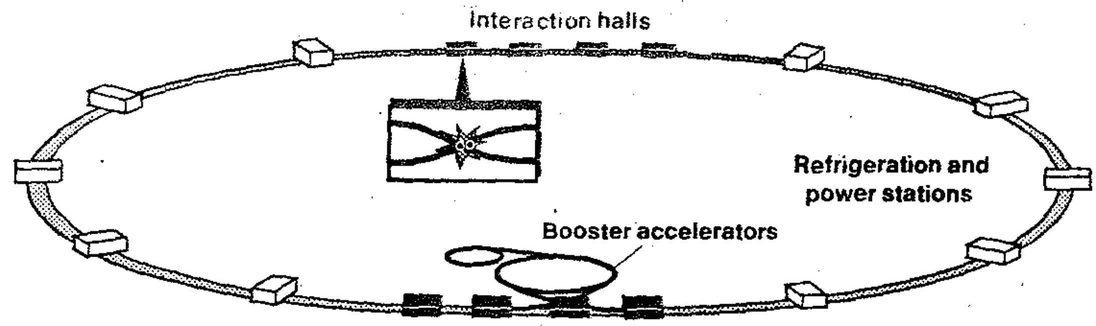
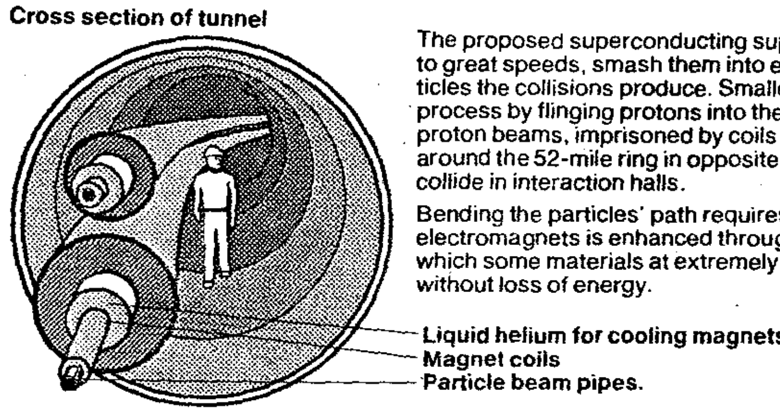


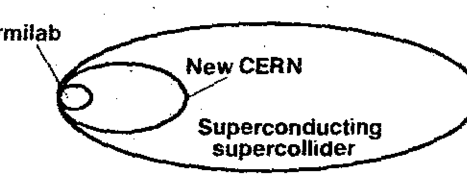
Cross section of tunnel



The proposed superconducting supercollider would accelerate protons to great speeds, smash them into each other and observe the new particles the collisions produce. Smaller booster accelerators begin the process by flinging protons into the accelerator's giant ring, where two proton beams, imprisoned by coils of superconducting magnets, speed around the 52-mile ring in opposite directions. The beams cross and collide in interaction halls.

Bending the particles' path requires powerful magnets. The power of electromagnets is enhanced through superconductivity — a state in which some materials at extremely low temperatures carry electricity without loss of energy.

Moving the particle beams at desired speeds requires accelerators of great size. The largest accelerators now in operation, both about four miles in circumference, are at Fermilab, in Batavia, Ill., and at the European Laboratory for Particle Physics (CERN), near Geneva. CERN is constructing a new accelerator that will be 16 miles in circumference.



The New York Times/Jan. 31, 1987

By BEN A. FRANKLIN

Special to The New York Times

WASHINGTON, Jan. 30 — The Administration announced today that it would immediately ask Congress for funds to start planning and building a giant $6 billion atom smasher.

The device, a superconducting supercollider in a 52-mile oval tunnel, would dwarf existing machines used to probe the secrets of matter and energy.

The project to build the world's largest research machine, in which subatomic particles moving at high speed would collide and burst, is as scientifically significant as America's 1969 manned landing on the moon, Secretary of Energy John S. Herrington said.

The device would accelerate atomic particles to an energy level 20 times greater than possible in existing laboratories. Mr. Herrington said that on completion in 1996, the supercollider would "bring answers to unsolved questions that have fascinated the world since the earliest times, such as what are the fundamental building blocks of matter."

The need for the device has been debated for years. Some scientists say it is crucial if the United States is to stay on the frontiers of particle physics. By enabling scientists to experiment at higher energies and smaller scales than before, proponents say, the supercollider may provide new insights into the elementary forces and particles of the universe.

Opponents of the project contend that it is too costly and unlikely to produce commensurate results.

At least 20 states have sought to be the home of the supercollider, but Mr. Herrington said a site decision was still months away at least.

The announcement by Mr. Herrington at a news conference this afternoon followed a series of showdown meetings at the White House on Thursday. Mr. Herrington was reported to have persuaded President Reagan to sup-

Continued on Page 10, Column 3

NEWS SUMMARY, PAGE 2

New York Times
JAN. 31, 1987

On Giant Atom Smasher

Continued From Page 1

port the huge project over the objections of high Administration officials concerned about its impact on the budget and the opposition of some other Cabinet members who one Administration official descibed as feeling that "the country didn't need it."

But one Administration official said today that after "a lot of missionary work in recent months by Secretary Herrington, the decision was not close." The fact that the President did not mention the project in his State of the Union Message on Tuesday was described as "just a scheduling thing — it didn't get through the Cabinet and the Domestic Policy Council until yesterday."

Foreign governments, and perhaps the state in which the project is eventually located, will be asked to share in the costs and will share in the scientific and economic benefits, the Secretary said.

Construction of the above-ground research facilities and the vast oval underground tunnel would create 4,500 jobs, the Energy Department said. A staff of scientists and technicians would total at least 2,500, with 500 others to have visitor status.

How Collider Would Work

The accelerator will send two beams of protons speeding through the tunnel in opposite directions. At several junctures the beams will cross and collide, creating a flash of energy out of which subatomic particles will burst. The belief is that such collisions, taking place at energy levels higher than ever achieved before, will disclose the existence of a host of new particles and forces.

The speeding protons will be contained in their path by powerful electromagnets cooled by liquid helium to temperatures so low that their coils lose all resistence to electricity; that is, they will be superconductive.

Among the states vying for the project are California, Colorado, Illinois, New York and Texas. Alvin W. Trivelpiece, the department's director of energy research, said some states were offering $10 million to $15 million in inducements.

Mr. Herrington said the "fair and open" site-selection process would take months or years. Asserting firmly that "there is no front-runner" among the states, he promised to say more about site selection at another briefing on Feb. 10.

The project would be a costly venture into basic research yielding possibly major scientific insights into the creation of matter — of the universe and the world — but with few firmly predictable practical applications.

'No Military Applications'

Mr. Herrington stressed that there would be "no military applications," adding: "The nature of basic research is that you don't know, going into it, what you will find. But the American track record in this has been good."

At the Secretary's hurried presentation today, called suddenly after Senator Phil Gramm, Republican of Texas, said Thursday night that the President would approve the project, Mr. Herrington seemed to give as much emphasis to the psychological and national morale implications as to the scientific.

Reflecting the President's emphasis on American "competitiveness" in the State of the Union Message, Mr. Herrington said Mr. Reagan had made "a watershed" decision for the United States.

"This is a watershed for America's scientific and technological leadership and another clear sign that President Reagan is committed to keeping this nation on the cutting edge of world leadership and competitiveness," Mr. Herrington said, reading a statement.

Calling the decision "of tremendous scientific significance and historical consequence," the Secretary said: "It is a tremendous leap forward for America and for science and technology. Once again, this nation has said there are no dreams too large, no innovation unimaginable and no frontiers beyond our reach. By virtue of this decision we are embarking on an adventure of unlimited opportunity, tremendous promise and a new scientific world to be won."

Major Atom Smashers

The world's largest existing atom smashers, circular devices four miles in circumference, are at the Fermi National Laboratory in Batavia, Ill., and at CERN, the European Laboratory for Particle Physics in Geneva. Larger devices are on the horizon. Soviet physicists are building a 13-mile atom smasher, and in Western Europe, physicists are constructing a 16-mile accelerator.

Throughout the development of the supercollider plan, the project has had passionate supporters and bitter critics.

One advocate restrained his glee today. Dr. Stanley G. Wojcicki, of the Lawrence Berkeley Laboratory of the University of California, said no champagne corks were popping because the team's efforts, both technical and political, would have to be redoubled.

Project likened to manned landing on the moon.

"Everybody is obviously very, very pleased," he said. "But it's just the first step. The next is to convince the Congress and the American public that this is a scientific project that justifies the expenditure." "

Critics have contended that the project would sap Federal funds from less glamorous, but equally important, areas of scientific research. They also say there are no guarantees that the giant facility will yield more discoveries than current or planned facilities.

'Approaching a Budgetary Limit'

The supercollider "may be close to the end of the line of large science projects," said John E. Pike, associate director of the Federation of American Scientists, a private group in Washington.

"The assumption has always been that we're going to be able to understand everything," he added, but with this project "we're approaching a budgetary limit."

"These devices are becoming so expensive, and what they're trying to find is so obscure, that we may be at the point where scientists can no longer justify the cost," he said.

Dr. Arno Penzias, a Nobel laureate in physics at A.T.&T. Bell Laboratories, has criticized the supercollider as a threat to the rest of physics research in the United States, much of it based in small laboratories at universities.

"For scientists the question to be answered is, what contribution of resources should the rest of science be asked to make to permit high-energy physics to build and operate the superconducting supercollider?" he has written. "The supercollider's capital cost will clearly squeeze capital expenditures for the other sciences."

Asked by reporters to be more specific in describing the collider's scientific importance, Mr. Herrington said he would do that at his Feb. 10 briefing.

The Secretary said the $60 million required for an immediate start on design and site selection could come from funds appropriated for other projects. He predicted bipartisan support for it in Congress. Preliminary studies begun three years ago have cost about $20 million a year.

Inman Quitting Top Position at High-Tech Firm

By Michael Schrage
Washington Post Staff Writer

WASH POST 9/5

Retired admiral Bobby Ray Inman, a former National Security Agency director and CIA deputy director, is resigning as chief of Microelectronics and Computer Technology Corp., the Texas-based high-technology consortium formed in response to Japan's advanced computer successes.

Inman, 55, who recently served on a government commission examining the security of U.S. embassies, chose not to renew his contract and said he will leave after four years as head of the 21-company consortium exploring new computer designs and semiconductor technologies.

Inman announced his resignation at MCC's board meeting in Austin, Tex., Wednesday.

"It came as a surprise to all of us," said Samuel H. Fuller, Digital Equipment Corp.'s representative on the board. "My reaction is that he did an outstanding and unique job moving MCC from dream to reality."

Inman, recruited as MCC's first chief executive officer in 1983 after leaving the CIA, used his high Washington profile to lobby against antitrust rules that had prevented companies such as Advanced Micro Devices, RCA Corp. and Control Data Corp. from performing joint research.

Fuller and other MCC board members reported that Inman said he had no firm plans. Inman was unavailable for comment.

In a statement, he said he is concerned about the speed at which U.S. companies apply technology and that future activities are likely to "center around this very critical element in the U.S. ability to compete in the international marketplace."

Tiff/~~Joe~~/~~Dick~~
FYI
Nora

Question

You indicate in your statement that it is clear that the effort to do business on an international basis has been undercut but the failure of our managers to be as careful as they could have been in structuring international joint ventures. Is there some measurement of the size of that failure that you can give us? There are lots of problems internationally, and clearly respect of licensing arrangements is one of them, but I would like to see if we couldn't put a measure on it so that we know that by spending time on that, we are going to catch the right problem.

Answer

There is no in depth data available on international joint ventures which have been detrimental to U.S. business. I am attaching, however, four articles which in anecdotal form emphasize our deficiency in this area. These articles are:

1. Reich and Mankin, "Joint Ventures With Japan Give Away Our Future", Harvard Business Review, March/April 1986;
2. Prokesch, "Stopping the High-Tech Giveaway", New York Times, March 22, 1987;
3. "High Technology", The Economist, August 23, 1986; and
4. Gall, "Does Anyone Really Believe in Free Trade?", Forbes, December 15, 1986.

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.

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 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

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

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.

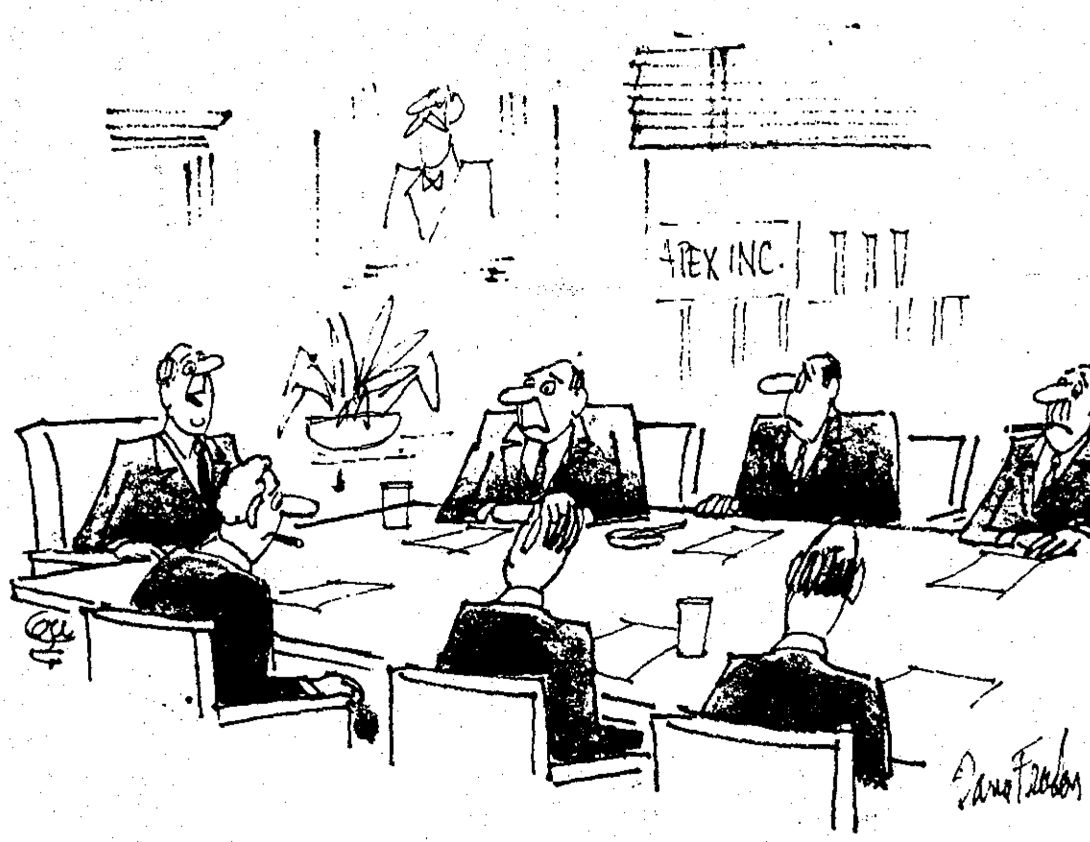
Or consider the case of Pratt & Whitney, which earns profits by distributing foreign-made machine tools. In July 1984, its president, Winthrop B. Cody, told the *New York Times*: "I wish we could make some of these machine tools here, but from a business point of view it's just not possible." Even U.S. 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."

tles, 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.

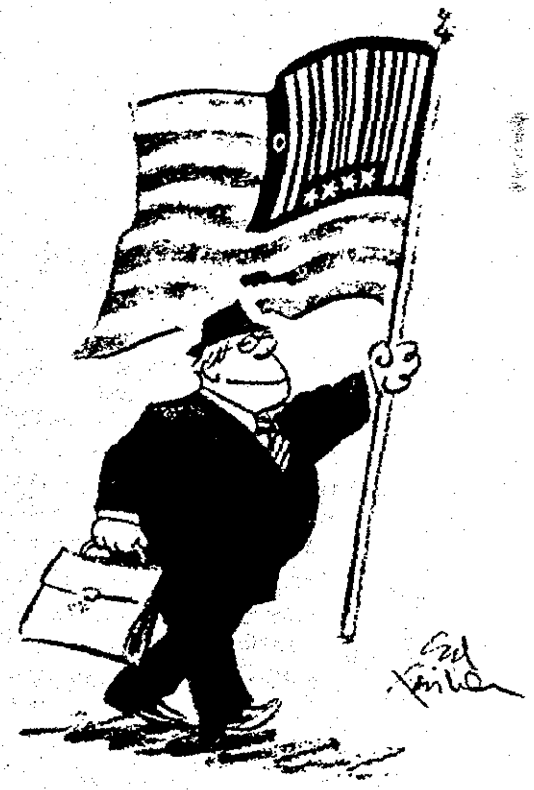
The reason is simple: the value provided by the U.S. partner in a sales and distribution agreement is potentially replaceable. The U.S. company gives away a portion of its market franchise by relying on a Japanese company for manufactured products – in essence, it encourages the entry of a new competitor. As shown by the Japanese-dominated consumer electronics 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 stud the factor cited most often by departing engineers wa "inadequate compensation," followed closely by "un certain future with the company" and "higher salar offer elsewhere."[2] Thanks to such high job mobility, engineers responsible for developing a new product designing a cost-saving manufacturing process at o company in one year may find themselves using th expertise to help another company in another year perhaps their first employer's chief competitor. Th companies that invest in production experience n 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.

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

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Section

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

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 5 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, eem here to stay. Indeed, even with he reassessment of ventures going n, no one expects any significant lowdown in their formation.

American inventiveness is admired roughout the world, but small companies, which account for so many iscoveries, must often turn to forign partners for help in maki... stributing their products — and for e capital needed to stay alive.

Even giants, though, will continue o link up with foreign companies. General Motors, Ford and Chrysler ow import not only components but ntire cars from Asia. Companies in usinesses ranging from appliances photocopiers to machine tools have esorted to the same tactic. Such arangements often force the American ompany to disclose vital design or roduct information.

Business leaders have also come to ew strategic alliances as a necesty in industries where product evelopment costs are exorbitant.

It costs $50 million to $100 million to ing a new drug to market, so pharaceutical companies have to mart it rapidly throughout the world to coup the investment. That requires rategic alliances, said Henry endt, president and chief executive the SmithKline Beckman Corporan, which has joint development and arketing agreements with Boehger Mannheim of West Germany, jisawa of Japan and Wellcome L.C. of Britain.

Similarly, virtually no single comny can afford the billions of dollars osts to develop a new commercial — not to mention the $500 million $700 million to develop the engines ower it. For that reason, international consortiums have become a y 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.

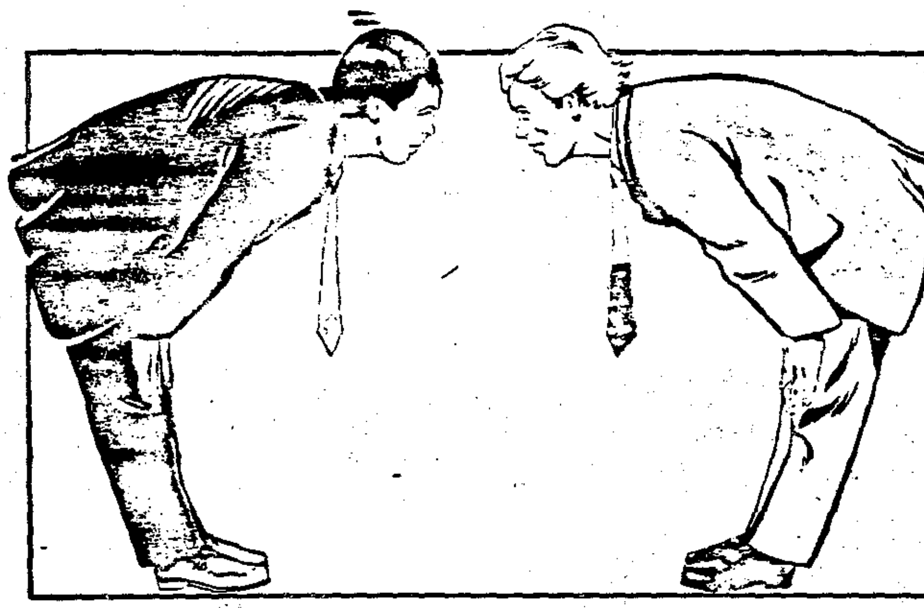
"There is no hysteria now" about the aerospace industry's competitiveness, said Crawford F. Brubaker, Deputy Assistant Secretary of Commerce. "But given what has happened in other industries, we don't want it to happen in this one." ■

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.



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.

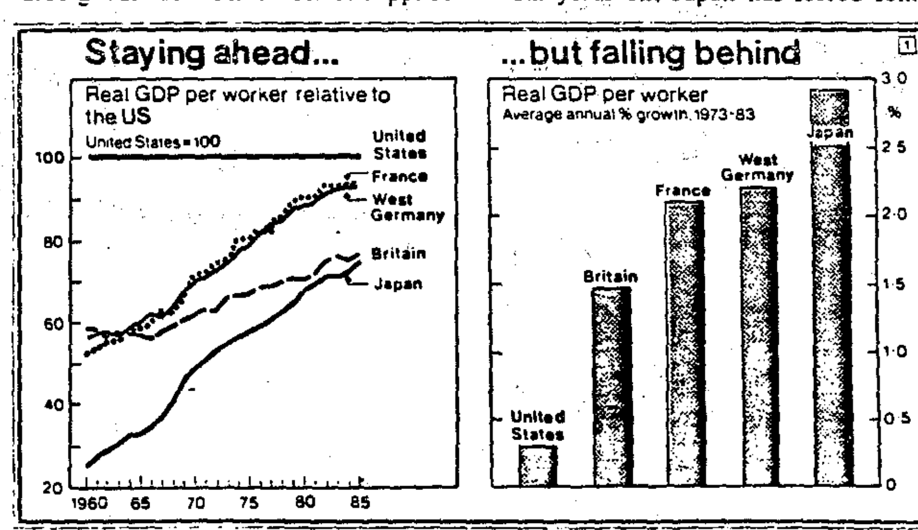
The agony for Americans does not end there. Over the past 25 years they have seen:

- 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"?

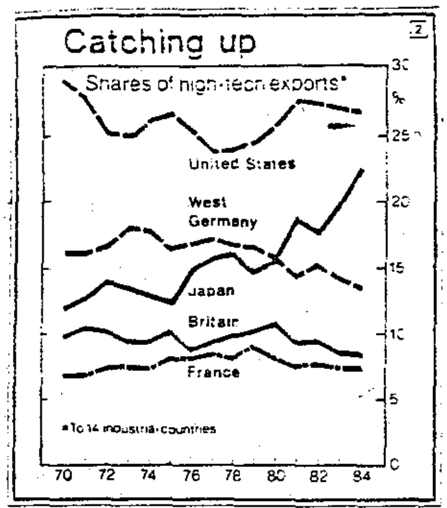
With the gloves now off, which of the two technological heavyweights should one put some money on? In the blue corner, Yankee ingenuity? In the red, Japanese production savvy?

*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:

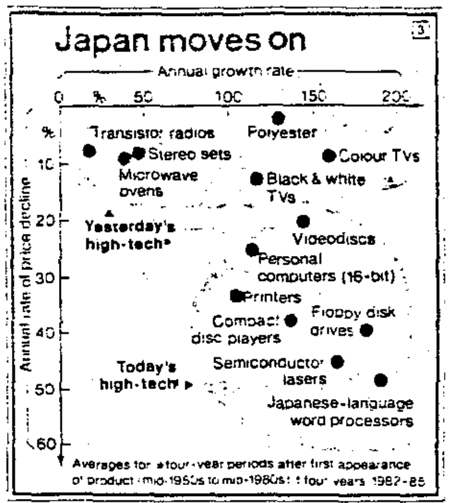
- As an industrial latecomer, it has always been trying to catch up.
- The Japanese tendency towards group conformity has made it difficult to win a hearing at home for radical ideas.
- Research in Japanese universities is bureaucratic, starved of cash and dominated by old men.
- The venture-capital 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) rôle 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.

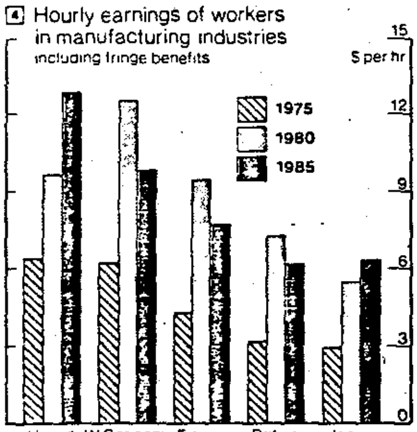
Today's most cited account comes from Mr George Hatsopoulos of Thermo Electron Corporation in Massachusetts. Comparing the cost of (non-financial) capital in the two countries between 1961 and 1983, Mr Hatsopoulos found real pre-tax rates ranged between 6% and 10% for Japanese firms and anything from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

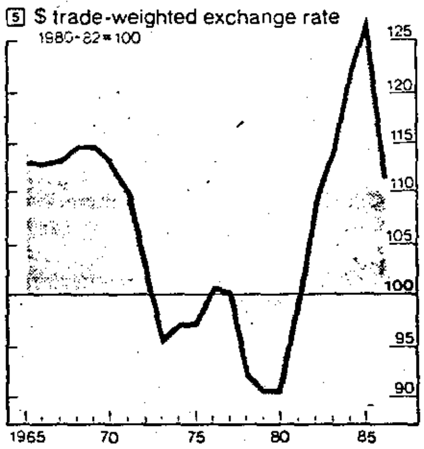
What is studiously ignored in the financial folklore about Japan Inc is the fact that, over the past decade, Japanese manufacturers have been getting out of debt as fast as decently possible (see the survey on corporate finance in *The Economist*, June 7 1986). The most compelling reason right now is 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?

4 Hourly earnings of workers in manufacturing industries
including fringe benefits



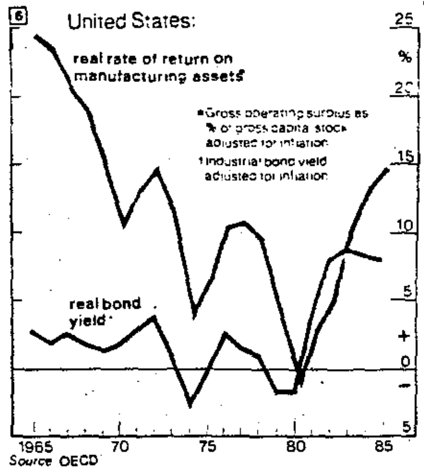
Source: US Department of Labour, Bureau of Labour Statistics, 1984

5 $ trade-weighted exchange rate
1980-82=100



Source: DRI

6 United States:



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.

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, semi-conductors, 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.

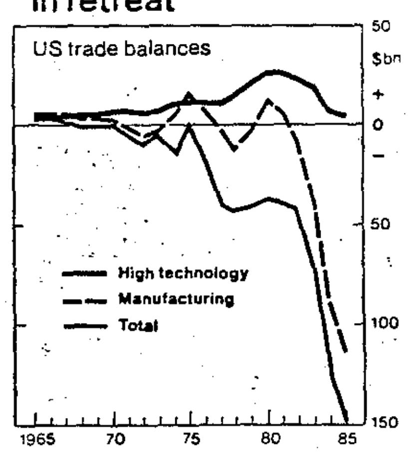
Of the ten industrial sectors designated high-tech (see feature above), America has managed to increase its share of the global market in only two: office automation and electronics. For which, it should thank the likes of IBM, Hewlett-Packard, Digital Equipment, Xerox, ITT, RCA, General Electric, Texas 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

In retreat



Source: US Department of Commerce

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.

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.

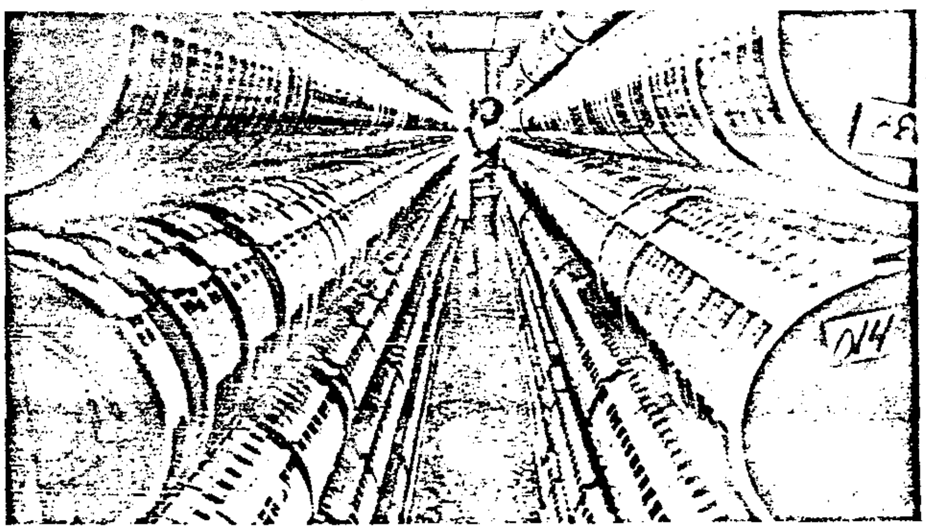
Most of Japan's computer makers came a cropper by riding a bit too blindly on IBM's coat-tails. Lacking the home-grown programming skills, Fujitsu, Hitachi and Mitsubishi made their computers imitate IBM's so they could sell cheaper versions to customers who were already using IBM machines equipped with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

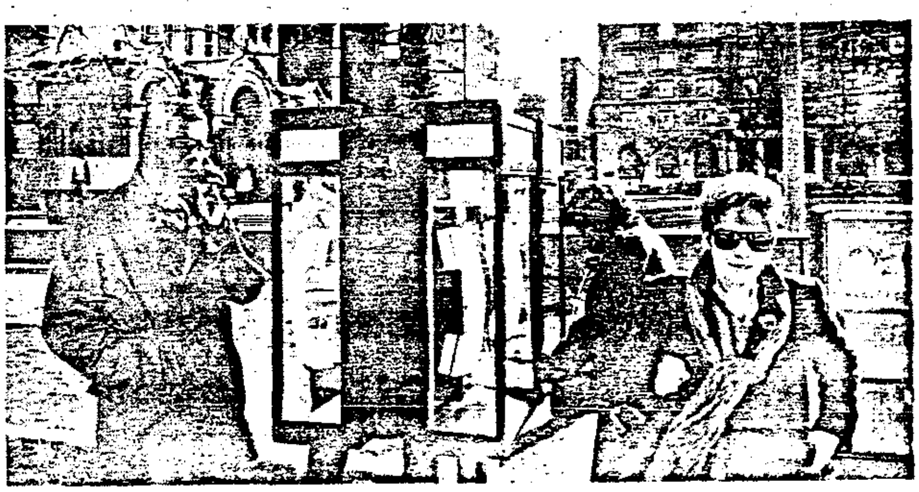
The other institution, the Microelectronics and Computer Technology Corporation (MCC), is an interesting experiment in its own right. Set up as a joint venture in 1983 by initially ten (now 21) rival American computer and semiconductor companies, MCC has 250 scientists carrying out research at its headquarters 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 émigrés 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 $55 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

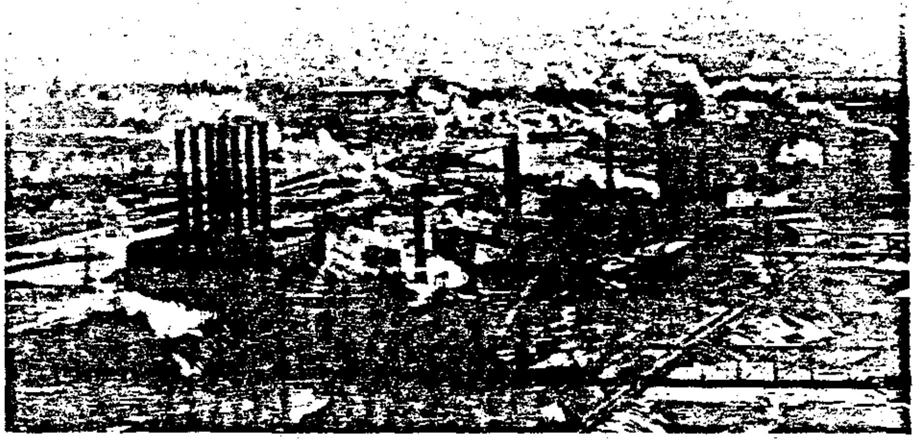
Classification codes continue to give the impression that making anything in a factory is going the same way as smokestack industry generally—up in smoke. Yet software engineering alone is an explosive new "manufacturing" industry that barely enters the American Treasury Department's calculations of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

. . . to robots . . .

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.

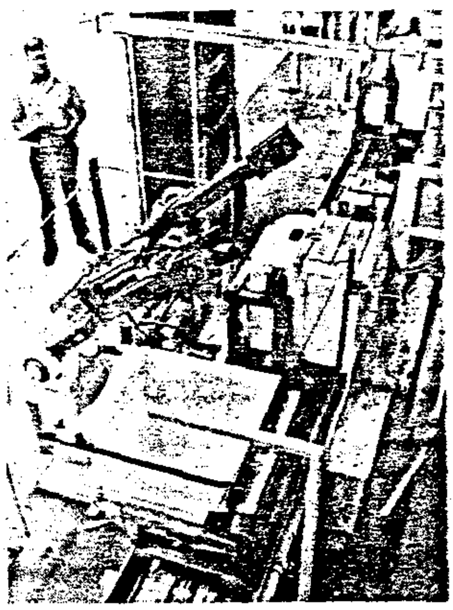
The heart of a CIM plant is a flexible manufacturing shop which can run 24 hours a day, but which is capable of being retooled in minutes rather than days, and able to turn out hundreds of different products instead of being dedicated to just one line. The difference between the best of traditional automation (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.

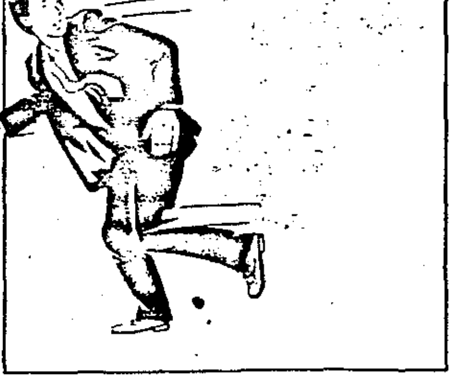
Every document in Xanadu's database has links to its intellectual antecedents and to others covering related topics. The linked references work like footnotes, except that Xanadu offers an electronic "window" through which they can be accessed there and then. Because the whole process works in a non-sequential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