as the ones and zeros of computerspeak. The transmission part is easy, but optical switching has presented horrendous headaches and the competition here is fierce.

But American makers have used their knowhow to better commercial ends. In particular, digital transmission has been used to speed the growth in data traffic between big computer systems, especially those owned by airlines, banks, insurance companies and financial institutions. Here, the Federal Communications Commission has taken the initiative, by freeing America's telecommunications networks so anyone can plug in, switch on and sell an information service. Other countries—Britain and West Germany particularly—have been inexplicably making life as difficult as possible for their own infopreneurs.

The lesson has not been wasted on telecommunications mandarins in Japan. They have seen how getting the government off the back of the telephone companies in America has spurred a vibrant free-for-all in "value-added networking", creating numerous jobs in information services and giving local manufacturers a headstart in carving out a piece of a brand new high-tech business for themselves.

This new communications freedom—even more than the changes in digital switching and new transmission technologies—is one of the key driving forces behind the merger between computing, office automation and telecommunications that is beginning to take place within the United States. Last year, computer maker IBM absorbed Rolm, a leading manufacturer of digital private-branch exchanges. At the same time the telephone giant, AT&T, broadened its growing base in computing and office equipment by buying 25% of Olivetti in Italy. The leader of the office-automation pack, Xerox, is still suffering from a surfeit of exotic technology dreamed up by engineering wizards at its PARC laboratories in California.

Japan has no intention of being left behind. The government in Tokyo is pressing on with its plan to privatise as much of its telecommunications services as possible. And while the big names of the Japanese telecoms business (Fujitsu, Hitachi, NEC and Oki) may have deficiencies of their own, each is nevertheless a big name in computing too. And though smaller, all are more horizontally integrated than AT&T, IBM or Xerox.

Will Japan close the technological gap in telecoms with America? Quite possibly. But only through setting up shop in the United States. The reason concerns one missing ingredient, now as essential in telecoms as in computing: ingenious software. Just as Motorola and Texas Instruments have built semiconductor factories in Japan to learn the secrets of quality and cost control, Japanese firms will have to establish telecoms plants in the United States if they are to acquire the necessary software skills. NEC has now done so—for precisely that reason.

Getting smart

Manufacturing is also going high-tech, threatening to turn today's dedicated factories full of automation into relics of the past

Microchips, computers and telecoms equipment will be to the next quarter century what oil, steel and shipbuilding were to the years between Hiroshima and the Yom Kippur war. More than anything else, these three technologies will fuel the engine of economic growth in countries that learn to manage their "smart" machinery properly. This will hasten not so much the trend towards service jobs, but more the revitalisation of manufacturing itself.

Manufacturing? That grimy old metal-bashing business which the more prosperous have been quietly jettisoning for better-paid office jobs in the service sector? It is true that manufacturing jobs in all industrial countries (save Italy and Japan) have been shed continuously since 1973. In the United States, employment in manufacturing industry fell 2.5% last year to less than 20% of the civilian workforce.

But looking at jobs alone is misleading. In terms of manufacturing's contribution to GNP, for instance, little has changed. In fact, manufacturing's share of value added (at current prices) in America was 22% of GNP in both 1947 and 1984, and has wavered narrowly within the 20-25% band for close on 50 years. So much for de-industrialisation.

Manufacturing still means big business in anybody's book. It currently contributes $300 billion and 20m jobs to the American economy; about $350 billion (at today's exchange rate) and 15m jobs in Japan. But manufacturing is really a matter of how you define it. Traditional measures based on Standard Industrial

Classification codes continue to give the impression that making anything in a factory is going the same way as smokestack industry generally—up in smoke. Yet software engineering alone is an explosive new "manufacturing" industry that barely enters the American Treasury Department's calculations of growth, let alone its vision of what constitutes industry.

What is for sure is that the new battle in manufacturing competitiveness and productivity is going to be fought in the fields of process and design technology. Here is what Mr Daniel Roos of Massachusetts Institute of Technology has to say:

> Over the next 25 years, all over the world, semi-skilled labour—whether cheap or expensive—will rapidly give way to smart machinery as the key element in competitiveness. Neither cheap Korean labour nor expensive American labour is our real problem. Rather the challenge lies in rapidly introducing and perfecting the new generations of design and process equipment—and the complex social systems that must accompany them.

It does not require an MIT professor to explain why conventional manufacturing is limping out and new computerised forms of design and fabrication are muscling in. Using the favoured yardstick of productivity (return on investment after discounting for the current cost of money) even back-of-the-envelope calculations show only two factors really count. Energy costs are irrelevant, being typically 3-4% of factory costs. Much the same is true for labour, which now accounts for only 5-15% of total costs.

"The only significant, and controllable, factors are material costs and production volume", preaches Dr Bruce Merrifield of the American Department of Commerce. Thus, with roughly 30% of material costs being in inventory, a "just-in-time" delivery system (like the Japanese *kanban* method for supplying components to motor manufacturers) could improve the real return on investment by as much as 15%.

Getting manufacturing volumes right is trickier. Here high technology is making the whole notion of the special-purpose factory—with its automated equipment purring smoothly along as it churns out millions of identical parts all made to the same high standard of precision—a relic of the smokestack past. The marketplace is much more competitive today, no longer accepting the 10-12 year product life cycles needed to justify the investment of such dedicated plants. The pace of technological change is demanding that manufactured goods be replaced every four or five years; in consumer electronics, every two or three years.

The Japanese factory devoted solely to turning out 10,000 video recorders a day with a handful of operators is the end of the line—not quite yet, but destined shortly to become a magnificent anachronism and epitaph to the age of mass production. It was a brief and grimy era, spanning just the single lifetime from Henry Ford to Soichiro Toyoda. To take its place, a whole new concept of manufacturing is being hustled out of the laboratory and on to the factory floor. This is the final melding of microchips, computers, software, sensors and telecoms to become in themselves the cutting tools of manufacturing industry.

From smokestack . . .

. . . to robots . . .

The retooling of America

Flexible make-anything factories are beginning to sprout across America, bringing back jobs that had slipped offshore

American engineers call it CIM. Computer-integrated manufacturing—hurried into the workplace by a kind of Caesarian section—has arrived before managers have had a chance to find out what they really want or are able to handle. The trouble—and there have been plenty of teething troubles—is that CIM has a grown-up job to do right now. To corporate America, it is the one remaining way of using the country's still considerable clout in high technology to claw back some of the manufacturing advantage Japan has gained through heavy investment, hard work and scrupulous attention to detail.

American companies began pouring big money into high-tech manufacturing around 1980. All told, firms in the United States spent less than $7 billion that year on computerised automation. Today they are spending annually $16 billion, mostly on more sophisticated CIM equipment. By 1990, investment in computer-integrated manufacturing will have doubled to $30 billion or more, forecasts Dataquest of San Jose, California.

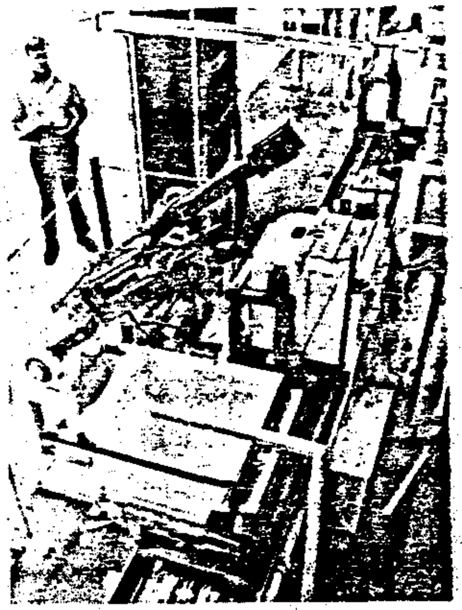
General Motors has spent no less than $40 billion over the past five years on factories of the future. Even its suppliers are being hooked into GM's vast computerised information net, allowing them to swap data with the giant motor maker as a first step towards integrating them wholly within its CIM environment. IBM has been spending $3 billion a year on computerising its manufacturing processes. In so doing, it has been able to bring numerous jobs, previously done offshore, back into the United States. Pleased with the results so far, IBM has raised its investment in CIM to an annual $4 billion.

The heart of a CIM plant is a flexible manufacturing shop which can run 24 hours a day, but which is capable of being retooled in minutes rather than days, and able to turn out hundreds of different products instead of being dedicated to just one line. The difference between the best of traditional automation (for example, Toyota's Corolla line in Nagoya) and the best of new style CIM plants (for example, General Electric's household-appliance centre in Kentucky) is that the former automates just the flow of material through the factory, while the latter automates the total flow of information needed for managing the enterprise—from ordering the materials to paying the wages and shipping the finished goods out of the front door.

The aim of CIM is not simply to reduce the amount of direct labour involved in manufacturing a product (only 5-15% of the cost). The real savings come instead from applying strict computer and communications controls to slash the amount of waste (typically 30% of the cost) through having up-to-the-minute information on tool wear, while minimising the handling, management and overhead charges (rarely less than 40%) by knowing precisely where items are at any instant during the manufacturing process. The net result is that a CIM factory has a much lower breakeven point than a highly automated conventional plant. The majority of the CIM plants now onstream in the United States break even at half the level of a conventional plant (typically 65-70% of full capacity). And because it does not have to operate flat out from the start to be efficient, a CIM plant makes it easier and cheaper to launch new products. That spells shorter life cycles—and hence more frequent (and more attractive) model updates.

That would be reason enough for enterprising high-tech companies to invest in CIM. But a number of American corporations are being encouraged for other, more strategic, reasons to integrate their computerised manufacturing processes. The Pentagon sees CIM as a nifty way of allowing manufacturing capacity to be sprinkled lightly across the land, instead of being concentrated heavily in targeted areas along the Ohio Valley, parts of Illinois and up through Michigan.

The generals also see CIM plants—with their rapid response and flexible, make-anything nature—as handy standby capacity ready to be instantly reprogrammed to meet the military surge of a national emergency. Apart from its costly military stockpiles, the Pentagon has to underwrite a good deal of redundant and idle capacity among America's defence contractors. That is a political luxury it can no longer afford.



... to CIM

Pressure from other parts of Washington is also helping to usher high-tech manufacturing into American factories. To government gurus like Dr Bruce Merrifield, the attraction of these flexible manufacturing plants is that they are ideal not just for industrial giants like General Electric, Westinghouse or IBM, but even more so for the tens of thousands of tiny workshops across the country. While Japan has two-thirds of its industrial output within the grasp of broad-based *keiretsu* manufacturing groups, American industry by contrast has always relied heavily on its 100,000 or so independent subcontracting firms. In metal working, for instance, 75% of the parts made in the United States are manufactured by small independent workshops in batches of 50 or less.

The American Commerce Department sees no antitrust reasons why smaller firms should not band together to share a flexible manufacturing centre, making spindles for washing machines one minute, wheel bearings the next, then switching to precision mounts for a microscope maker, crankshafts for diesel engines, microwave cavities for radar equipment, nose-cones for missiles and so on. This would reduce the investment risk for the individual firms, while providing a higher return for the CIM plant as a whole. It could also help rebuild much of the industrial base of rustbowl America.

Let the daisies grow

Bureaucratic guidance is still no match for a fertile economy where anything can take root and flower

Who, then, is better suited to life on the high road of technology—America or Japan? The answer is complicated by the way the two industrial superpowers have honed their separate skills in wholly separate ways (table 3). American technology is overwhelming in big systems, software, computing and aerospace. But nobody can touch Japan in the process technologies that underlie conventional manufacturing. American technology reaches out for the unknown: Japan's bends down to tend the commonplace.

The differences in style mirror the differences in ideals that the two peoples hold dear. The Japanese have a saying: "The nail that stands up will be hammered flat." The Americans say: "Let the daisies grow." So it is hardly surprising that American technology is individualistic, often erratic and always iconoclastic. Japan's, if anything, is pragmatic, geared primarily to problem-solving and hustled along by a herd-instinct.

To date, Japan's high-tech success has been almost exclusively with developments that were predictable—like packing more and more circuits into dynamic RAM chips, or making video recorders smarter and smaller. This is a result of having total mastery of the process technologies. While all the basic breakthroughs for making semiconductors—electron beam lithography, ion implantation, plasma etching, etc—came from the United States, Japanese firms improved the ideas step by step until their equipment was a match for anything made abroad.

By carrying out development continu-

Table 3: Balance of forces

Japanese strengths	American strengths
Applied research and development	Basic research
Incremental improvements	Breakthroughs and inventions
Commercial applications	Military applications
Process and production technology	New product design
Components	Systems integration
Hardware	Software
Predictable technologies	Less predictable technologies
Quality control	New functionalities
Miniaturisation	New architectural designs
Standardised, mass volume	Customisation

Source: *"The Positive Sum Strategy"*, National Academy Press, Washington DC, 1986 ously in small incremental steps (instead of the American way of great quantum leaps every decade or so). Japanese firms have been able to bombard customers with a barrage of new models offering yet better value, quality and reliability. American firms, by contrast, have traditionally made cosmetic improvements every few years, and then brought out complete model overhauls once a decade or so. That has made their products look long in the tooth, then suddenly change dramatically—often for the worse while design bugs and production wrinkles are sorted out.

American technology has also tended to be geared for use mainly at home (for example, telephone systems, motor cars). With its smaller domestic market, Japanese technology has been forced to look farther afield. The Stanford economist, Mr Daniel Okimoto, makes the point that though Japanese firms have excelled at technologies tied closely to commodities with huge export markets (for example, continuous casting in steel, emission-control for motor cars, optical coatings for camera lenses), lately they have begun to do well in technologies for domestic use too. Some examples include gamma interferon and Interleukin II in pharmaceuticals, digital switching and transmission in telecommunications. And with their breakthroughs in gallium arsenide semiconductors, optoelectronics, superceramics and composite materials, the Japanese have shown themselves selectively capable of innovating at the frontier of knowledge as well as anyone.

On the whole, however, Japanese firms have been less successful with technologies that are inherently complex, not particularly predictable and dependent upon ideas springing from basic research. Making jet engines is one such technology. Designing air-traffic-control radars is another. Developing computer-aided design and manufacturing systems is a third. And despite MITI's "targeting" of lasers as a technology to be conquered, little progress has been made here to date—because not enough basic research has been done in the necessary branch of physics.

Such incidents point to serious problems in Japan's educational system. While Japanese youngsters out-perform western school children in all meaningful tests of mathematics and science, their training stresses rote learning rather than critical analysis and creative synthesis. At university, their skills in problem-solving are enhanced at the expense of their abilities to conceptualise.

As faculty members, Japanese academics are civil servants unable to fraternise as paid consultants in industry during the summer vacation. So Japan has none of the cross-fertilisation between basic research and commercial development that characterises MIT and Route 128, Stanford and Silicon Valley and a hundred other campuses across America. Also, because all the leading universities in Japan are state-owned and run rigidly by a conservative central bureaucracy, it is difficult to allocate grants (by peer-review) to the most deserving researchers rather than the most senior.

In the days when Japan could storm the

Lift-off for the airborne economy

Forget about America's underground economy of do-it-yourselfers pushing hamburger carts, paint brushes and illicit drugs. Above the conventional economy, a star-spangled wealth launcher lifted off three or four years ago—to take advantage of the soaring power and plummeting cost of microchips, the breakup of the geriatric telephone monopoly, the chimera of President Reagan's space shield and, above all, the technological collision of computing, communications and office automation. Meet America's exciting new airborne economy.

The first thing to understand is that nobody is quite sure how well even America's conventional economy is performing, let alone its underground or overground components. The only items reported properly seem to be imports and unemployment. The trouble is that the economy is changing so fast—from old-fangled businesses based on metal bashing and carting things around to new-fangled ones that massage, transmit and memorise scraps of information. What is for sure, the leading economic indicators—those monthly headlines that send shockwaves around the world's financial markets—seriously underestimate some of the most important growth sectors within the United States.

Because the statistics have not kept pace with the way American business is becoming internationalised, computerised and more service-oriented, the picture the statisticians paint depicts an economic landscape of a decade or two ago. Here are some examples of lagging statistical response:

- Companies are classified by industrial sectors using definitions last updated in 1972.
- Twenty years after computers swept manual accounting into the dustbin, the first price index for computers has just been introduced—and is still incomplete. Where America's computing costs have been assumed to be fixed, henceforth they will be deemed to fall (as they have actually been doing) by at least 14% a year—adding nearly 1% to GNP.
- An archaic processing system for logging foreign trade, confronted with a 90% increase in imports over the past decade, is ignoring America's growth in foreign sales. A significant proportion (some say 15-20%) of American exports now goes unreported.
- Measures of family income, designed in an age when welfare was a dirty word, omit non-cash components such as company fringe benefits for professionals (pension rights, deferred income plans, health and life insurance, etc) and in-kind government assistance for the poor (food stamps, rent subsidies, etc).
- Poverty is still defined by consumption patterns of the mid-1950s, when a family of three spent a third of its income on food. The same food basket today costs a fifth the equivalent family's income.

Don't snigger. Despite budgetary cuts, the American statistical system is still one of the best in the world. Its only real weakness is that—employment figures aside—the statistics used for determining, say, GNP or growth tend to be by-products of non-statistical agencies (such as the Internal Revenue Service, the Customs Service, Medicare and the Department of Agriculture). As such, they are far from being as clean, complete or timely as the experts would like.

Consider some recent anomalies caused by the quickening pace of technological change. With 70% of Americans being employed in the service sector, you might be tempted to categorise the United States as essentially a service-based economy. It is. But you would not think so from the Standard Industrial Classification (SIC) used in generating the input-output tables for measuring GNP. This has 140 three-digit codes for manufacturing firms, only 66 for services. Moreover, since the SIC system was last revised in 1972, whole new business activities (for example, video rental, computer retailing, software retailing, discount broking, factory-owned retail outlets) have sprung up, while others have withered away.

Nuts and bolts, for instance, are in an SIC category all of their own, employing a grand total of just 46,000 people. Envelope makers, again with their own SIC category, provide fewer than 25,000 jobs. Yet one SIC code in the service sector alone, general medical and surgical hospitals, now covers some 2.3m people. Lots of high-tech service businesses—including computer stores and software publishers and manufacturers—do not even qualify for their own SIC codes yet.

There is no reason why all SIC categories should be the same size. But the imbalance exaggerates the importance of traditional manufacturing at the expense of services in the American economy. Above all, it allows whole sections of America's booming high-tech economy to go unreported.

Back to the future

A glimpse or two at the future will dispel any doubts about Yankee ingenuity as it probes the limits of tomorrow's technology. First, to Silicon Valley where Mr Alan Kay, refugee from such technological hotbeds as DARPA, Stanford, Xerox PARC and Atari, is nowadays visionary-at-large at Apple Computer. Building on the learning theories of John Dewey and Jean Piaget, Mr Kay is trying to create a "fantasy amplifier"—a computer with enough power to outrace the user's senses, enough memory to store library loads of reference material, and enough clever software to couple man's natural desire for exploring fantasies with his innate ability to learn from experiment.

The concept, called "Dynabook", combines the seductive power of both a video game and a graffiti artist's spray-can with the cultural resources of a library, museum, art gallery and concert hall combined. Difficult to make? You bet, especially if the whole gizmo has to fit in a package no bigger than a notepad and be cheap enough for every schoolkid to own.

Smalltalk is the computer language Mr Kay has developed to allow kids to converse with the fantasy amplifier. The rest of the ingredients are all technologically imaginable, just prohibitively expensive and unwieldy for the time being. But a decade ago the first personal computer was just being built at considerable expense. Its functional equivalent today costs less than $50. Still only in his mid-40s, Mr Kay has ample time to put a Dynabook in the hands of millions of youngsters with open minds and a sense of wonder still intact.

Next, meet Mr Ted Nelson, gadfly, prophet and self-confessed computer crackpot, with a lifetime's obsession wrapped up in an enormous program called (after Coleridge's unfinished poem) Xanadu. Boon or boondoggle, nobody is quite sure. But the giant piece of software for steering one's own thought processes (including alternative paths, mental backtracks and intellectual leaps) is hardly lacking in ambition or vision.

Conceived originally by Mr Nelson while a student at Harvard as simply a note-keeping program for preserving his every thought, Xanadu has evolved into a total literary process: creating ideas; organising the thoughts, with traces showing backtracks, alternative versions and jumps to cross-referenced documents; manipulating the text; publishing the results; and logging a share of the royalties to every other author cited.

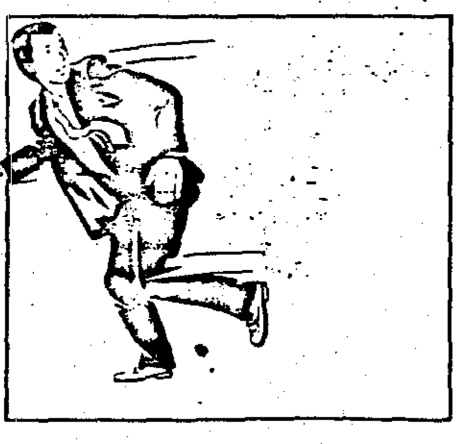
Every document in Xanadu's database has links to its intellectual antecedents and to others covering related topics. The linked references work like footnotes, except that Xanadu offers an electronic "window" through which they can be accessed there and then. Because the whole process works in a non-sequential way, the inventor calls the output "hypertext".

Mr Nelson looks forward to the day when anybody can create what he or she wants—from recipes to research papers, sonnets to songs—and put it into Xanadu's database and quote or cite anybody else. Royalties and sub-royalties, monitored automatically by the host computer, would be paid according to the amount of time a user was on-line and reading a specific document. It sounds pretty wild at the moment, but hypertext could be commonplace before the century is out.

industrial heights with foreign licences, homegrown development and production excellence, the inadequacies of its educational system and academic research hardly mattered. But such shortcomings are becoming increasingly a problem as high-tech competition intensifies.

Nor can Japan call on its little firms to provide the invigorating fillip of innovation such enterprises provide in the United States. And with their lifetime employment practices, Japan's big technology-based corporations rarely get a chance to attract high-flying talent from outside. Technological diffusion between small firms and large corporations, and between companies generally as engineers swap jobs, is one of the more invigorating forces for innovation in the United States.

Nor, also, is there an adequate way in Japan for financing risky innovation outside the big corporations. Since 1978, American equity markets have raised $8 billion for start-ups in electronics alone and a further $3.3 billion for new biotech companies. Over the same period, Japan's venture-capital investments in high-tech have totalled just $100m.



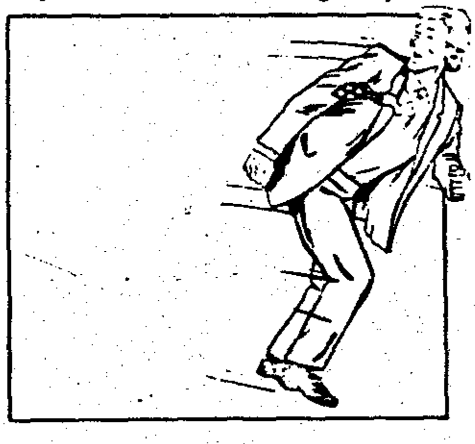
Lacking all these things, the Japanese have sought a substitute. This is one of the main reasons for MITI's special emphasis on collaborative research projects—as in VLSI or fifth-generation computers. To Mr Gary Saxonhouse of the University of Michigan, Japan's lauded industrial policies are little more than a substitute for the ingredients that American companies enjoy from their vibrant capital and labour markets.

As for MITI's infamous industrial targeting, many Japanese (as well as foreigners) have long doubted its effectiveness and believe it is now wholly inappropriate anyway. All technologies have started moving simply too fast to wait upon the whim of bickering bureaucrats. It is not as though Japanese civil servants have shown themselves any better at picking industrial winners than officials elsewhere; and none has bettered the invisible hand of the marketplace.

Apart from possessing vastly greater resources of well-trained brains, more diverse and flexible forms of finance, and a bigger and more acquisitive domestic market, America has one final, decisive factor moving in its favour—the pace of innovation itself.

High-tech products tend to have two things in common: they fall in price rapidly as production builds up (they possess steep learning curves) and they get replaced fairly frequently (they have short life cycles). The trend in high-tech is towards things becoming steeper and shorter. So the competitive advantage of being first to market is going increasingly to outweigh almost everything else.

This spells an end to the traditional low-risk, low-cost approach that Japanese companies have used so successfully to date—coming in second with massive volume and forward prices after others have primed the market. Henceforth, Japanese firms are going to have to take the same technological risks—and pay the same financial penalties—as everyone else. And that puts the advantage decidedly on the side of Yankee ingenuity.



UNCLE SAM, RESEARCH DIRECTOR

The nation's 400 national labs want to transfer their know-how to you. For sale: 28,000 patents.

BY JAY FINEGAN

Imagine, for a moment, that there were a research apparatus available to your company with 200,000 engineers and scientists working with the most sophisticated equipment, with an annual budget of some $20 billion. Too good to be true? Not really. For such are the assets of the federal government's 400 national laboratories—labs that now have a mandate to share their know-how with U.S. business.

PATRICIA BARRY LEVY

Harold Hubbard, director of the Solar Energy Research Institute
"If nobody can make a buck with government technology, nobody will use it."

National labs work on everything from particle beams to cures for cancer. They can be world-renowned, such as the mega-medical center National Institutes of Health, and Los Alamos National Laboratory, where the first atom bomb was made. Or they can be positively obscure. (Ever heard of the Neutron Depth Profiling Facility? Or the Boll Weevil Research Laboratory?) But no matter their profiles, until recently nearly all of the federal laboratories, by tradition and federal regulation, had kept their distance from private companies. Their researchers had spent very little time trying to turn their discoveries into commercial products. And private companies had been wary that any association with such government-owned facilities would tie them up in endless red tape.

"Institutionally, R&D for the government had always been that you do a specific job and then stop," explains Edward Lehmann, who works at the U.S. Commerce Department's Center for the Utilization of Federal Technology. "It had always been assumed that the transfer of the knowledge will occur through publications or presentations at conferences. That was a very passive approach—a misconception." The upshot: of the 30,000 patents held by the federal government, 28,000 lie dormant.

Now, things are changing. Washington, showing rising alarm over the country's eroding technological lead, is seeking more bang for its research buck. In a series of changes in federal law and regulation dating to 1980, the President and Congress have made it clear that they want the national labs to become more like a national R&D resource (see box on the following page, "Tapping into Federal R&D"). And although the research priorities will still be set by the government, the benefits are now supposed to be shared more quickly, and more readily, with U.S. firms. Already, one in nine government patents is being licensed within a year of its being issued.

Perhaps no federal lab has had a more clear-cut mandate to share its research and technology with private industry than the Solar Energy Research Institute (SERI), in Golden, Colo., just west of Denver. The lab opened in 1977 to develop new technologies that could blunt the effects of OPEC's rising oil prices. But it is only now, after nearly a decade, a drop in world oil prices, and the changes in federal law, that SERI is finally channeling some of its efforts into commercial ventures and profitable products.

"For the most part, we have not been that good at judging what is marketable," concedes Harold Hubbard, SERI's director. In the beginning, the institute suffered an image problem with businesspeople who looked on it as a refuge for backpacking, pot-smoking solar fanatics to whom business was a dirty word. But even as that image began to fade with the arrival of researchers from top universities, private firms were still wary about collaboration.

Ask David Benson. Benson, a SERI physicist, has developed a new vacuum window—two panes of glass with a vacuum in the middle. Whereas normal windows have an insulating value of R-2, his window has one of R-16—or roughly the equivalent of a wall. Research shows that about 5% of the total energy used in the United States is lost through windows. "And with some 350 million square feet of insulating windows added each year, this new window could make a difference," he says.

Benson pitched his product to all the major window companies, but none were interested. So he tried striking a deal with the industry as a whole, making a presentation to the Sealed Insulating Glass Manufacturers Association convention held last summer in Denver.

"We offered to conduct a collaborative research program, which they would partially fund and, in return, would receive proprietary rights to all the technology," Benson explained. They said, 'Thanks, but no thanks.' Their justification was that their association represents both large and small manufacturers, but by far the largest number are small firms manufacturing their windows locally. And you couldn't possibly do that with a vacuum window. It has to be made at a big plant that would cost around $10 million. So you'd need big companies."

It was much the same story when Benson tried to stir up some interest in his electrochromic windows, which operate similarly to sun-sensitive eyeglasses, turning darker on hot days to shield out sunlight and lighter on cold days to let in the passive solar heat. Only 3M Co. has shown an interest in the concept, but it hasn't provided funds yet.

In the meantime, SERI has found itself fighting other battles. A budget crisis has prompted Congress to slash the lab's $112-million budget nearly in half, forcing a staff reduction from about 1,000 to fewer than 500. One casualty: the industrial-applications program charged with technology transfer. Then came the end to the solar tax credit and the collapse of world oil prices, which together have helped to wipe out 80% of the solar energy industry, SERI's core constituency.

In the face of all this adversity and neglect, SERI has hung on grimly, the righteousness of its efforts embedded in its culture. And with the added flexibility provided by the new law governing federal labs, its prospects may finally be improving.

Spire Corp., for example, a publicly traded, $14-million electronics firm in Bedford, Mass., is working with SERI on a program to develop cheaper amorphous silicon cells, devices that convert sunlight to electricity. Today, a residential solar system using silicon cells would cost a homeowner $30,000 to $40,000. Spire hopes to get the figure down to around $6,000.

To win a three-year contract from SERI, Spire had to chip in $900,000 to obtain what amounts to a $2.1-million SERI grant. And should the collaboration yield a cheaper silicon technology, Spire—not SERI—will hold the patent and with it the exclusive right to profit from government-sponsored and -subsidized research.

Not surprisingly, Roger Little, Spire's president, likes these cost-sharing deals with government laboratories. "What happens is you get people in the business interested in doing the research themselves, as opposed to the Washington Beltway bandits," he says, referring to the scores of research firms located on the highway that rings the nation's capital. "The government-contract dollar goes to people who are really serious about the work. So that's a big step toward commercialization and technology transfer."

But others ask why the free market can't provide for its own R&D, and why taxpayers should foot the bill to develop a technology from which they will never benefit directly. Among them is Arun Madan, one of the pioneers in the field of amorphous silicon who spent 18 months at SERI before leaving to establish his own company, Glasstech Solar Inc., just outside of Denver.

Madan agrees that "when a technology is in its infancy, government needs to encourage industry to get into it, because it's a very high-risk situation. But at a certain point," he continues, "the technology goes beyond high risk, and then it's time to ask whether companies are just using government money for their own ends." Madan says that with amorphous silicon products already on the market, and with some 35 commercial applications envisioned, the technology has clearly shot past the high-risk stage.

SERI officials, reflecting the new enthusiasm for technology transfer, dismiss concerns like Madan's. "Some people think that nobody should make a buck off the public's money," says director Hubbard. "The problem with that is that if nobody can make a buck from the public's money, nobody is going to do anything with the public's technology."

Larry Flowers, manager of SERI's solar buildings program, points to the erratic interest of big oil companies, which jumped into the solar industry when the price of oil was high, then bailed out at breakneck speed when the near-term prospects turned sour. Without government subsidy, he says, "You can't depend on industry to sustain an effort."

Providing a reliable stream of research money, however, is only one method by which government labs can speed up the pace of technology transfer to commercial applications. Providing an incubator for would-be entrepreneurs, and sophisticated equipment for private research, are others.

Take the case of Industrial Solar Technology, founded by former SERI engineers Randy Gee and E. Kenneth May. Located near Denver, the fledgling $390,000 company manufactures parabolic-trough collectors—curved devices that reflect sunlight to heat circulated fluid. In one application, these collectors produce warm water and hot showers for a community swimming pool. In another, the device produces hot water and electricity for a county jail.

"SERI gave us a lot of experience in this area. It got the pot boiling," says Gee. Moreover, when Gee and May were ready to go out on their own, personal contacts formed at the lab helped them find financial partners. "The network system really makes a difference," Gee claims.

Outsiders, however, are also welcome. SERI, for example, has provided a wind-test site, hardware, and consulting technicians, at no charge, to Four Winds Energy Systems, a wind-turbine manufacturer in nearby Englewood, Colo. "Without the help," admits vice-president John Kunz, "I doubt that we would still be in operation."

Of all the entrepreneurs who have taken advantage of the new commercial orientation of the national labs, perhaps none has been as resourceful as Gilbert Brassell. A chemist and materials specialist, Brassell worked at the Sandia and Oak Ridge laboratories before landing at Rocky Flats, a Department of Energy nuclear-weapons

TAPPING INTO FEDERAL R&D

Here are some approaches for linking the private sector and public labs.

☐ **COOPERATIVE R&D.** Federal labs can now enter into a wide range of agreements with businesses, universities, even municipalities. Lab directors are free to decide which proposals from the outside best coincide with their overall mission. As part of such arrangements, labs supply researchers, equipment, and even funds.

☐ **EXCLUSIVE LICENSING.** In the past, the government made it difficult to obtain exclusive rights to its patents. But without protected positions, companies shunned nonexclusive arrangements as too risky. So the new law permits labs to sell off exclusive rights for "whatever we can get," according to one lab's attorney. It is now the individual lab, not government attorneys in Washington, that has the authority to strike such deals.

☐ **CLEARINGHOUSE FOR INFORMATION.** The Federal Laboratory Consortium for Technology Transfer now acts as a clearinghouse for federal R&D information. Each federal member will designate a full-time technology-transfer officer to keep tabs on all work of potential commercial value and be the liaison with the business community. The consortium will also keep a centralized computer bank that will be able to tell companies what research is being done at what labs.

☐ **INCENTIVES FOR GOVERNMENT INVENTORS.** Under the old law, lab staffers who came up with something patentable got a plaque and a bonus. Now, if the lab licenses rights to that patent, the inventor receives at least 15% of net royalties due the laboratory. That's an attractive incentive—so attractive, in fact, that it's controversial. Purists worry that the lure of big dollars could divert scientists from the labs' fundamental role: long-range, high-risk research that industry often doesn't do because the payoff is neither quick nor certain.

installation near Denver. While at Rocky Flats, Brassell ran across a problem with the containers in which nuclear waste was stored: as hydrogen gas built up inside, there was a risk that they could explode. To solve the problem, Brassell developed a carbon-composite filter that vented the gas while trapping 99.97% of the radioactive particles that otherwise would have escaped with it. Rocky Flats managers were somewhat blasé about this discovery until they found out that Brassell had made a move to patent his idea. Quickly, they moved to assert the lab's right to the filter, but then agreed to transfer it to Brassell for the cost of patent application, about $4,000.

In keeping with its federal lab origins, Brassell's Nuclear Filter Technology Inc. set up shop in a small-business incubator that SERI helped to found right next door, in Golden. SERI has also made its lab space and equipment available to Brassell, services that might cost him tens of thousands of dollars—money that he could not otherwise afford. And now, the government's help is beginning to pay off. In 1986, its second year, Nuclear Filter logged sales of $300,000, up from only $60,000 a year earlier. Among his clients: E. I. du Pont de Nemours, EG&G, Her Majesty's Ministry of Defence, and the U.S. Navy. And, oh yes, the national laboratory at Rocky Flats. □

LABORATORIES FOR ENTREPRENEURS

The government wanted Gary Seawright to help cattlemen keep track of their herds. His "failure" spawned a whole new business.

Although many of the national labs conduct secret research for military and intelligence agencies, unclassified work usually goes on right down the corridor.

Take the Los Alamos National Laboratory, birthplace of the atom bomb. There, veterinarian Gary Seawright spent several years working on an electronic-identification system for livestock—a project of the Department of Agriculture. Seawright's concern was for animal disease control, and the system would have allowed tracking of cattle from sales and feed barns right through to slaughter pens.

Only thing was that cattlemen weren't ready for it, which was all Seawright needed to stir his own entrepreneurial urges. He and his team reworked their idea a bit and came up with an application in the transportation field, tracking rail cars and ship-to-truck cargo containers as they move through seaports and rail yards around the country. The idea looked so promising that the Los Alamos lab helped them to secure the patents on the concept.

Patent in hand, Seawright quit the lab, rounded up $500,000 in seed capital from a Dallas investor, and founded Amtech Corp., which he located down the street from the Los Alamos lab. For his staff, he brought in five key members of the original research crew. Los Alamos was quite decent about it. The lab's legal staff was very helpful in the reassignment process of the two patents to Amtech. And a few of Amtech's principals were granted two-year leaves of absence, with their old

PATRICK BERRETT

Amtech founder Gary Seawright
Staff and technology are from Los Alamos

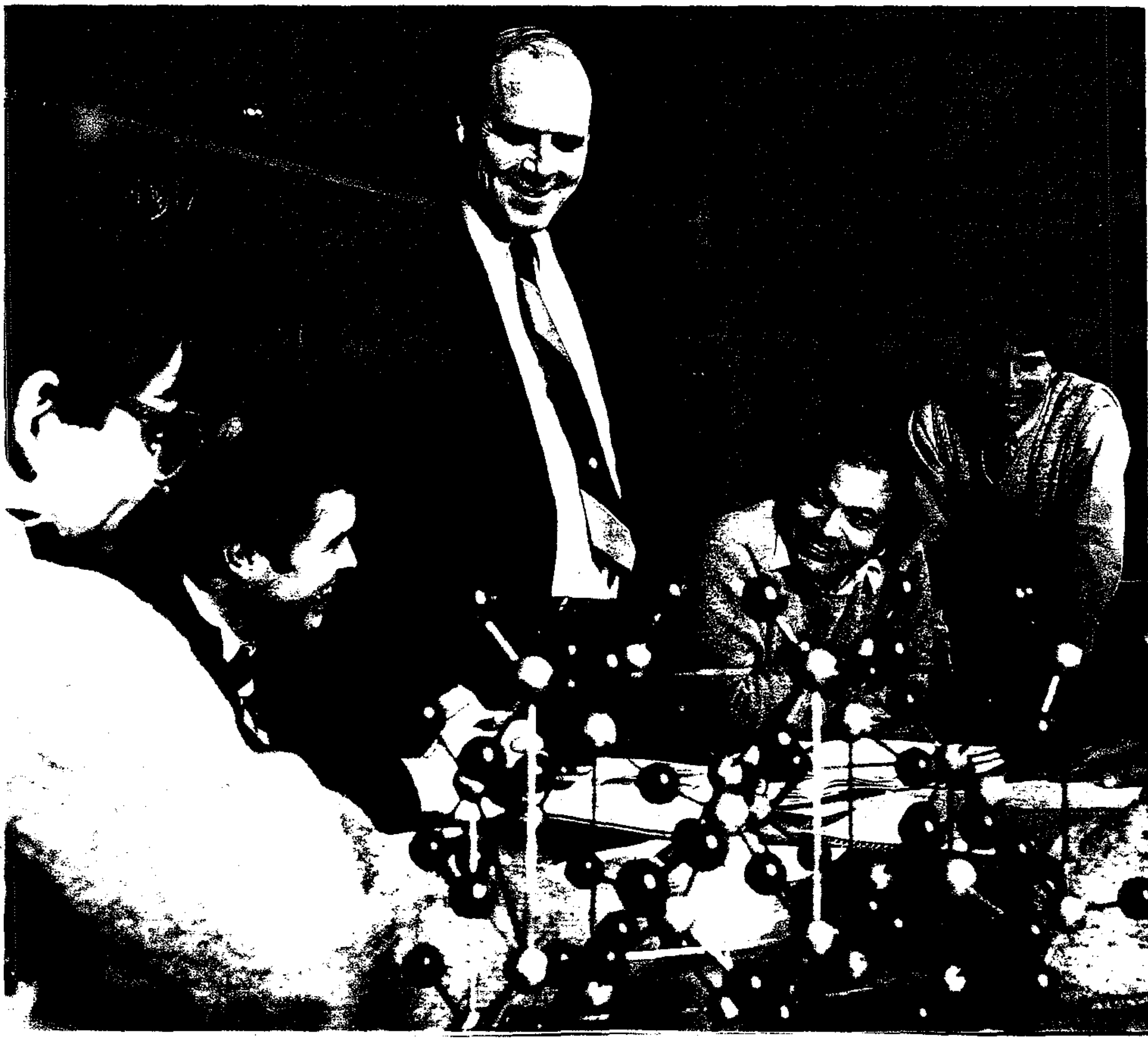
jobs guaranteed if the company flopped.

Instead, the company is growing. In its second year of operation, Amtech last year booked $300,000 in sales. The company now has a $150,000 contract with American President Lines, a major shipping company, and another contract with Union Switch & Signal Division to package and market the system to railroads and mass-transit authorities worldwide. And turnpike operators in the Northeast see in the system a way to unclog congestion at toll plazas, where computers could automatically identify a commuter vehicle and bill at the end of the month; the car wouldn't even have to stop. The first installation: New York's Triborough Bridge.

MANAGING

BUSINESS GOES TO COLLEGE FOR A BRAIN GAIN

As never before, universities are luring companies with partnership agreements and research parks. Some are even promoting high-tech start-ups on campus. ■ *by Jeremy Main*



FOUR high-browed Ph.D.s solemnly carried out their assignment: Redesign a coffee maker. They belong to the Center for Industrial Innovation on the wind-swept campus of Rensselaer Polytechnic Institute (RPI) in Troy, New York. Wait a minute. A university designing a coffeepot? What's going on here? Why would a distinguished institution of higher learning put aside thoughts of quarks and quasars to play with something so pedestrian?

The answer is that RPI took on the project in exchange for a $116,000 fee from Norelco, one of the big-name corporate supporters of the innovation center's manufacturing productivity unit. Founders like IBM and Alcoa contributed up to $500,000 apiece; affiliates, including Timex, General Dynamics, and Norelco, pay $40,000 a year. All have the right to hang around the productivity unit, one of three research groups at the center. They get an early look at what the scientists are doing—and they can woo the best students at the same time. They can also hire the center for proprietary research, as Norelco did. In that case the result was a coffee maker with snap fasteners instead of screws to make manufacturing easier, and with added features to entice the consumer.

Academe and industry, long disdainful antagonists, have discovered that they need each other badly. Some colleges have always had ties to business, but the connection has never been so close as it is today. Nothing seems likely to slow what a recent National Academy of Sciences report described as a "virtual explosion over the past several years in the number and variety of university-industry alliances."

For universities, association with business means research funds above all. The government continues to be the predominant source, but federal spending has leveled off at $6.5 billion of the $14.2 billion spent annually on university research.

Probing glassmaking, *one of Corning's top scientists, Michael Teter (standing), gets help at Cornell's Theory Center, directed by Nobel laureate Kenneth Wilson (second from left).*

Industry added only $600 million last year, but its support has tripled since 1980. Universities also benefit from the up-to-date equipment business can donate, the extra income professors and graduate students can earn, and the stimulation of doing research that moves rapidly into the marketplace. One buzzword of the new alliance is "technology transfer," which means turning research into products. "Tradition has it that science to be good has to be so pure as to be useless," argues Cornell President Frank H. T. Rhodes. "It's not so." Says Wesley Posvar, president of the University of Pittsburgh: "Serendipitous academic research typically takes ten to 15 years—or forever. There's no reason why it should be so protracted."

Four Ph.D.s *at Rensselaer Polytechnic Institute, led by Leo Hanifin (second from right), helped Norelco build a better coffee maker—for a $116,000 fee to RPI.*

OVAK ARSLANIAN

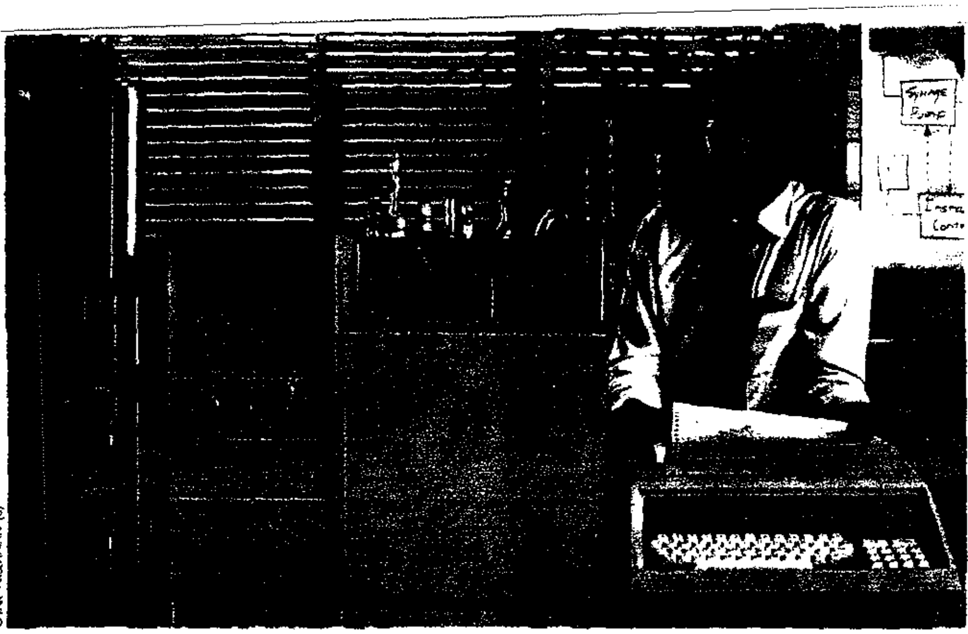
While universities are the more ardent partners, companies also have good reason to get cozy. Says Herbert I. Fusfeld, head of RPI's Center for Science and Technology Policy: "Many corporations are realizing they can no longer be self-sufficient technically." High-tech companies, for example, find that the time lag between pure research and product has shrunk so much that they need to be where the pure research is performed. "We need a window on innovation," says James P. Baughman, who supervises management development for General Electric. "When someone yells 'Eureka' at RPI or Stanford, we'll hear it." Explaining why his company has given Cornell's supercomputer center about $30 million, including use of an IBM 3090-400, John Daily, who manages IBM's Academic Information Systems, says: "This puts us in a highly visible environment where the performance of IBM's best can be tested by the best people from all over the country."

Business-university alliances also improve both the local economy and the competitiveness of U.S. industry. But they have been a long time coming. For universities, alliances raise troublesome questions about academic freedom, the purity of research, and the amount of professors' time and energy that should go into off-campus activities. Companies worry that their secrets will leak out on gabby campuses. At Carnegie Mellon University in Pittsburgh, IBM invested more than $25 million in a sophisticated network (called Andrew, after the university's two founders) that connects every conceivable place on campus where a terminal might be used—10,000 rooms in all. At first IBM insisted on security passes for the Information Technology Center that runs the system because it contained the powerful new RT PCs, which had not then been unveiled. Now that the RT is public, the normal free access of a university has been restored.

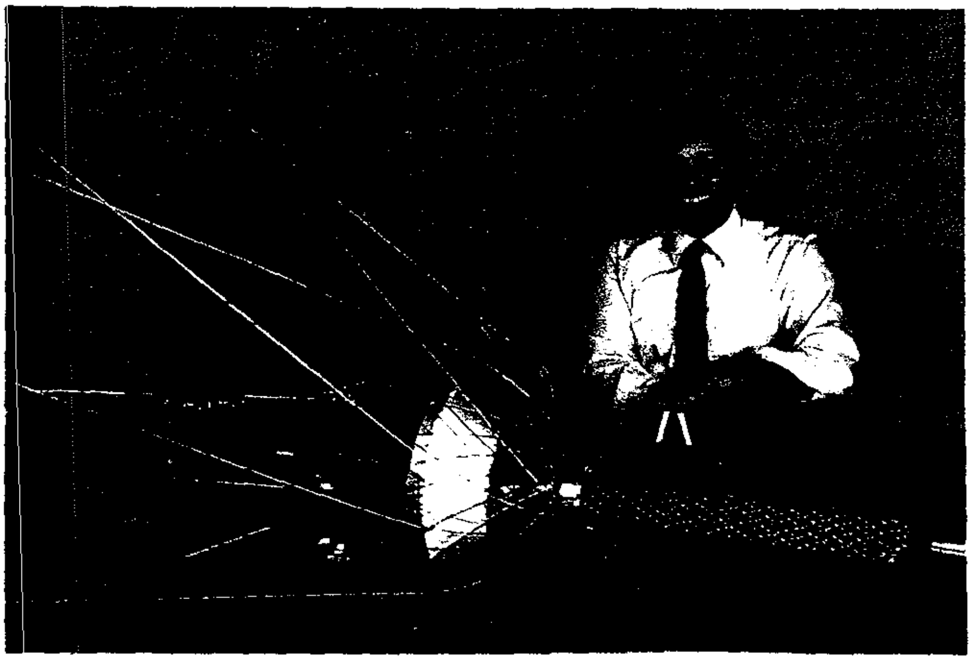
As the industry-university marriage evolves, such problems increasingly seem more theoretical than real. Considering the animosity toward business that students and faculty felt in the 1960s, which survives in the form of South Africa divestment protests, universities and industry have come together with remarkably little outcry. Qualms about academic purity may have been eased in part by the discovery that a professor can get rich by turning entrepreneur. Some 3,000 science and engineering professors own stock in companies that are based on their own research, and a number have become multimillionaires.

Today's entrepreneurial university can provide a framework for the whole life cycle of a business. Suppose an undergraduate finds a subject that excites him. He becomes a graduate student and makes a discovery. The university helps him write a business plan, acquire a patent, and raise seed money.

continued



OVAK ARSLANIAN (3)



He takes his first steps in the university's incubator building for newly hatched entrepreneurs, moves to the university's research park when sales pick up, and improves his product in the university labs. Finally he succeeds, making a fortune. Naturally, he becomes a generous benefactor of the school.

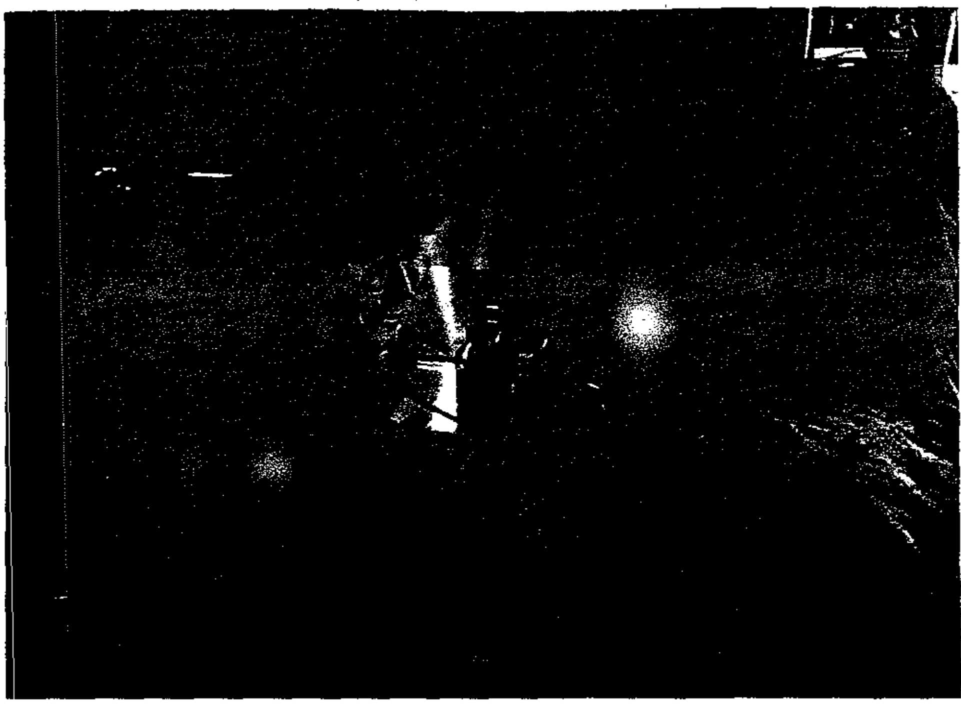
ALONG WITH RPI, the University of Pittsburgh and its neighbor, Carnegie Mellon, have pushed the business alliance further than most. Lalith Kumar, a 28-year-old native of India, is one of the entrepreneurs nurtured at Carnegie Mellon. As a doctoral student in the early 1980s, he studied supercritical fluid extraction, the science of separating the compounds of a fluid by using precise high pressures. He wanted to apply the technology commercially and found that by using it to analyze chemicals he might develop a market. While continuing to work for the Ph.D. that he finally got in 1985, he co-founded Suprex Corp. and moved rent-free into an old commercial garage that Carnegie Mellon had turned into a business incubator.

"We needed inexpensive space to survive," says Kumar. "Sometimes we couldn't even pay the engineer." The university also invested $20,000. Faculty members helped with fund raising and scientific advice. On the strength of $2.3 million in venture capital, Kumar moved to Pitt's new 85-acre U-Parc research center a year ago. He hopes to reach $2 million in sales this year.

In their newfound worldliness, universities are offering sophisticated inducements to get more support from industry. Each college has its own combination of deals. Here are the choices a company might have:

▶ **THE RESEARCH PARK.** Universities with acreage to spare look enviously at the pioneering Stanford Research Park, established in 1951 and a key ingredient in the growth of Silicon Valley. Now fully developed, the park has yielded Stanford $2.1 million annually on average for the past 30 years, counting substantial prepayments on leases. Some parks, like Princeton's Forrestal Center, are treat-

Campus entrepreneurs *can get advice, office space, and even capital from universities. Lalith Kumar (top) set up a company to make chemical-analysis equipment while earning his Ph.D. at Carnegie Mellon. John Matrone (center) and Hugo Kruesi (bottom) have started companies at Rensselaer Polytechnic Institute's research park. Matrone makes automated systems for testing circuit boards, and Kruesi produces new, extra-strong materials.*



WAYNE SORCE

Visiting Hoechst scientist *Siegfried Stengelin works with Harvard researcher Mary Ellen Rowe at a molecular biology lab the West German company built at Massachusetts General Hospital.*

ed simply as real estate investments available to any tenant; others, like RPI's, are open only to companies doing research that complements the university's.

University research parks are breaking out all over. In 1983 there were a scant dozen. Today there are 80. Pitt got U-Parc ready-made last year as a result of Chevron's acquisition of Gulf Oil. Chevron gave the university Gulf's research center 14 miles from Pittsburgh, complete with 55 buildings and research equipment. Pitt has already signed up 36 tenants.

Still, only a handful of new parks will reach the status of Stanford's, according to Reginald W. Owens, a park development consultant and president-elect of the new Association of University Research Parks. He argues that it takes a great research institution to create a major park, and even those that reach for success on a small scale will need "the ultimate in amenities." Good transportation is crucial too. "Without an airport, you're dead," he says. Cornell's modest park, with only a small airport next door, is unlikely to blossom.

Even under the best of conditions, parks mature slowly. Few produce much income for their academic landlords. The University of Utah's park, with 56 tenants, has never topped $500,000 in annual rentals. But parks do wonders for the surrounding community. Each professional researcher adds about $125,000 a year to a local economy, says RPI's Fusfeld. North Carolina's Research Triangle, bounded by three major universities (Duke at Durham, the University of North Carolina at Chapel Hill, and North Carolina State at Raleigh), employs 9,000 Ph.D.s.

▶ **AFFILIATES.** MIT set the pattern in 1948 by establishing a program that gives companies access to the university for a fee. Today MIT has 300 affiliates, including one-third of the FORTUNE 500 companies that do serious scientific research. MIT's affiliates pay $10,000 to $100,000 a year, depending on their size. In return, their executives can attend seminars, get advance word of scientific papers, and even call professors to discuss problems. Sometimes professors visit companies. For a fee, corporations can send their own scientists to work in MIT labs. The program, administered by a 50-person industrial liaison office in Cambridge and a branch in Tokyo, raised a good chunk of the $38 million that industry contributed in 1986 to MIT's $256-million research budget.

Today it would be hard to find a university without an affiliate program. Fees can range up to the $250,000 a year charged by Carnegie Mellon's Magnetics Technology Center. At Cornell's new Theory Center, which houses the IBM 3090-400 supercomputer, affiliates pay $100,000 a year each. The Corning Glass Works' contribution entitles the company to send one of its top scientists, Michael P. Teter, to do research in the Theory Center. He spends a couple of days a week at Cornell working on such fundamental problems as three-dimensional fluid flow modeling of the glassmaking process. He says the supercomputer enables him to work out simulations in three months that would take 20 years in the arcane world of glassmaking. More important than the supercomputer, says Teter, are insights he gets from access to half a dozen of the world's top mathematicians and physicists, including the center's director, Nobel laureate Kenneth G. Wilson.

▶ **PARTNERSHIPS.** Universities and corporations sometimes go beyond mere affiliation to merge forces in joint ventures. When Monsanto wanted to expand from chemicals into biotechnology in 1982, it signed a joint research agreement with Washington University, a neighbor in St. Louis that is strong in biology. Monsanto will pay the university $62 million over 8½ years. Hundreds of Monsanto and university scientists are working on some 30 projects that show promise of pushing the results of basic research rapidly into the market. The partnership has already started clinical tests on several products. At least one of them—synthetic atrial peptides, like the protein fragments produced naturally by the heart to regulate blood pressure—may be on sale by the end of the decade. Washington University scientists synthesized the atrial peptides; Monsanto's purified them and produced more for tests. The university will own the patents, but Monsanto will have exclusive rights to them.

GERMANY'S Hoechst AG, the world's fourth-largest chemical company, provides all of the support for the molecular biology department at Massachusetts General Hospital in Boston, a teaching hospital for Harvard's medical school. Hoechst spent $10 million to build the department's labs and offices, equipped them for another $1.5 million, and provides the entire $6-million annual operating budget. The department does no directed research for Hoechst and would resist any request to do so, says its chief, Howard M. Goodman. But it sure can help.

Hoechst has a new herbicide called Basta that leaves no residue but kills crops and weeds alike. As often happens in the business-university alliance, Hoechst's practical problem spurred the Harvard scientists into solving a theoretical problem: They did the basic thinking about genetic engineering that

REPORTER ASSOCIATE *Barbara Loos*

will help make desirable plants immune to the herbicide. Now Hoechst scientists are applying those theories to create resistant strains of corn and beets. Most important to Hoechst, Harvard gives it a window into molecular biology, a field in which it feels weak. Hoechst has the right to assign four scientists to the lab and to have company scientists and executives get regular briefings.

▶ **PATENTS.** Academics used to think it was wrong to take out patents to profit from inventions that they felt should be freely available to the public. This altruism was dented in the 1970s by the recognition that companies are unwilling to invest much in unprotected inventions. Besides, why should universities give up an extra source of income? Most now have patent offices and require professors to assign rights to their inventions to the university, unless the government has financed the work. The professor and the college split any income.

Stanford hopes to beat all records with some 80 licenses taken out on the university's recombinant DNA patent, one of the most scientifically exciting and financially promising inventions of recent decades. Stanford almost missed that golden goose. When Stanley Cohen of Stanford and Herbert Boyer of the University of California at San Francisco discovered the key to genetic engineering in the 1970s, they delivered a paper making their work public. In the academic tradition, they did not file for a patent. The university's news director, Robert Beyers, spotted a newspaper account of their research and took it to the office of technology licensing. The university filed for a patent just before expiration of the one-year period after which their ideas would have been in the public domain. In five years, says Niels Reimers, head of the office of technology licensing at Stanford, that patent will be worth more than $10 million a year. Genentech, the company created by the patent, is even more valuable. Boyer put $500 into the company ten years ago and today owns shares worth $105 million. Reimers says his staff of 13 evaluates about three discoveries a week and licenses about one out of eight. He expects revenues to reach $6 million this year.

> Harvard President Derek Bok aroused his faculty to fury when he tried to get the university a 10% stake in Genetics Institute Inc., a biotechnology company founded by two Harvard professors.

Despite such bonanzas, "most patents are junk," says RPI President Daniel Berg. Harvard's patent office, opened in 1977, took in a meager $200,000 last year. Still, many colleges figure that if they build up their bank of patents and more research becomes salable, income will increase substantially.

▶ **EQUITY PARTICIPATION.** If professors' equity in their companies can be worth millions, why don't universities take a piece of the action? A few do, but most feel the risk of conflict of interest is too great. Says Cornell's Frank Rhodes: "If a university has equity in the companies of its faculty members, that makes the university less than impartial in promotions, support, and so forth." Harvard President Derek Bok aroused his faculty to fury in 1980 when he tried to get the university a 10% stake in Genetics Institute Inc., a biotechnology company founded by Harvard professors Mark Ptashne and Tom Maniatis. Bok backed off. Other institutions, among them Carnegie Mellon, Washington University, and the University of Utah, are willing to take positions either directly or through foundations they control.

By now equity participations and other questions of academic integrity are pretty well covered by rules worked out with much windy discussion but remarkably little controversy. Professors have long been allowed to work off campus one day a week, usually as consultants, and the rule now extends to academic entrepreneurs. They can put in that day as board members or consultants at their own companies, but if they want to be line executives they must quit or go on leave.

One big problem for companies that want to hang on to competitive secrets is universities' commitment to publishing research results. Most universities will not undertake secret or proprietary research for companies, and if they do, they insist on the right to publish—though not immediately. Some will wait a month; Carnegie Mellon permits a three-month delay if a company insists. Since academic journals are notoriously slow anyway, the lag is immaterial. By having an early look at the research, the companies get all or most of the head start they need.

RESERVATIONS about the university-business alliance seem strongest at well-endowed liberal arts colleges and scarce at technically oriented schools that have to scramble for money. At rich old Princeton, the new dean of engineering, Hisashi Kobayashi, has begun to encourage mingling with industry. Even so, he is cautious. "The atmosphere is different here," he says. "Our traditional strength lies in scholarly work and publishing rather than running around developing products and starting companies. If we emphasized industrial collaboration too much, the atmosphere of the university would change."

These are honeymoon days for the new alliance. "There's no downside to it that I could discern," says David Gardner, president of the University of California system and head of the University of Utah for ten years as it built exceptionally close relations with business. But problems will surely surface. Some universities will see their research parks fail; others may find they have strayed uncomfortably far from teaching and disinterested research. But the relationship plainly offers a way to get the fruits of invention into the economy faster and better, which cannot help but make the U.S. more competitive. Carnegie Mellon President Richard M. Cyert believes that universities cooperating with industry could act as an informal answer to Japan's vaunted Ministry of International Trade and Industry (MITI), the powerful government-business partnership that has done so much for Japan. By and large, that American odd couple, colleges and commerce, looks to be a lasting union. ■

Through gift, theft and license, our technology is leaking abroad almost as fast as we develop it. So scratch the long-term dream of a U.S. living off exports of high-technology goods and services.

Does anyone really believe in free trade?

By Norman Gall

NEVER MIND if the U.S. loses its manufacturing skills; we'll just import manufactured goods and pay for them by exporting high technology and knowledge-oriented products. Steel in, software out. Autos in, microchips out.

That's a comforting theory held by a lot of people. Is it workable? Increasingly it looks as if it is not workable. The whole concept is being seriously undermined as U.S. innovations in technology are adopted not only by Japan but also by such fast-developing countries as South Korea, Brazil, Taiwan, even India.

While these countries are more than happy to sell us manufactured goods, they closely control their own imports of technology goods they buy from us. Exports of computers and other high-technology products from the U.S. are still huge, but the long-term prospects are in question. In areas of medium technology, minicomputers in particular, developing countries are adapting or stealing U.S. technology or licensing it cheaply to manufacture on their own. Many of the resulting products are flooding right back into the U.S.

The Japanese developed this policy to a fine art: Protect your home market and then, as costs decline with volume, manufacture for export at small marginal cost. A good many developing countries have adopted the Japanese technique.

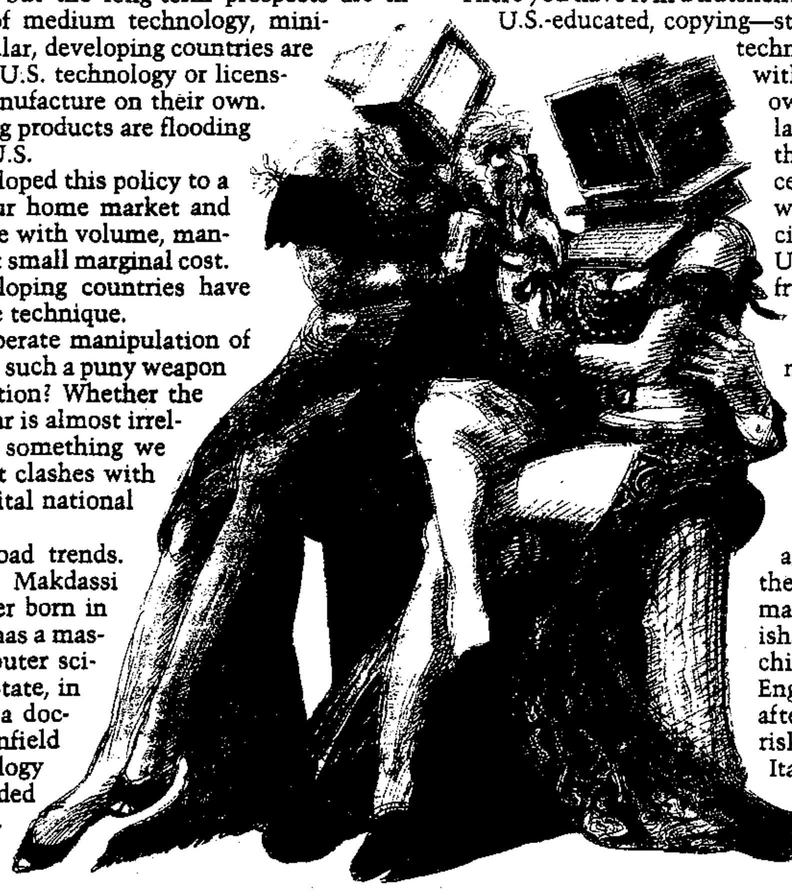
Against such deliberate manipulation of markets, what avails such a puny weapon as currency devaluation? Whether the dollar is cheap or dear is almost irrelevant. Free trade is something we all believe in until it clashes with what we regard as vital national economic interests.

These are the broad trends. Now meet Touma Makdassi Elias, 41, an engineer born in Aleppo, Syria. Elias has a master's degree in computer science from San Jose State, in Silicon Valley, and a doctorate from the Cranfield Institute of Technology in England. Grounded in European and U.S. technology, Elias is now a Brazilian.

His company, Microtec, is Brazil's first and biggest producer of personal computers. Elias came to São Paulo eight years ago to teach night classes in engineering. In 1982 the Brazilian government banned imports of small computers. Seizing the opportunity, Elias started making the machines in the basement of a supermarket in the industrial suburb of Diadema.

Technology? "We worked from IBM technical manuals," Elias told FORBES. "We had a product on the market by 1983. We started making 20 machines a month. Soon we'll be making 2,400. Now my brother may be joining our firm. He's a graduate of the Sloan School of Management at MIT. He's been managing an investment company in Dubai, in the Persian Gulf, but we need him here. Brazil is one of the world's fastest-growing computer markets."

There you have it in a nutshell: foreigners, some of them U.S.-educated, copying—stealing, to be blunt—U.S. technology and reproducing it with protection from their own governments. An isolated development? No, this is the rule, not the exception, in much of the world. How, under such circumstances, can the U.S. expect to reap the fruits of its own science and technology?



Time was when technology spread slowly. Communications were sluggish and nations went to great lengths to keep technological innovations secret. In northern Italy 300 years ago, stealing or disclosing the secrets of silk-spinning machinery was a crime punishable by death. The machines were reproduced in England by John Lombe only after he spent two years at risky industrial espionage in Italy. At the height of the Industrial Revolution, Britain protected its own supremacy in textile manufacture through laws banning both exports of machines and emigration of men who knew how to build and run them.

These embargoes on the export of technology were eventually breached. France sent industrial spies to England and paid huge sums to get British mechanics to emigrate. By 1825 there were some 2,000 British technicians on the European continent, building machines and training a new generation of technicians. A young British apprentice, Samuel Slater, memorized the design of the spinning frame and migrated to the U.S. in 1789, later establishing a textile factory in Pawtucket, R.I. So, in the end, the technology became commonplace, but it took decades, and, in the meantime, England was profiting handsomely from its pioneering.

Not so today, when 30% of the students at MIT are foreigners, many destined to return to their native lands and apply what they learn of U.S. technology. What once was forbidden, today is encouraged. Come share our knowledge.

Consider the case of Lisiong Shu Lee, born in Canton, China in 1949, raised in Rio de Janeiro, now product planning manager for SID Informatica, one of Brazil's big three computer companies. Like many leading Brazilian computer technicians, Lee is an engineering graduate of the Brazilian air force's prestigious Aerospace Technical Institute near São Paulo. Born in China, raised in Brazil, educated in the U.S. "When I was only 24," Lee says, "I was sent to the U.S. to debug and officially approve the software for the Landsat satellite surveys devised by Bendix Aerospace." Lee later worked eight years with Digital Equipment's Brazilian subsidiary.

Like Microtec's Elias, Lee had learned most of what he knew from the Americans. In teaching this pair—and tens of thousands like them—U.S. industry and the U.S. academies created potential competitors who knew most of what the Americans had painfully and expensively learned. Theft? No. Technology transfer? Yes.

In Brazil over the past few years, the Syrian-born, U.S.-educated Elias played cat-and-mouse with lawyers representing IBM and Microsoft over complaints that Microtec and other Brazilian personal computer makers have been plagiarizing IBM's BIOS microcode and Microsoft's MS-DOS operational software used in the IBM PC. The case was settled out of court. Brazilian manufacturers claimed their products are different enough from the original to withstand accusations of copyright theft.

Where theft and copying are not directly involved in the process of technology transfer, developing countries find ways to get U.S. technology on terms that suit them. They get it cheaply. Before President José Sarney departed for his September visit to Washington, the Brazilian government tried to ease diplomatic tensions by announcing approval of IBM's plans to expand the product line of its assembly/test plant near São Paulo. IBM will invest $70 million to develop Brazilian capacity for producing the 5-gigabyte 3380 head disk assembly (HDA).

Ah, but there is a tradeoff involved in the seeming concession by the Brazilians. The tradeoff is that IBM's expansion will greatly improve the technical capabilities of local parts suppliers to make a wider range of more sophisticated products. About a third of the key components in IBM's HDA catalog will be imported, but Brazilian suppliers will get help in providing the rest, some involving fairly advanced technologies.

But does what happens in Brazil matter all that much? Brazil, after all, is a relatively poor country and accounts for a mere $3 billion in the U.S.' $160 billion negative trade balance. Brazil matters very much. For one thing,

Photos by Paulo Fridman/Sygma

Microtec's personal computer factory in São Paulo
Designs cribbed from IBM technical manuals, but different enough to withstand accusations of copyright theft.

Mictrotec founder Touma Makdassi Elias
From Syria to São Paulo via Silicon Valley.

Newsstand in São Paulo
Plenty of reading choices for computer hackers, too.

what happens there happens in similar ways in other developing countries—and some developed ones as well. Brazil, moreover, is fast adapting to the computer age. The Brazilian computer industry employs over 100,000 people. It includes everything from the gray market of São Paulo's Boca de Lixo district to the highly profitable overseas subsidiaries of IBM and Unisys. Both subsidiaries have been operating in Brazil for more than six decades and, for the time being, have been profiting from Brazil's closed-market policies. It includes many manufacturer/assemblers of micro- and minicomputers and of peripherals. Companies also are appearing that supply such parts as step motors for printers and disk drives, encoders, multilayer circuit boards, high-resolution monitors, plotters and digitizers. The Brazilian market is bristling with new computer publications: two weekly newspapers, ten magazines and special sections of daily newspapers.

Brazil is only a few years into the computer age. Its per capita consumption of microchips works out to only about $1.40 per capita among its 140 million inhabitants, vs. $100 in Japan, $43 in the U.S. and about $6 in South Korea. But given the potential size of the market and Brazil's rapid industrialization, it could one day absorb more personal computers than France or West Germany.

The point is simply this: In their natural zeal to make Brazil a modern nation rather than a drawer of water and hewer of wood, its leaders are determined to develop high-technology industry, whether they must beg, borrow or steal the means. Failing to develop high-technology industry would be to court disaster in a country where millions go hungry. But in doing what they must, the leaders of Brazil and other developing countries run strongly counter to the economic interests of the U.S.

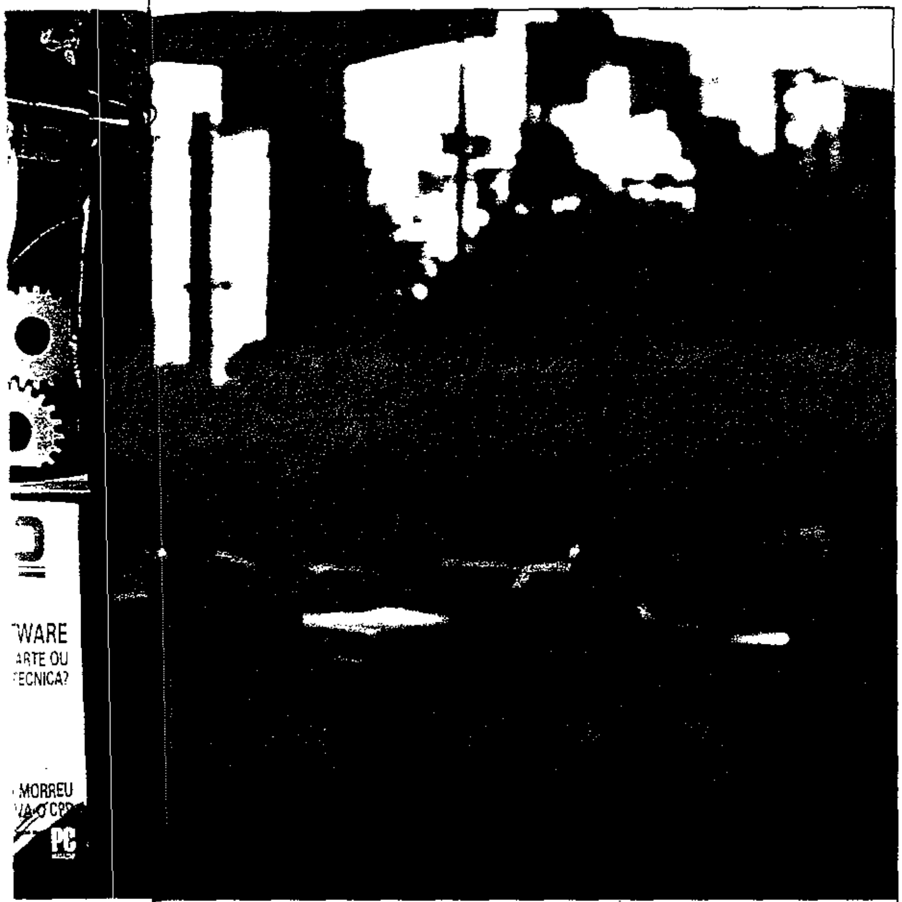
Because of these nationalistic policies, foreign-owned firms are banned from competing in Brazil's personal computer and minicomputer market. Brazil's computer industry is not high tech, if that means being near the cutting edge of worldwide technological advance. But it does show the ability of Brazilian businessmen and technicians to shop for and absorb standard technology, without paying development costs. In computers, where knowledge is the most expensive component, it becomes cheap to manufacture if you get the knowledge free or almost free. The U.S. develops, Brazil copies and applies. There are perhaps a dozen Brazils today.

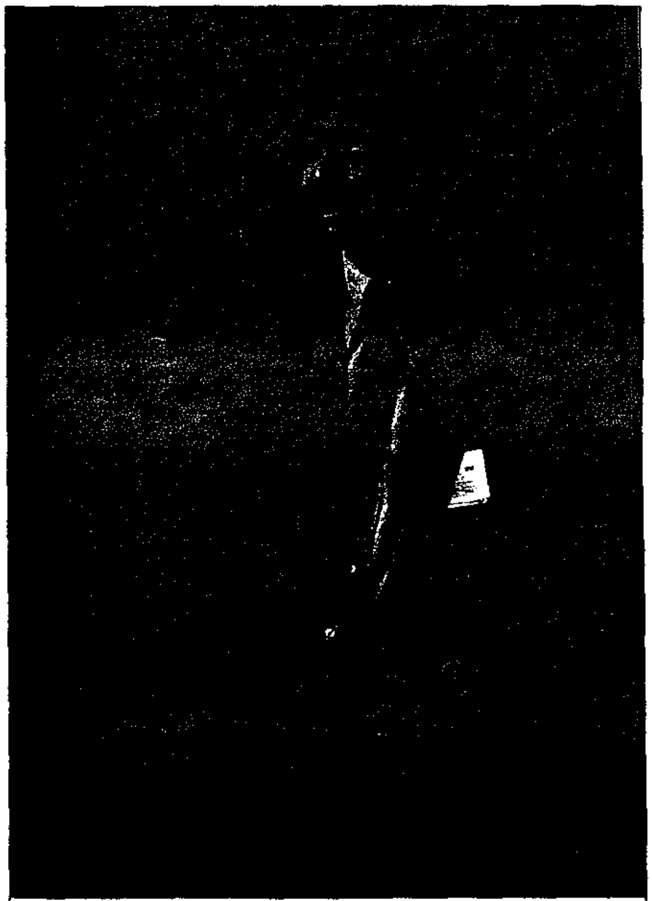
"We're a late entry and can pick the best technology," says Ronald Leal, 36, co-owner of Comicro, a CAD/CAM equipment and consulting firm. "We don't waste money on things that don't work. In 1983 we saw a market here for CAD/CAM done with microcomputers. We shopped around the States and made a deal with T&W Systems, a $10 million California company that has 18% of the U.S. micro CAD/CAM market. T&W helped us a lot. We sent people to train and they came to teach us."

Comicro learned fast. Says Leal: "We developed new software applications that we're now exporting to T&W."

Brazil exporting computer designs to the U.S.? Only five years after IBM began creating a mass market for the personal computer, the U.S. home market is being invaded by foreign products—of which Comicro's are only a tiny part. Technological secrets scarcely exist today.

Aren't the Brazilians and the others simply doing what





Lisiong Shu Lee of SID Informatica
Theft? No. Technology transfer? Yes.

the U.S. did a century and a half ago—protecting its infant industries?

If that were all, the situation might not be so serious for the U.S. But pick up any U.S. newspaper these days and count the advertisements for Asian-made personal computers claiming to be the equivalent of the IBM PC but selling at maybe two-thirds of IBM's price.

According to Dataquest, a market research firm, Asian suppliers will produce nearly 4.5 million personal computers this year. At that rate, they should capture one-third of the world market by next year. Taiwan now is exporting 60,000 personal computer motherboards and systems monthly, 90% of which are IBM-compatible. Of these, 70% go to the U.S. and most of the rest to Europe. Korea, Hong Kong and Singapore together ship another 20,000 each month.

Dataquest says it takes only three weeks after a new U.S.-made product is introduced before it is copied, manufactured and shipped back to the U.S. from Asia.

Thus the U.S. bears the development costs while foreigners try to cream off the market before the development costs can be recouped. That is the big danger. The days when a person could be executed for industrial espionage are gone.

President Reagan recently warned that the U.S. is being victimized by the international theft of American creativity. Too many countries turn a blind eye when their citizens violate patent and copyright laws. In 1985-86 U.S. diplomats successfully pressured Korea, Singapore, Malaysia, Taiwan, Hong Kong and Thailand to pass or at least to draft legislation enforcing patents and copyrights more strictly. Brazil is a major holdout.

The difficulties between Brazil and the U.S. over computers crystallized in the 1984 Informatica law, which Brazil's Congress passed overwhelmingly near the end of two decades of military rule. The law, in effect, legalizes stealing—so long as the victims are U.S. technology exporters. Complains the head of a leading multinational whose business has been curtailed under the new law: "They want our technology but want to kill our operations. This whole show is sponsored by a handful of sharp businessmen with connections in Brasília who are making piles of money from their nationalism."

The new law formally reserved the Brazilian micro- and minicomputer market for wholly owned Brazilian firms. It allowed wholly owned subsidiaries of foreign companies—IBM and Unisys—to continue importing, assembling and selling mainframes, but not out of any sense of fairness. It was simply that Brazilian companies were unable to take over that end of the business.

Under the law, joint ventures with foreign firms were allowed only if Brazilians owned 70% of the stock and had "technological control" and "decision control."

The main instruments for implementing this policy were tax incentives and licensing of imports of foreign hardware and knowhow, all to be approved by the secretariat of information science (SEI).

In 1981 Brazil's then-military government decreed that SEI would control the computer and semiconductor industries and imports of any and all equipment containing chips. The implications are especially ominous for U.S. interests: Brazil's SEI is modeled, quite openly, on Japan's notorious Ministry of International Trade & Industry (MITI). Brazil's computer policy today follows the line of a mid-Fifties report by MITI's Research Committee on the Computer.

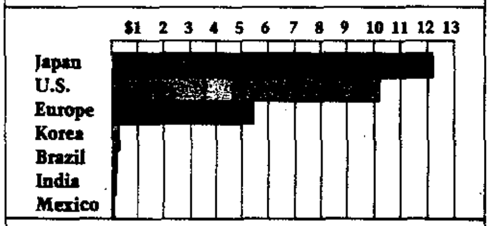
In the 1950s and 1960s MITI used Japan's tight foreign exchange controls to ward off what its nationalist superbureaucrat of the day, Shigeru Sahashi, called "the invasion of American capital." In long and bitter negotiations in the late Fifties, Sahashi told IBM executives: "We will take every measure to obstruct the success of your business unless you license IBM patents to Japanese firms and charge them no more than 5% royalty." In the end, IBM agreed to sell its patents and accept MITI's administrative guidance on how many computers it could market in Japan. How many Japanese products would be sold in the U.S. today if this country had imposed similar demands on the Japanese?

Some U.S. economists are describing the result of the Japanese policy as the "home market effect." They mean that protectionism in the home market tends to create an export capability at low marginal cost.

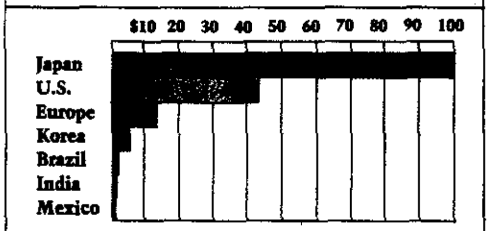
Where the chips fall

No matter how you slice it, per capita or by dollar volume, most of the world's semiconductors go to the U.S., Japan and Europe. Don't be misled, though. The smaller markets matter, especially to the governments that work so hard to protect them.

Semiconductor consumption ($billions)



Dollars per capita consumption



"Home market protection by one country sharply raises its firms' market share abroad," says MIT's Paul Krugman, reporting the results of computer simulations of international competition in high technology. "Perhaps even more surprising, this export success is not purchased at the expense of domestic consumers. Home market protection lowers the price at home while raising it abroad."

Brazil surely has similar intentions. IBM and other U.S. computer companies are transferring technology to Brazil as never before.

The Brazilians may have grasped a reality that the U.S. has been unable politically to address: that while there is no way to check the fast dissemination of technology today, the real prize in the world economy is a large and viable national market—a market big enough to support economies of scale and economies of specialization. In short, while a country can no longer protect its technology effectively, it can still put a price on access to its market. As owner of the world's largest and most versatile market, the U.S. has unused power.

Taiwan, Korea, Hong Kong and Singapore, lacking large internal markets, could develop only because they had easy and cheap access to the rich U.S. market.

Why doesn't the U.S. reciprocate? The Reagan Administration has threatened to restrict imports of Brazilian exports to the U.S. by Dec. 31 if Brazil doesn't 1) protect software with new copyright legislation, 2) allow more joint ventures with foreign firms, and 3) publish explicit rules curtailing SEI's arbitrary behavior.

But the Brazilians are hardly trembling in their boots. Brazilian officials hint that if Brazilian exports to the U.S. are curbed, Brazil won't be able to earn enough dollars to service its crushing external debt. Diplomats of both countries want to avoid a showdown, so they keep talking. And while they talk, the Brazilians do what they please.

U.S. Customs has responded to manufacturers' complaints by stopping pirated products at the border. But the Taiwanese now have such cost advantages that they can easily afford to license technology that they have already copied. The Koreans are more scrupulous, but pirated technology not reexported to the U.S. is very hard to control.

More than three years ago Edson de Castro, president of Data General, told a Commerce Department panel that foreign nations' computer policies "threaten the structure and future of the U.S. computer industry." De Castro explained why: "U.S. computer companies are reliant on international business and derive a substantial portion of revenues from exports. Because of the rapid pace of technological development, the industry is capital intensive. Growth and development rely heavily on an expanding revenue base. This can only come from full participation in established and developing global markets. Reliance upon domestic markets is not enough."

Yet after resisting the Brazilian government's demands for a decade, de Castro's Data General is selling technology for its Eclipse supermini to Cobra, the ailing government computer company. Other U.S. computer manufacturers are following suit.

Hewlett-Packard, in Brazil since 1967 with a wholly owned subsidiary to import and service the company's products, has just shifted its business into partnership with Iochpe, a Brazilian industrial and finance group. A new firm, Tesis, 100% Brazilian-owned, will make HP calculators and minicomputers under its own brand name.

"Only a few years ago HP refused to enter joint ventures, but now we have ones going in Mexico, China, Brazil and Korea," says a company executive. "In the past we felt, since we owned the technology, why share the profits? Then we found we couldn't get into those foreign markets any other way."

Harvard Professor Emeritus Raymond Vernon, a veteran analyst of international business, says of world technology markets: "Except for highly monopolistic situations, the buyer has a big advantage over the seller. Countries like Brazil and India can control the flow of technology across their borders and then systematically gain by buying technology cheaply."

Vernon draws an ominous parallel: "A century ago the multinationals were in plantation agriculture and electric power. Now they're all gone because their technology and management skills were absorbed by local peoples. The same thing is happening in other fields today, including computers."

This is why it makes little difference whether the dollar is cheap or dear. In this mighty clash between nationalism and free trade, nationalism seems to be winning. Where does this leave the U.S. dream of becoming high-technology supplier to the world? Rudely shattered. ■

WASH. STAR OCT. 1, 1978

Federal Regulations Stifle Smaller Firms, Say Critics

By Leonard Curry
Washington Star Staff Writer

Ned Heizer is head of the biggest company of its type in the country. But he isn't happy about it.

"The only reason we're the biggest is because securities regulation is killing off the rest," says Heizer. And he claims his own company, Heizer Corp., is next on the list.

Heizer is in the venture capital business. That means his firm bankrolls innovative businesses that can't get cash anywhere else.

In nine years, Heizer Corp. reports financing 33 companies that now have over $1 billion in sales, pay $150 million in taxes and employ 20,000.

"Common sense would say that Heizer Corp. should continue in businesss," he says. But Heizer says the company's stockholders want the firm to go public so they can cash in their interests at some point.

Federal investment company regulation prohibits the offering and the Securities and Exchange Commission is unlikely to grant an exemption, says Heizer, who has hired former SEC Chairman Ray Garrett to represent the company in the attempt.

There is a general feeling, true or not, that government regulation is strangling small businesses that are the backbone of the nation's commerce.

WILSON JOHNSON, president of the National Federation of Independent Businesses, insists it is a fact. "A form that is a snap for a major corporation to complete is often unintelligible to small business. It simply lacks the expertise."

Johnson says small businessmen frequently aren't even aware some regulations exist until there is a violation.

Six of every 10 jobs are in the small business sector. Small businesses generate nearly half the gross national product, and most of the important innovations — a fact which often turns them into big businesses, Texas Instruments being a recent example.

In the wake of the California vote to roll back taxes and reduce government, a flood of bills was introduced in Congress to remove some of the regulatory burden on business, particularly on companies with gross sales in the low millions of dollars.

Although little noticed at first because they were set aside to await agency comment, these bills are now building support in Congress and the business community and drawing sharp complaints from regulatory officials that the public interest is not being served.

Even their sponsors don't believe the bills will advance far before the current Congress expires, but they do expect significant gains to be made in the new session that begins in January. A bill requiring regulatory agencies to analyze the impact of regulations on small business has cleared the Senate Judiciary Committee. Similar legislation is now moving through the House.

REP. CALDWELL BUTLER, R-Va., who introduced one of the impact bills, says he is "a little disappointed" that it hasn't advanced more than it has.

"I think it's going to move right along next year," Caldwell said, because the agencies have finally completed their reviews and made comments. "There's a lot of interest in it."

Rep. Martin A. Russo, chairman of the House subcommittee on special small business problems, expresses concern that excessive regulation will create an economy environment under which only the biggest and strongest corporations will exist.

The government passes regulations that are burdensome for small companies to carry out and are often in conflict, the Illinois Democrat says.

Rep. Bob Eckhardt, D-Texas, chairman of a House Commerce subcommittee, complains that excessive regulation by the Securities and Exchange Commission is drying up new capital sources that are vital to finance innovations that will make life better in the future.

"Throughout the 1970s, the amount of capital flowing to small business ventures has been declining dramatically," Eckhardt says. He notes that general economic conditions and investors burned in the go-go market of the late 1960s are partly responsible.

But Eckhardt says "other reasons are more subtle." These include securities regulations that foreclose from the market companies seeking to provide capital — like Ned Heizer's company — for new products and concepts that are highly speculative.

SINCE MOST of these ventures fail, the SEC has taken a dim view. But a few will be successful, often spectacularly so. But Eckhardt says the SEC is blocking these companies by foreclosing them to investors anxious to take plunges.

In other areas of regulation like the Environmental Protection Agency and the Federal Trade Commission, the burden is weighed against small business as big government tries to deal with big business.

"When the same regulation is applied equally across the board to both large and small businesses, the comparative burden is much greater on the small concerns," says Milton D. Stewart, chief counsel at the Small Business Administration.

Stewart says a company wouldn't collapse because of one regulation, but the cumulative impact is debilitating. "It is time that government regulation take into account the size of and impact on the particular companies being regulated."

But the regulatory agencies are resisting changes in their rules and orders. SEC Chairman Harold M. Williams said mass exemptions to securities laws for small business would erode the agency's mandate to protect the investing public.

And A. Daniel O'Neal, chairman of the Interstate Commerce Commission, complains that legislation to require impact statements on truckers with $6.5 million in annual revenues would include a large number of the nation's biggest carriers.

The Washington Post
Thursday, October 16, 1986

PETER BEHR

Plugging the U.S. Knowledge Leak

The United States has quarreled with its trading partners over autos, TV sets, oranges, steel bars and semiconductors. Next comes a battle over knowledge.

The protection of American inventions, laboratory research and intellectual property from unfair exploitation has moved to the top of the Reagan administration's agenda for the next round of international trade negotiations.

It also has become a prime issue for leaders of universities and government labs, who argue that the basic research at their institutions constitutes America's best remaining competitive edge in world trade.

There are now suggestions that some of that research be put off limits to foreigners or that access be limited, at least temporarily. Call it a "buy American" approach to government-funded research and development.

Richard M. Cyert, president of Carnegie-Mellon University—one of the nation's centers of research on advanced industrial processes—says the competitive importance of the U.S. research establishment must be recognized.

"The United States, in my view, is in an analogous position to being on the frontier in colonial times. We really are fighting for our economic life. Unless we are able to do some things in universities to help in this, I think our whole way of life, our whole standard of living in this country is going to go down the drain."

Cyert said he would be willing to consider a proposal that would boost federal research support for American universities—with the requirement that the research work be restricted to U.S. citizens.

"I'd be interested in it, if we limited the period .... I'd be willing to go along with that for a little while. I'm sure it would be unpopular, in the sense that we like to think of ourselves as world citizens.

"It's obviously something I'm uncomfortable with. . . . But we want to have America get some temporary advantage from the research that we can do. . . . The notion that somehow you want to do something for your country should not be something that a university president is ashamed of," said Cyert.

Congress is not considering such a proposal. But it has approved and sent to President Reagan

See BEHR, E2, Col. 4

BEHR, From E1

legislation called the Federal Technology Transfer Act of 1986.

The bill's main purpose is to help American companies, universities and other institutions tap research in the nation's 700 federal laboratories. The labs would be authorized to enter into cooperative joint research arrangements aimed at speeding their technology into commercial use.

Foreign companies aren't prohibited from joining in such cooperative ventures, but preference is to be given to American firms that agree to manufacture in the United States.

Senate Majority Leader Robert J. Dole (R-Kan.), and Sen. John D. Rockefeller IV (D-W.Va.) added a section that is aimed at assuring that American companies get reciprocal access to foreign labs. In reviewing proposals by foreign companies, federal lab directors "may examine the willingness of the foreign government to open its own laboratories to U.S. firms," the legislation says.

Although the bill has strong congressional backing, there is some question whether Reagan will sign it.

Access to American research facilities—government and university—will become even more important in a competitive sense as these laboratories try to push their discoveries into the marketplace more rapidly.

University of Michigan has set up an "intellectual properties" office to help inventors obtain patents and to offer advice and aid in turning the inventions into products or commercial services. Like Carnegie-Mellon and most other major universities, Michigan is expanding its connections with American manufacturing companies.

In all of these area, universities must walk the narrow line between advancing the U.S. national interest and maintaining a tradition of open access to all. It is a microcosm of the free-trade, fair-trade dilemma confronting Congress and the administration.

Gilbert R. Whitaker, dean of the University of Michigan's Graduate School of Business Administration, notes that the school still looks actively for non-American MBA candidates.

"The Japanese send 10 to 15 students a year. Now we're getting increasing numbers of Koreans. They're obviously here to learn something about American culture and American business to take back with them. We're trying to learn similar things about their culture," he said.

Whitaker believes that the United States has more to gain through a continuing exchange of ideas, technology and expertise. "We'd like to get technology from elsewhere to put together with our knowledge. . . . We don't have a monopoly on brains."

Cyert agrees, with one qualification. "One of the great accomplishments of the United States has been the dissemination of its knowledge and technology around the world. . . .

"We want the bucket to leak. We do want the stuff out there. To the extent we can hold back a little bit, say by some restrictions on licensing, or on access to the most up-to-date [research], it would give us a little bit of a comparative advantage."

The search for that advantage promises to transform the way universities, company managers and politicians think about the American research establishment.

Academic Freedom and the Classified Information System

Robert A. Rosenbaum, Morton J. Tenzer, Stephen H. Unger
William Van Alstyne, Jonathan Knight

Summary. Executive Order 12356, signed by President Reagan on 2 April 1982, prescribes a system for classifying information on the basis of national security concerns. The order gives unprecedented authority to government officials to intrude at will in controlling academic research that depends on federal support. As such, it poses a serious threat to academic freedom and hence to scientific advances and the national security.

A recent report (*1*) on the network of statutes and regulations which have been invoked by government officials to restrain unclassified research and travel and publication by academic researchers concluded that these restrictions abridge academic freedom significantly beyond the needs of national security. It was also argued that the nation's security is ill-served by the restrictions in that barriers to learning from others, as well as the suppression of innovative work whenever its originality might be useful even to the industrial or technological progress of other nations, are necessarily discouraging to the maintenance of research leadership within the United States.

A recent event tends to justify such criticism. A university professor submitted two papers for presentation, and subsequent publication, to the 26th Annual Technical Symposium of the Society for Photo-Optical Instrumentation Engineers meeting in San Diego in August 1982. The professor's research, supported by a grant from the Air Force, was not classified, in accordance with the university's stated policy "to undertake only those research projects in which the purpose, scope, methods, and results can be fully and freely discussed." As he had done routinely in the past, the professor also sent the papers to the program officer in the Air Force who told him, a week before the symposium, that his papers had not been cleared and therefore should not be presented. The professor, while vigorously protesting, withdrew the papers.

Certain research conducted in universities may have immediate and direct national security implications. Some of that work is undertaken pursuant to Department of Defense contracts. Universities generally recognize that such arrangements may compromise their commitment to academic freedom, and they vary in their policies respecting the wisdom and acceptability of such arrangements. The American Association of University Professors (AAUP) has thought it inappropriate to condemn faculties and universities for making such arrangements per se, but it has regularly expressed concern that inconsistency with respect to academic freedom is a genuine danger that all academic institutions should weigh carefully in the research and restrictions they accept.

The implication of the earlier report (*1*) was to favor a limited classification system, to the extent that it might minimize uncertainty and provide a less random threat to academic freedom. Ideally, a clear and circumspect classification system should state what research and publication must necessarily be treated in confidence according to needs of national security that are plain and compelling. It should enable universities and their faculties to make informed decisions about their research. Very different, and strongly objectionable, is a classification system that sweeps within it virtually anything that might conceivably be useful industrially, technically, or militarily to at least someone and that is administered by officials who feel compelled to classify as secret any information about which they have doubts.

Here we review briefly the recent changes introduced into the classification system by Executive Order 12356, issued by President Reagan on 2 April 1982. A recent report of the National Academy of Sciences Panel on Scientific Communication and National Security (*2*) concluded that a national policy of security through openness is much preferable to a policy of security by secrecy. We agree. We believe the enlargement of the classification system as stated in Executive Order 12356 is seriously mistaken. It poses an unwarranted threat to academic freedom and hence to scientific progress and the national security.

Summary of Recent Changes

Executive Order 12356 is the most recent presidential executive order prescribing a system for classifying and declassifying information on the basis of national security concerns. President Franklin Roosevelt issued the first such order in 1940. Succeeding executive orders were signed by Presidents Truman, Eisenhower, Nixon, and Carter. In their details, these earlier executive orders differed on such matters as what information was to be classified, for what period of time, and according to what standards. Their similarities, however, are more noteworthy than their differences. They sought to preserve the public's interest in the free circulation of knowledge by limiting classification authority, by defining precisely the purposes and limits of classification, and by providing procedures for declassification.

By contrast, Executive Order 12356 significantly broadens the authority of government agencies to classify information as secret. It removes a previous requirement for classification that damage to the national security be identifiable. It resolves doubts about the need to classify in favor of classification. It permits indefinite classification. It provides for reclassification of declassified and

This article is adapted from a report issued in October 1982 by the American Association of University Professors' Committee A on Academic Freedom and Tenure. The report was prepared by Committee A's Subcommittee on Federal Restrictions on Research. The members of the subcommittee are R. A. Rosenbaum, professor of mathematics, Wesleyan University, Middletown, Connecticut 06457, *Chair*; M. J. Tenzer, professor of political science, University of Connecticut, Storrs 06268; S. H. Unger, professor of computer science, Columbia University, New York 10027; W. Van Alstyne, professor of law, Duke University, Durham, North Carolina 27706; and J. Knight, associate secretary, American Association of University Professors, Washington, D.C. 20036.

ublicly released information. It expands the categories of information subject to classification to include nonclassified research developed by scientific investigators outside the government.

Main Provisions

The preamble to Executive Order 12356 states that the "interests of the United States and its citizens require that certain information concerning the national defense and foreign relations be protected against unauthorized disclosure." To prevent "unauthorized disclosure," the order establishes three levels of classification: top secret, secret, and confidential. The standards for top secret and secret are the same as in previous executive orders. However, Executive Order 12356 omits the earlier qualifying word "identifiable" in describing the damage to the national security that can justify classification at the lowest, or confidential, level. The text reads: "confidential shall be applied to information, the unauthorized disclosure of which reasonably could be expected to cause damage to the national security." At a congressional hearing, a Deputy Assistant Attorney General explained the deletion of the requirement of identifiability as follows:

> Every new qualifier or adjective, such as "identifiable," added to the requirement of showing "damage" or any other requisite element of proper classification, raises new uncertainties or areas of ambiguity that may lead to litigation. . . . [T]he requirement of "identifiable" damage may be construed to suggest that disclosure must cause some specific or precise damage, a requirement that the government might not reasonably be able to meet in some cases. . . . Provisions of such orders should be simple, general, less complex and require no more precision than the subject matter reasonably allows. The requirement of "identifiable" damage fails on all these counts.

In the event that a government official is uncertain about the security risk of some information, the doubt will be resolved in favor of classification pending a final determination within 30 days. In addition, if there is doubt about the level of classification, the information will be classified at a higher level, also pending a final decision within 30 days. Once the information is classified, it can remain so at the discretion of government officials "as long as required by national security considerations." There is no provision in Executive Order 12356 for justifying the need for classification beyond a stated period of time. (President Nixon's executive order called for automatic declassification after 30 years, unless it was determined that continued classification was still necessary and a time for eventual declassification was set; President Carter's executive order established a 6-year declassification period.) The latest order makes no comment on whether declassifying information is generally desirable.

If information is declassified, it may be reclassified under Executive Order 12356 following the requirements for classification. Information that has been properly declassified and is in the public domain apparently may remain "under the control" of the government (the order defines information as "any information or materials . . . that is owned by, produced by or for, or is under the control of the United States Government") and thus can be reclaimed by the government.

The executive order provides for limitations on classification. It states that "basic scientific research information not clearly related to the national security may not be classified." Early drafts of the order had not included this provision; it first appeared in the executive order issued by President Carter. It was retained mainly as a result of protests from the scientific community. However, it is not clear what this provision actually safeguards.

Sanctions for violations of the executive order may be imposed on the government's "contractors, licensees, and grantees."

Comments

National security obviously requires some classification of information as secret. It is also obvious that freedom to engage in academic research and to publish the results is essential to advance knowledge and to sustain our democratic society.

The possibility for friction between classification and academic freedom is always there. The friction can be reduced if classification is invoked before research has begun and is cautiously applied for a limited period of time and only to matters of direct military significance. Classification defeats its own purpose, however, if it imperils the freedoms it is meant to protect. In our judgment, Executive Order 12356 does exactly that. It gives unprecedented authority to government officials to intrude at will in controlling academic research that depends on federal support. It allows classification to be imposed at whatever stage a research project has reached and to be maintained for as long as government officials deem prudent. Academic research not born classified may, under this order, die classified.

The provision in the executive order that "basic scientific research information not clearly related to the national security may not be classified" carries the suggestion that it may be classified if it is determined by the government to be "clearly related to the national security." This standard for classification is looser still than "could be expected to cause damage to the national security." We may be reading too much into this provision; we hope that it will be interpreted as an exemption and nothing more. Unfortunately, even with its most favorable gloss it is a weak safeguard for scientific inquiry. The government official who cannot fix a clear relationship between scientific research and national security but nonetheless has doubts could still classify government funded or contracted research consistent with other provisions in the executive order.

In the pursuit of knowledge, academic researchers should not have to look backward either in hope of favor or in fear of disfavor. In an era of reduced federal support for research except in the area of national security, and with investments in research programs and facilities significantly reliant on previously allocated federal funds, academic researchers are under great pressure to submit to classification no matter how restrictive or apparently arbitrary the demand. The adverse effects on academic freedom and thus on the advancement of knowledge and on the national security can be grave.

The executive order can inhibit academic researchers from making long-term intellectual investments in research projects that are potentially classifiable. It can serve to foster unnecessary duplication of research efforts. It is likely to inhibit the sharing of research methods and results with professional colleagues, because something that a government official can call harmful to the national security might unwittingly be revealed. Classification, or the worry that it might be imposed, could result in the isolation of academic researchers, cut off from the free exchange of ideas and exposure to constructive criticism. Those concerned in government with the uses of new knowledge are not likely to obtain the benefit of the widest possible evaluation of their plans and projects. All of these consequences of the executive order are likely to be felt outside as well as within

Linkage between Basic Research Literature and Patents

Mark P. Carpenter, Martin Cooper and Francis Narin

The study reported here uses data on U.S. patent citations as evidence that technological developments are dependent upon basic scientific research.

Federal support of basic research is usually justified in terms of the value of increased knowledge to the nation's technological progress, economic growth, and to improved public health and safety. One of the many problems faced by science policy analysts is to determine — to document and measure — the benefits derived from such basic scientific resarch.

Past studies of research output have tended to use one of two approaches:

(1) Literature publication and citation studies (*1*) which count the number of scientific publications in a given area and trace the acknowledged utilization of these articles by other researchers.

(2) Anecdotal tracer studies which seek to determine how individual researchers or ideas contributed to significant innovations.

The first technique is subject to the criticism that literature citations are internal to science, and fail to demonstrate benefits external to the research community. The second has been criticized as not wholly representative. Recent economic studies aimed at determining the public and private rates of return from R&D investment have tended to concentrate on the more applied research or development activities, which are easier to delineate than are the more indirect benefits of basic research.

M.P. Carpenter is a staff analyst and group leader in charge of advanced computational work at Computer Horizons. Since 1972 he has played a lead role in the development of international publication and citation measures. M.J. Cooper is current manager, research planning at Occidental Research, the corporate research laboratory for Occidental Petroleum Corporation. At the time this study was performed Dr. Cooper was the director, Division of Strategic Planning and Analysis at the National Science Foundation and the NSF Project Officer on the study. F. Narin, president and founder of Computer Horizons, Inc., has been active in the field of research and technology analysis for more than a decade and has authored more than 50 research publications.

As one means of exploring the utilization of basic research in technological innovation, we selected U.S. Patent citations of the scientific and technical literature. In this study we sought to determine if U.S. patent applicants and examiners do utilize and cite available research results. The U.S. Patent files were selected as an appropriate vehicle since the patent process meets several minimal criteria. The files are external to science, demonstrate active utilization, and can be searched without a-priori selection of scientific topical areas. The files provide a documentable source of information with the applicant and examiner citations providing parallel and complementary views of the pertinent literature.

Thus, the study reported here provides a direct technique for linking the patent literature, a body of knowledge of technological and commercial interest and external to basic science itself, with the standard measure of scientific research — the scientific article. We structured the study to investigate four aspects of the patent to literature linkage.

(1) The extent to which patent applicants and examiners utilize research finding, as evidenced by their citation of the technical literature.

(2) The nature of the cited research activity: are the citations referring to basic research or applied work, to a narrow or wide swath of scientific investigation, to old or recent papers?

(3) The acknowledged source of financial support for the research cited by the applicant and the examiner.

(4) The performers of the cited research.

Funding and manpower limitations required that we limit this pilot effort to only two areas: gas lasers and prostaglandins. Gas lasers were selected because of their growing application in many areas of technology and because we could handle the

Reprinted from RESEARCH MANAGEMENT, Vol. XXIII/No. 2 (March, 1980)

entire data file. Prostaglandins were selected because of their very significant medical potential.

Examination of Patents

Copies of all 319 Gas Laser patents and the most recent 399 prostaglandin patents were obtained from the U.S. Patent Office and the following relevant information extracted:

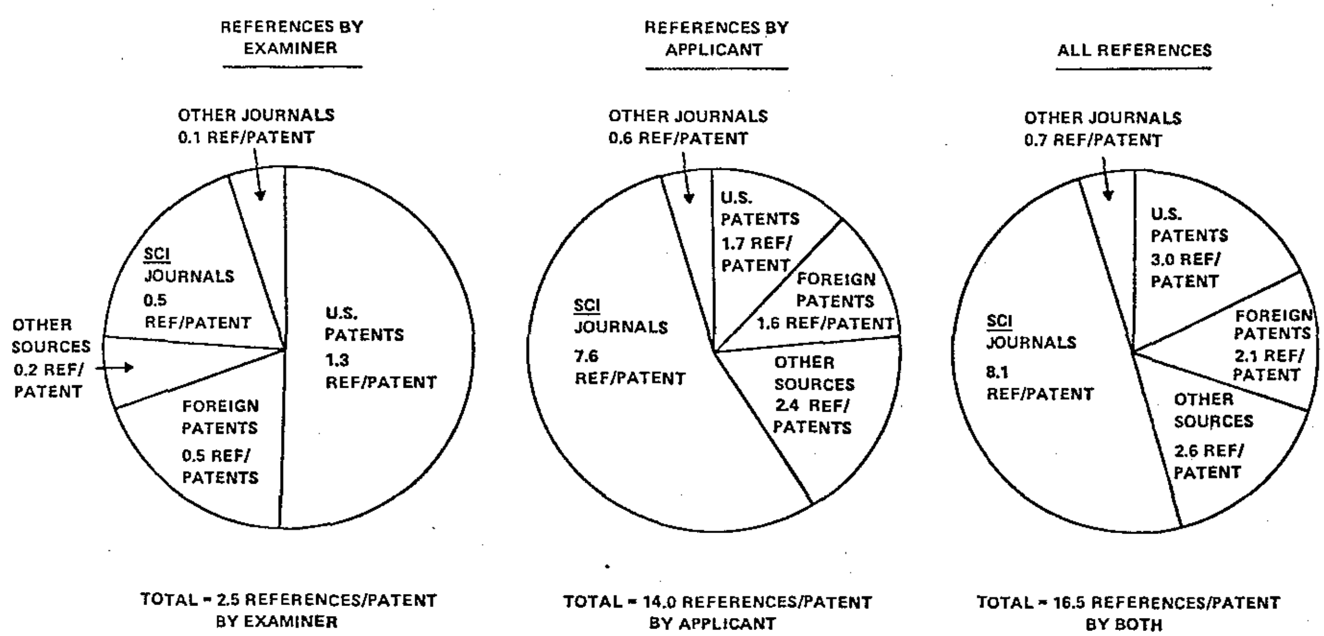
1. Patent Number
2. Date Patent Awarded
3. Inventor(s) and country or state of origin
4. Inventor(s) institutional affiliation
5. Date filed
6. Title
7. Number of citations to U.S. Patent literature by the examiner and by the applicant
8. Number of citations to foreign patents by the examiner and by the applicant
9. Number of other non-journal citations by the examiner and by the applicant
10. All journal citations by the examiner and by the applicant

Each citation to a specific scientific or technical journal article was individually recorded and a bibliographic data base constructed containing the cited author's name, journal name and article title, volume, page, date. Note was made as to whether the reference was made by the patent applicant or by the examiner.

From this initial review of the available data, we had already acquired a substantial quantity of information including number, type, and age of citations given by examiners and applicants in the two classes of patents. Table 1 summarizes the organizational sector assignment of the patents. For prostaglandins, domestic private companies account for 301, or 79%, of the patents. Some 17% of the patents went to various foreign groups, with the remaining 4% scattered among individuals, universities, and various non-profit groups. None were assigned to the federal government. Of the 301 patents assigned to private firms, 166 were assigned to one firm — the Upjohn Company of Kalamazoo, Michigan.

For gas lasers the pattern shown in Table 1 is quite different. Private firms still dominate with 59% of the 319 patents. However, one-fifth of the patents are assigned to the federal government. Foreign groups hold 14%, with the remaining 7% distributed among individuals, universities, and private non-profit organizations.

Figure 1 summarizes the distribution of references found in the individual prostaglandin patents, and shows quite clearly that there are substantial numbers of citations to the scientific journal literature from these patents. The 399 most recent prostaglandin patents contained 6593 references, 85% given by the patent applicant. On



Ninety-four percent of patents studied were filed in 1974, 1975 or 1976.

Figure 1/*Distribution of 6593 references contained in 399 prostaglandin patents.*

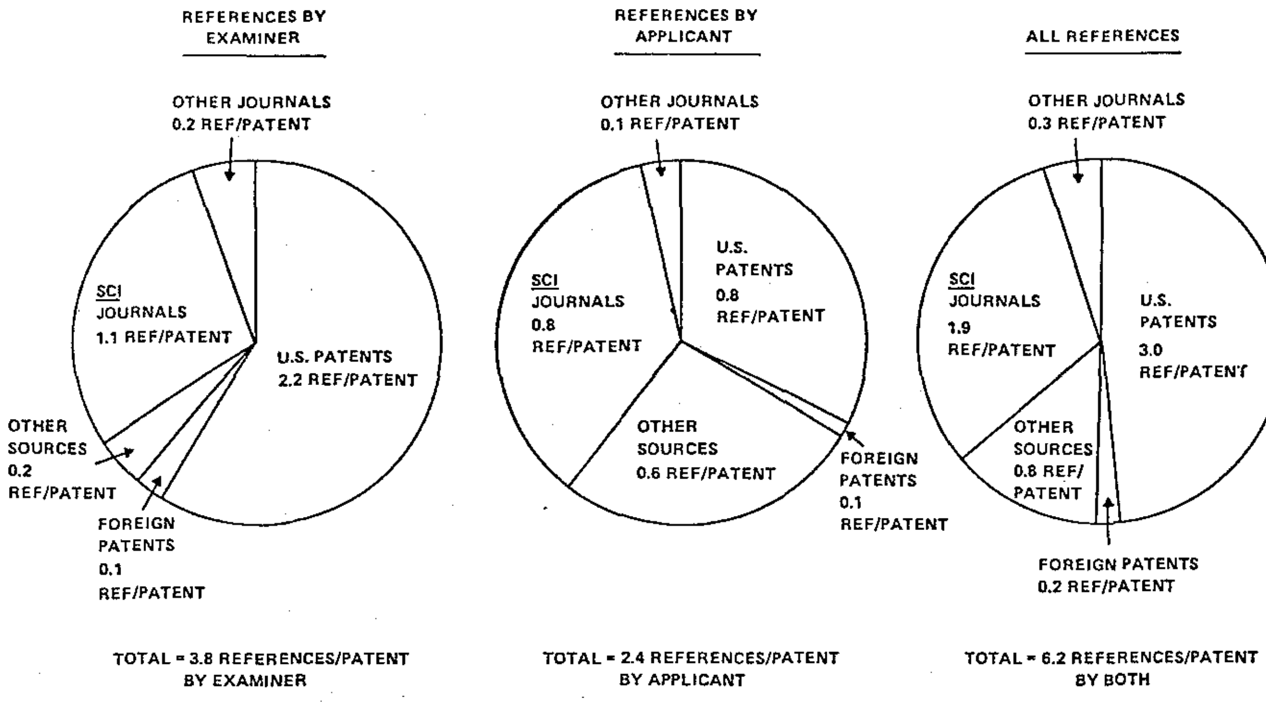


Figure 2/*Distribution of 1969 references contained in 319 gas laser patents**

average there were 16.5 references in each patent, 14 by the applicant, 2.5 by the examiner. Slightly more than half of the 2.5 examiner references per patent were to other U.S. patents. For both the applicant and the examiner the very great majority of the references to the scientific literature, 92% and 83% respectively, are to articles in journals covered by the *Science Citation Index* (*SCI* journals), which are often considered to be the central core of the world's journals (2). This high citation of papers in the *SCI* journals is remarkably close to the 80-90% of citations within the *SCI* journals which are to *SCI* journals. Apparently, patent applicants and examiners consider the *SCI* covered journals to contain most of the citable articles, just as the *SCI* covered authors do.

Table 1/*Sector of Patent Assignee*

Sector	% of Patents
Prostaglandins (399 Patents)	
Upjohn	42
Other Private Companies	37
Foreign Groups	17
Individuals	2
Private Non-Profit Groups	1
Universities	1
Gas Lasers (319 Patents)	
Sector	**$ of Patents**
Private Companies	59
Federal Government	20
Foreign Groups	14
Individuals	5
Universities	1
Private Non-Profit Groups	0.3
Unknown	0.3

Figure 2 presents analogous data for the 1969 references contained in 319 gas laser patents. These patents were filed between 1960 and 1977. The average gas laser patent contains 6.2 references, only a third as many as contained in a typical prostaglandin patent. Again, the examiner and applicant cite differently; however, the direction of the difference is opposite that of prostaglandins. The gas laser patent examiner cites U.S. patents more frequently than the applicant; he also cites the scientific journal literature more frequently than the applicant. However, as in the case of prostaglandins, the majority of examiner references are to other patents, while only a third of applicant references are to other patents.

The referencing here is more scattered. Overall, a third of the references are to journals, half are to U.S. patents, and most of the rest are to "other sources". Of the references to scientific journals, as with prostaglandins, the great majority (85%) are to journals covered by the *Scientific Citation Index*.

Another question raised at the outset of the study was whether the scientific papers cited by patents would be the older, classic papers that

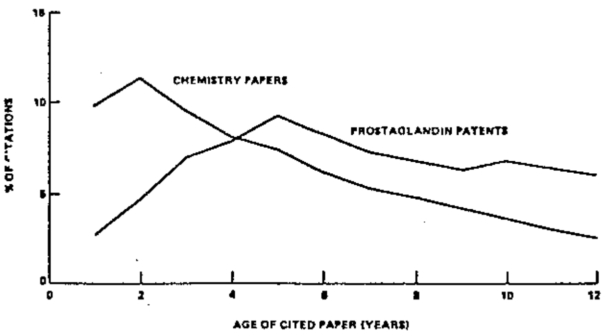


Figure 3/*Age of cited papers: prostaglandins*

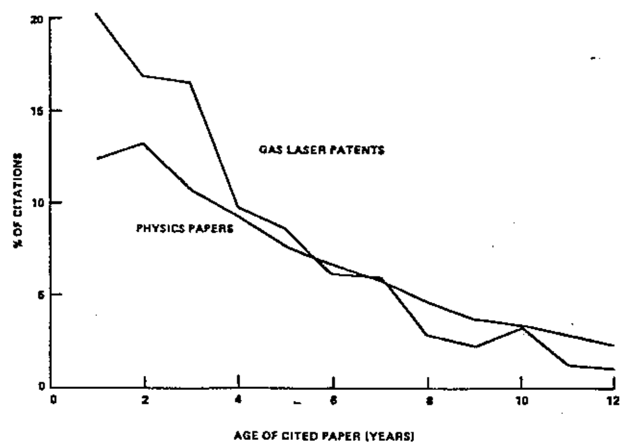


Figure 4/*Age of cited papers: gas lasers*

underlie current scientific work, or whether the patents could show a strong dependence upon current literature. Citations to current literature would be an indicator of close ties between current technology and current science. For patents the age of the cited papers was calculated relative to the date the patent was filed, since the time between filing and approval varies widely. The filing year was counted at year zero. Thus, a reference to a 1960 journal article by a patent filed in 1970 would have an age of ten years.

The ages of the papers cited by the two classes of patents are illustrated by Figures 3 and 4. In both cases the difference between the ages of papers cited by the patents and the age of the papers cited by the scientific literature is not large: patents cite recent scientific articles. Prostaglandin patents are citing literature that is only two to three years older than the literature cited by chemistry papers, while gas lasers patents are apparently citing the scientific literature with even more rapidity than typical papers appearing in physics journals. The median age of a paper cited by gas laser patents is only three years, whereas the median age of papers cited by a typical physics article is five years. However, the fact that gas lasers represent a recent scientific breakthrough may strongly affect the rapidity of citation. Journal citations in this specific area of physics may be as rapid as the patent citations.

Highly Cited Papers

Individual inspection of the patent files, together with library retrieval of each cited paper, permitted a more detailed analysis of the citation patterns to the scientific literature. A special interest was multiple citation (i.e., papers which have been cited by many different patents). We found multiple citing to be very significant. This is especially true for the prostaglandin patents where a large number of journal items were cited many times. The total of 3600 or so citations went to only 860 articles, for an average of more than four citations per cited article. One article "The Sterochemistry of the Phosphonate Modification of the Wittig Reaction" by D.H. Wadsworth published in the *Journal of Organic Chemistry* was cited by 113 different patents. The predominance of multiple citation was less evident among the gas laser articles due, we suspect, to the very large (18 year) time spread of the gas laser patents.

Eighteen papers were cited by more than 25 different prostaglandin patents. These papers, constituting 2% of all the cited papers, received a total of almost 25% of all the citations. These highly cited papers appear to be of two kinds; half are rather basic chemistry research papers, while the rest are papers that seem to be more directly related to prostaglandins. The authors of these papers are affiliated with a mixture of universities, private companies, and specialized laboratories, especially the Karolinska Institute. NIH supported three of the 18 papers.

Since the gas laser patents are distributed over more than a decade in time, it is much less likely that different patents would be citing the same papers. The cited papers seem to be a mix of applied physics papers on lasers and masers, plus a few papers which appear to have a somewhat more basic orientation. Bell Labs is very prominent as the source of a number of these papers; the DOD seems to support a fair number. In all, the papers highly cited by both classes of patents are quite scientific.

Subject and Level Classification of Cited Journal

A straightforward classification of cited journals generalizes the observation made with the highly cited papers; that is, the patents are heavily citing relatively basic research in appropriate subject areas.

As part of previous literature studies, Computer Horizons, Inc. (CHI) has devised a system for the subject classification of the 2400 journals covered by the *Science Citation Index*. Most of the journals are classified into one of 106 subfields which, in turn, are aggregatred into nine fields. A complete list of this classification is contained in CHI's monograph (*1*).

A parallel product of the journal classification system is its assessment of the applied to basic research orientation of scientific journals. The research level classification of a journal provides an indication of the research orientation of the average paper in the journal. There are four levels ranging from the most applied (Level 1) to the most basic (Level 4). Examples of the research levels follow:

Level	Description	Example
Level 1	Applied Technology (Clinical Observation in Biomedicine)	J Iron & Steel Inst J Am Med Assn
Level 2	Engineering-Technological Science (Clinical Mix in Biomedicine)	J Nuc Sci & Tech Proc IEEE New Eng J Med
Level 3	Applied Research (Clinical Investigation in Biomedicine)	J Appl Phys Cancer Res J Clin Invest
Level 4	Basic Scientific Research	Phys Rev J Am Ch Soc J Biol Chem

Each of the 2400 *SCI* covered journals is assigned to one of these four levels.

Table 2 summarizes the subject and level distributions of the papers in *SCI* covered journals which were cited by the patents. The prostaglandin patents cited very heavily into organic chemistry and biochemistry research. Sixty percent of the references were to articles in chemistry journals; the great majority of these were either to organic chemistry journals, or to organic chemistry papers in general chemistry journals. Some 20% of the references were to biochemistry papers within the biomedical research literature, and 16% to clinical medicine.

This pattern of referencing to basic scientific areas is substantiated by the level classification — 80% of the citations are to papers in Level 4, basic research journals while 13% are to Level 3, applied research journals. Only 7% of the papers cited by the prostaglandin patents are to the more applied Level 1 and 2 journals.

For gas lasers the pattern is very similar, although the cited journals are not quite as basic as for prostaglandins. Some 82% of the citations are to papers in physics journals, with more than half of these to applied physical journals, and the rest to general and other physics journals. Eleven percent of the references are to engineering journals with a few scattered to chemistry and other fields. By level, a third of the references from the gas laser patents are to Level 4, basic research journals, while more than half are to Level 3, applied research journals. Only 11% are to the engineering science and technology journals at Levels 1 and 2.

Table 2/*Patent References to Journals by Level and Field of Cited Papers (*SCI *covered journals only)*

Prostaglandins:		
By Subject:	60%	to Chemistry General Chemistry—38% (mostly Organic) Organic Chemistry—19% Rest of Chemistry—3%
	21%	to Biomedical Research (almost all Biochemistry)
	16%	to Clinical Medicine
	3%	to all the rest
By Level:	80%	to Level 4
	13%	to Level 3
	7%	to Levels 1 and 2
Gas Lasers:		
By Subject:	82%	to Physics Applied Physics—49% General Physics—14% Rest of Physics—19%
	11%	to Engineering
	3%	to Chemistry
	4%	to all the rest
By Level:	33%	to Level 4
	56%	to Level 3
	11%	to Levels 1 and 2

Table 3/*Acknowledged Support in Cited Papers*

Prostaglandins (1778 Cited Papers)	
NIH	25.3%
NSF	3.1
Other Government	1.6
Foreign	10.1
University	4.8
Private-for-Profit	3.2
Private-non-Profit	1.0
None	50.8
Gas Lasers (676 Cited Papers)	
DOD	18.1%
AEC	2.4
NSF	1.4
NASA	1.3
Other Government	0.9
Foreign	4.8
University	0.3
Private-for-Profit	0.6
Private-non-Profit	1.0
Unknown	1.5
None	67.6

Support Sources and Organizations

The research support acknowledgements contained in most research papers provide a fruitful source of information on the financial underpinnings of scientific research (*3*). Table 3 summarizes the support acknowledged in the cited papers. Early references were omitted because acknowledgement customs have changed in the last two decades, with earlier papers less careful about support acknowledgement.

It should be noted that almost half the citations by the prostaglandin patents and almost two-thirds of the citations by the gas laser patents go to papers which do not acknowledge any source of outside support. This is in large part due to the fact that many papers were authored by scientists situated at private companies, who did not have a source of support external to their organization.

The largest source of outside support for papers cited by prostaglandin patents was NIH, supporting almost a quarter of the papers. NSF supports about 3% of the papers cited by the prostaglandin patents. This ratio of eight to one for support by NIH/NSF is quite similar to the overall ratio of NIH/NSF support in the Level 3 and 4 biomedical literatures, which is approximately 7.5:1 (*3*). Thus, given their relative roles within this literature, NIH and NSF supported papers are being cited with roughly the same frequencies by the prostaglandin patents.

For gas lasers the agency providing the largest sources of outside support is DOD, which supported 18% of the papers, reflecting the very extensive Defense Department support of this work during the 1950s and 1960s. Collectively, other government agencies supported about 6% of the papers.

Conclusions

The data in the study clearly demonstrates extensive utilization of basic scientific literature by patent applicants and examiners. Close to 90% of all journal references in both categories are to basic or applied scientific journals, as opposed to engineering and technological literature.

The study also showed that many of the cited references were to scientific articles not directly related to the immediate research field. Roughly 80% of the references in the prostaglandin patents were to papers in organic chemistry or biochemistry journals, with many of these references to papers that were not specifically related to prostaglandin research.

It was also found that the time between publication of a journal article and the patent application citing that article was relatively short — generally, three to five years, which is quite similar to the amount of time that elapses between the publication of a scientific article and its citation by other scientific articles.

In addition, the scientific articles cited by patent applicants and examiners are quite clearly within the central core of the scientific literature covered by the *Science Citation Index*, which is cited in a similar manner by scientific articles.

Thus, in many ways, the swath of the literature cited and the nature of the citing by patent applicants and examiners is quite similar to the swath and nature of the articles cited by scientists themselves publishing in the open journal literature. This clearly indicates that the process of reduction to practice in the industrial community continues to require recent science, and the support of such science is a necessary prerequisite for the continuing emergence of new technology.

References and Notes

1. A comprehensive review of the use of publication and citation counting techniques in science studies is contained in Computer Horizons, Inc. monograph "Evaluative Bibliometrics: The Use of Publication and Citation Analysis in the Evaluation of Scientific Activity". NTIS Accession No. PB252339/AS.
2. *Science Citation Index, SCI*, copyright Institute for Scientific Information, Philadelphia, PA.
3. The use of research support acknowledgements in defining agency activity is covered in F. Narin, R. Shaprio, "The Extramural Role of the NIH as a Research Support Agency", *Federation Proceedings*, Vol. 36, No. 11, 2470-2475, October, 1977.

4. This paper is based on work performed for the National Science Foundation, Division of Strategic Planning and Analysis, under Contract NSF PRM-7801694. Martin J. Cooper was Director of that division during the initiation and conduct of the research. The findings and opinions expressed are those of the authors and do not necessarily represent the views of the NSF.

World Patent Information, Vol. 3, No. 4, pp. 160-163, 1981.
Printed in Great Britain.

0172-2190/81/04 0160-04 $02.00/0
Pergamon International Information Corp.

Citation Rates to Technologically Important Patents

Mark P. Carpenter, Francis Narin and Patricia Woolf, CHI Research, Computer Horizons, Inc., Cherry Hill, New Jersey, U.S.A.

Summary

The purpose of this study was to determine whether the average number of citations received by issued U.S. patents from subsequently issued U.S. patents is higher for patents associated with important technological advances than for a group of randomly selected patents. Analysis of examiners' citations to 100 selected patents showed that these selected patents, which underlay technically important products, were more than twice as frequently cited (significance level of 0.0001) as a randomly selected set of 102 control patents. This finding provides strong evidence for the hypothesis that patent citation data can be used in technological indicators development, and in technological policy analysis, since it implies that the location and analysis of groups of highly cited patents can provide a valid indicator of patent areas of technical importance.

Introduction

The problems of defining progress along the many stages from basic research to commercial production, and the difficulty of linking events along this continuum of R & D activity, are well known within the policy analysis community. The intrinsic difficulty of understanding this complex process has been compounded by the rapid growth of science and technology into positions of critical importance in the economies of all western countries.

In recent years, at the scientific end of the technical spectrum, bibliometric (publication and citation based) analyses of the professional journal literature have been useful in formulating and evaluating science policy alternatives, and in evaluation of the research productivity of individuals and institutions.

Although these scientometric methods are relatively new, they are being used increasingly because scientists and planners realize how difficult it is to assess the importance of a scientific program. In the past scientists have relied primarily on the judgement of other scientists to evaluate the quality of research. These individual judgements, though professionally informed, are necessarily somewhat subjective and of decreasing reliability as the area being judged becomes larger[1]. As a result there is a growing acceptance of studies based on publication rates and on the analysis of citations as supplements and in some cases as substitutes for professional opinion. The most widely accepted and visible aspect of this transformation is the highly visible, highly cited and well accepted series of *Science Indicators* reports issued by the National Science Board of the U.S. National Science Foundation[2].

Naturally, because science is a conservative as well as a progressive enterprise, there have been critics of these new, quantitative methods of evaluation. In response to some of their objections, other scientists, such as bibliometricians and sociologists of science, have compared quantified citation-based appraisals with other, independent measures of quality, such as peer ratings, achievement of professional rank and status and awards of scientific prizes.

In these studies, it is generally found that peer evaluations of publications, universities, departments, research institutes, and individual scientists correlate well with bibliometric measures, including correlations with quantity of publication, citation counts and other influence measures based on aggregated citation statistics. The recent papers by Jones[3], and the monograph by Narin[4] provide extensive reviews of this literature.

Although much analysis has been done of the scientific literature, relatively little has been published on the patent literature and its policy implications. Yet the patent literature is an important potential resource for measuring and comparing technological capabilities at national, regional, institutional and individual levels. Indicators of technological capacity in various specialty or patent classification areas is not only valuable itself, but it can also be assessed and compared with achievements in basic scientific research or in industrial R & D.

The opinions expressed herein are those of the authors and not necessarily those of the National Science Foundation.

In the *Science Indicator* series[2] patents have been aggregated by country, product class, ownership, etc., and used as indicators of inventive activity. The Office of Technology Assessment and Forecast (OTAF) of the U.S. Patent Office[5] has issued a series of nine reports including much data on patent activity in specific technologies and general classes, and for individual countries. Some of the applications of patent counts were also discussed at the two recent OECD Science and Technology Indicators Meetings[6] and by Kronz in a recent issue of this journal[7].

Despite this start, the patent literature has not been studied from a policy viewpoint nearly as thoroughly as the professional journal literature of science. It has not been examined in the depth or detail which characterizes modern scientometric analyses. Patent counting is perhaps the least subjective and most replicable technique; but because of the great differences in quality and utility among patents, simple patent counting may not be an adequate measure of technological advance or industrial innovation.

The work reported herein is a first step in the eventual application of bibliometric techniques to the analysis of technological activity, through the analysis of issued patents and the patent-to-patent citation network in which they are embedded. By studying examiners' citations to important patents, and comparing their rates of citation to important patents with their citation rates to a control set of patents, this study shows that examiners' citation patterns can be used as an indicator of patents which represent technical achievement.

Data Acquisition

A set of 100 important patents and a set of 102 control patents were selected*. The set of important patents was obtained by attempting to determine the key patent underlying a product which received the IR100 award established by the journal *Industrial Research and Development*. This award

> "honors the 100 most significant new technical products – and the innovators responsible for them – developed during the year. From thousands of entries, the distinguished Editorial Advisory Board of *Industrial Research* selects the 100 products that are most important, unique, and useful. Extensive local and national press and television coverage of the winning entries and awards presentations has made the IR100 award the most coveted achievement in the applied research and development field."[8]

Patents related to the 1969 and 1970 awards were used in order to ensure that there was sufficient time for the patents to be cited to their full potential. The names of the developers of the prize winning products were located in the *Index of Patents* of the U.S. Patent Office. For each product we chose a set of several candidate patents which were important for the product and then selected a single patent which was most closely associated with the innovation of the product. This choice was based on the title of the patent and (in some cases) on brief descriptions of the patents in the *Official Gazette* of the U.S. Patent Office. Thus we obtained a set of 100 patents issued in the years 1968 to 1974 (hereinafter called product patents) underlying 100 products of certified industrial or commercial importance.

The set of patents to serve as controls was chosen so that the number of control patents issued in each year was the same as the number of product patents. We equalized the time distributions since subsequent citation by patent examiners was to be determined, and common sense would argue that the older a patent is the more citations it would be likely to receive. Also, in the scientific literature we have found that the number of citations depends on the amount of time available for the articles to be cited. Within each cited year the control patents were chosen at random.

The subsequent citation by examiners of the patents in each set was determined using information obtained from Search Check, Inc., a private corporation located in Alexandria, VA. Search Check provided lists of the patents from which examiners cited each of the patents in our product set and our control set. Thus, for each patent in the study we counted the total number of citations it received from examiners subsequent to its issue.

Analysis

The statistical technique used to compare the product and control patent sets was two-way analysis of variance. The two factors of interest were patent set (product vs. control) and year of issue (1968,..., 1974). Our familiarity with the skewed nature of citation distributions caused us to use a transformed variable in the analysis: log [number of citations + 1/2]*. Table 1 shows the result of this analysis.

There is no indication of significant interaction or issue year effects. The patent set effect is significant, indicat-

Table 1. Results of analysis of variance

Dependent Variable: Log [number of citation + 1/2] Source	DF	Sum of Squares†	F	Prob > F
Issue Year	6	6.24	1.15	0.33
Patent Set	1	31.38	34.82	0.0001
Issue Year by Patent Set	6	7.95	1.47	0.19
Residual	188	169.4		

* A chi-square analysis of the residuals from ANOVA showed that they were not significantly different from normal ($P > 0.2$).

†The sums of squares are sequential. That is, each line of the ANOVA is the sum of squares with the preceding effects included in the model.

* Although 100 controls were to be selected by project design, a data entry error resulted in two additional controls being selected.

Table 2. Statistical summary of citation counts by issue year and patent set

Issue Year	Patent Set Product	Control	Total
	7	7	14
1968	1.671	0.661	1.166
	6.286	1.714	4.000
	21	21	42
1969	1.114	0.495	0.805
	3.905	1.905	2.905
	11	12	23
1970	1.725	0.928	1.309
	6.818	3.500	5.087
	26	26	52
1971	0.972	0.631	0.802
	3.962	2.077	3.019
	26	27	53
1972	1.601	0.235	0.905
	6.077	1.444	3.717
	8	8	16
1973	0.978	0.474	0.726
	3.375	2.500	2.938
	1	1	2
1974	1.705	0.405	1.055
	5.000	1.000	3.000
	100	102	202
Total	1.305	0.521	0.909
	4.940	2.039	3.475

Values in the table are:
Number of patents
Average log [number of citations + 1/2]
Average number of citations per patent.

ing that the product and control patents are different with respect to the number of citations received. In order to further investigate the data, we use Table 2 which summarizes the citation counts by issue year and patent set. For every year in the table and for all years combined, the product set mean number of citations is significantly higher than the control set mean (Scheffe's method[9], $\alpha = 0.05$). In fact, the product set patents receive an average of $2\frac{1}{2}$ times more citations than the control set patents. The complete citation distributions (all years combined) for the two patent sets are given in Table 3. If seven citations are set as the level for high citation, then 28% of the product set patents reach that level, versus only 5% of the control set patents. In addition, product patents are less likely to be uncited, with 11% receiving no citations versus 31% of the controls, and 72% of the randomly selected controls receiving two or fewer citations as compared to only 35% of the product set patents.

Table 3. Citation distribution for product set and control set patents

N = Number of Citations	Number of Patents Receiving N Citations: Product set Patents	Control Set Patents
0	11	31
1	12	23
2	12	17
3	15	12
4	12	6
5	3	5
6	7	3
7	5	1
8	4	
9	2	
10	4	3
11		1
12	4	
13	4	
14	1	
15	1	
16		
17	1	
18	1	
19	1	
Total Patents	100	102
Total Cites	494	208
Cites/Patent	4.94	2.04

Table 4. Average citations received per patent, by IR100 product class for patents in the product set

Product Class	Mean	S.D.	N
Analytical Instruments	3.3	3.2	18
Ceramics and Other Non-metals	5.7	6.7	3
Chemicals and Plastics	6.1	4.4	11
Computers and EDP	11.2	5.1	6
Electronic Instruments	3.6	3.1	7
Electronic and Mechanical Components	3.9	2.3	7
Lasers and Masers	6.3	5.2	8
Measuring and Testing Equipment	3.0	3.1	8
Metals and Alloys	5.0	4.8	5
Oceanographic Equipment	2.7	2.9	6
Photographic and Optical Equipment	7.0	7.7	4
Vacuum/Cryogenic Equipment	2.3	2.4	7
Other Products	7.2	4.6	10
Total	4.94	4.5	100

Table 4 breaks the citation data down by product class for the set of product patents. Though the data are sparse, with small numbers of patents in each class, there are differences. Although there are only six patents, the 'Computers and EDP' product class stands out with an average of 11.2 citations to each patent. Some of the other classes with 2–3 citations to each patent appear to be below the norm for the set as a whole.

Comments on the Methodology

Because this study was designed to be an inexpensive pilot project to determine whether an extensive investigation of examiners' citations was warranted, there were several methodological problems which could not be overcome because of limits on time and money. However, there are common sense arguments that many of the difficulties – which will be discussed later – tended to work against a positive result for the study. Hence the strong positive results are even more outstanding.

One problem is that the IR100 awards concentrate on industrial or research use rather than consumer products. These product patents then are concentrated in the Electrical classification with Mechanical and Chemical categories less well represented than in the control set of patents. There is evidence from another study[10] that the average number of examiner citations is lower in Electrical and higher in the Mechanical concentrated in what appears to be a low citation class. Since the control set patents were not matched on the basis of classification, their lower citation rates are even more meaningful.

The second problem is that the choice of an important underlying patent for each product was problematic. It is possible that in some cases we were unable to find the most important one for the innovative product. But since care was taken to ensure the relevance of the patent for the product, this is probably not critical: had a *more* important patent been chosen the results would most likely have been more, not less positive.

Finally, the choice of the IR100 award products is problematic as is any subjective choice of excellence. *Industrial Research and Development* does not describe in detail the processes by which the award products are chosen. No list of 100 products could be universally accepted as *the* 100 most important commercially or technologically. On the other hand, the IR100 award products are certainly among the most important products. For purposes of this study, all that is crucial is that the products are relatively important. In that case the underlying patents would tend to be more important than a randomly chosen patent.

Conclusions

The results clearly show that relatively high citation by examiners of subsequent patents is associated with the patents of innovative and important products. These results suggest that quantitative methods such as citation analysis will be useful in identifying important patents. When refined and brought to the degree of sophistication which is currently being utilized to examine the scientific literature, these methods should extend the capacity for scientometric analysis from merely quantitative measures to measures of quality and commercial utility of patent holdings. The application of bibliometric techniques to the patent literature holds great promise for the development of indicators of scientific and technological capability for industries, institutions and nations.

Acknowledgements – The authors wish to express their gratitude to Ms Jennifer S. Bond and Dr Robert R. Wright of the Science Indicators Unit, National Science Foundation, for their guidance and assistance in formulating this work, supported by NSF Contract SRS-8012254.

References

(1) F. Narin, Objectivity vs. relevance in studies of scientific advance. *Scientometrics* 1, 35–41; 1978.

(2) *Science Indicators 1972, 1974, 1976, 1978.* Reports of the National Science Board, National Science Foundation, Washington, D.C.: Government Printing Office, 1973, 1975, 1977, 1979.
Science Indicators 1980. Report to the National Science Board, National Science Foundation, Washington, D.C.: Government Printing Office (forthcoming).

(3) L. V. Jones, The assessment of scholarship. *New Directions for Program Evaluation* 6, 1–20; 1980.

(4) F. Narin, Evaluate bibliometrics: the use of publication and citation analysis in the evaluation of scientific activity. Contract NSF C-627, National Science Foundation. March 31, 1976. Monograph: 456 pp. NTIS Accession No. PB252339/AS.

(5) Series of nine reports issued by the Office of Technology Assessment and Forecast (OTAF), U.S. Department of Commerce, Patent and Trademark Office: 1. *Initial Publication,* May, 1973; 2. *Early Warning Report,* December, 1973; 3. *Third Report,* June, 1974; 4. *Fourth Report: A Review of Patent Ownership,* June 1974; 5. *Fifth Report,* August, 1975; 6. *Sixth Report,* June, 1976; 7. *Seventh Report,* March, 1977; 8. *Eighth Report,* December, 1977. 9. *Ninth Report,* March, 1979. Reports 1–6 are available from the National Technical Information Service (NTIS), Springfield, VA 22161. Reports 7–9 are available from the U.S. Government Printing Office, Washington, D.C. 20402.

(6) Papers presented at the *Second Workshop on the Measurement of the Output of R & D Activities,* OECD, Paris, France. December 6, 1979.
Papers presented at the *Science and Technology Conference,* OECD, Paris, France. September 15–19, 1980.

(7) H. Kronz and H. Grevink, Patent statistics as indicators of technological and commercial trends in the member states of the European Communities (EEC). *World Patent Information* 2, 1, 1980.

(8) *Industrial Research and Development* 13, p. 3, December, 1980.

(9) H. Scheffe, *The Analysis of Variance,* John Wiley, New York, 1959.

(10) C. V. Clark, Obsolescence of the patent literature, *Journal of Documentation,* 32, 32–52; March, 1976.