Chapter 7

Where We Stand: Public Policy and Technology

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Where We Stand: Public Policy and Technology

The science and technology policy of the U.S. Government has traditionally been concerned with basic science, health, energy, agriculture, and defense. It has been described as big science deployed to meet big problems,[1] and as mission-oriented rather than diffusion-oriented.[2] With few exceptions (the most important being agriculture and civilian aircraft), U.S. Government policy has not been directed toward helping private enterprises make commercial use of advances in technology. Only recently, as it became painfully obvious that one U.S. industry after another was losing technological leadership, have U.S. policy makers given serious thought to a different approach. Some changes are occurring, and of these, some are real departures from the past. But they have been made in a piecemeal, ad hoc fashion. No comprehensive set of government policies has yet been adopted to promote the use of technology for better performance in manufacturing.

The Federal Government undertook a truly novel venture when it went halves with the semiconductor industry in the Sematech R&D consortium, which seeks to improve the manufacturing process for the industry. Other government-supported R&D consortia have been considered (e.g., to promote R&D for advanced television systems). Repeatedly, Congress has enacted laws that urge the 700-odd Federal laboratories to make their research results more accessible to industry, and to undertake new R&D projects designed and operated in collaboration with industry. In establishing Engineering Research Centers in 18 universities, the National Science Foundation hopes to forge stronger links between academic engineering research and training and the world of industry. NSF is also encouraging U.S. scientists and engineers to acquaint themselves with research results coming out of Japan, and to foster the flow of technology from Japan to this country. A growing number of States are establishing industrial extension services to bring best practice technology to smaller manufacturers, and the U.S. Government is taking some initiatives in the same arena.

These programs represent deliberate actions by Federal, State, and local governments in the United States to improve the use of technology by U.S. manufacturers. Other government actions, also intended to improve industrial performance, work more indirectly. Among these are tax policies, such as the present tax credit for increased R&D or the past program of rapid depreciation for capital investments in up-to-date plant and equipment.[3] Laws protecting intellectual property (e.g., patent and copyright laws) are intended to reward innovation and thus to foster technological advance. Finally, Federal policies adopted for national goals other than international competitiveness may still affect it indirectly. One of these is antitrust law and enforcement.

The following sections describe and analyze government programs and policies as they existed in 1990 from the standpoint of their effect on U.S. manufacturing technology. Chapter 2 of this report, analyzing policy issues and options, discusses programs and approaches that Congress might wish to consider for the future.

INDUSTRIAL EXTENSION

In the United States, government technical and financial assistance to small and medium-sized business is patchy and thin. Federal programs do not begin to compare in size to the $31 billion per year that the Japanese national government pours into its combined program of direct loans and technical assistance to smaller businesses—not to mention the added contributions from prefectures, cities, and city wards, plus the $56 billion in guaranteed loans for small firms underwritten by government institutions.[4]

The U.S. assistance programs are not only much smaller than the Japanese but also more hit-or-miss. Every city in Japan and most rural towns have their industrial halls, or federations of small business, or chambers of commerce, dispensing technical help along with plentiful funding for purchase or lease of

[1] Alvin M. Weinberg, *Reflections on Big Science* (Oxford: Pergamon Press, 1967).

[2] Henry Ergas, 'Does Technology Policy Matter?' *Technology and Global Industry: Companies and Nations in the World Economy* Bruce R. Guile and Harvey Brooks (cd.) (Washington, DC: National Academy Press, 1987).

[3] Discussion of tax policies affecting R&D and capital investment is inch. 2.

[4] For a description of Japanese national government programs to assist smaller businesses, see ch. 6.

the latest production equipment. Japan is blanketed with government or quasi-public institutions at the service of small and medium-size enterprises. In the United States, a small manufacturer in need of technical advice is lucky to find a State or local agency capable of providing it, much less a Federal program that fits his needs.

Small firms form a sizable minority in U.S. manufacturing. Some 358,000 small and medium-size firms (defined as those with fewer than 500 employees) account for 98.8 percent of all manufacturing enterprises, and 35 percent of the manufacturing work forces According to one estimate, these small firms represented 21 percent of value added in manufacturing in 1982.[6] However, employment may be a better gauge of the contribution of small firms to manufacturing, since wages are the major component of value added and wages are lower in small manufacturing firms than in larger ones.

Many small outfits are suppliers of essential materials and parts for large manufacturing firms, and they are especially important in metalworking—the fabrication and machining of metal parts. Over 94 percent of the firms in five major metalworking industries are small plants with fewer than 100 employees.[7] How well these firms do their jobs affects the cost, quality, and marketability of major products from kitchen appliances to automobiles to bulldozers, drilling rigs, and jet airliners. Small to medium-size metalworking firms are also the heart of the industries making production machinery, from tools, dies, and jigs to block-long papermaking machines. In other words, the technological upgrading of small and medium-sized manufacturers has nationwide economic implications.

Many of these firms need technological upgrading. This does not mean that small factories need to install 21st-century computer-integrated manufacturing systems. It does mean they need to acquire up-to-date equipment, train people to use it well, and organize work efficiently. Getting best practice technology out to all corners of U.S. manufacturing is not easy. Owners of small manufacturing firms are often too busy doing a dozen jobs to find out for themselves about technology improvements. Many do not have their own manufacturing engineers, because the engineers cost too much, or are not needed full time, or are unavailable in out-of-the way places where some manufacturing plants are located. Consulting engineering firms are usually more geared to serving large clients than small ones, and many small manufacturers don't trust their ability to find a consultant who will tailor his advice to what the manufacturer needs rather than what the consultant has to sell. Vendors of production equipment can be good sources of technical advice, but often they fall short of what is needed, especially in adapting software to fit particular firms' requirements and in training workers to use the equipment. According to one director of a State industrial extension service, you can't just throw in a computer and read the manual-you have to train people. "We've had lots of companies with computers in their closets. " Finally, financing is the biggest hurdle for many small manufacturers. A small firm is less likely than a big one to have the contacts or track record needed to get loans or otherwise raise money for modernization, and financing is often more expensive for small firms.

Federal Programs for Technology Diffusion to Small Manufacturers

Recognizing the gaps in technology diffusion to small and medium-size manufacturers, Congress has recently created new programs of technical assistance to smaller firms. The Federal effort is still quite limited, however, and there are no Federal loan programs specifically aimed at promoting the adoption of new technologies by small manufacturers. In fiscal year 1989, financial aid administered by the Small Business Administration amounted to $47.3 million in direct loans (which are available only to disadvantaged people) $3.6 billion in loan guarantees, and a contribution of about $150 million to two quasi-public financing agencies for small firms. This

[5] *The State of Small Business: A Report of the President* (Washington, DC: U.S. Government Printing Office, 1989), table A.15, pp. 80-81, and table A. 17, pp. 84-5. The Japanese sector is more heavily weighted toward smaller fins; establishments with fewer than 300 employees are 99.5 percent of all manufacturing establishments and employ 74 percent of the sectoral work force.

[6] Joel Popkin & Co., "Small Business Gross Product Originating: 1958 -1982," contract report to the Office of Advocacy, Small Business Administration, cited in ibid., p. 31.

[7] In 1986, there were 134,700 enterprises in the five major 2-digit metalworking sectors, Fabricated Metal Products, Machinery except Electrical, Electric and Electronic Equipment, Transportation Equipment, and Instruments and Related Products (SIC 34-38), and of these, 126,700 were small enterprises with fewer than 1(X) employees. Ibid., table A.18, pp. 86-87.

aid is given to all kinds of small and medium-size firms (most small businesses are in retail trade and other services) for all kinds of purposes which may have little to do with improving technology.

The biggest U.S. Government program promoting technology advances in small manufacturing is the Small Business Innovation Research (SBIR) program, established by Congress in 1982.[8] Under this program, Federal agencies with R&D budgets of more than $100 million per year must set aside 1.25 percent to help small and medium-size firms compete for Federal research contracts and support these small firms in bringing their R&D results to the point of commercialization. In 1987, 1,276 small companies were awarded $350 million to do R&D work for 11 Federal agencies. The first phase in the SBIR program is feasibility studies of promising ideas (2,189 awards in 1987, for a total of $109 million); the next is development of the ideas with the greatest potential (768 awards, $241 million). SBIR does not fund the final stages of bringing a product to market, but the Small Business Administration does help firms that have gained a place in the R&D program find private financing for commercialization.

SBIR has been given high marks for funneling Federal R&D money to small fins, and for helping young, innovative companies develop advanced technology products.[9] Most of the projects are in the areas of defense, health, and energy, where Federal R&D is concentrated but where commercial possibilities are often limited. The program has been especially helpful, however, in at least one commercially oriented field-biotechnology .[10] What SBIR does not do, and was not designed to do, is give best practice technical assistance to the great majority of small manufacturing businesses, which are not involved in the development of products or processes at the frontier of advancing technology.

The Small Business Administration runs a few programs that dispense business management and marketing advice to the ordinary small company (which, as noted, is most often in services or retail trade). One of these is the counseling and brief workshops on business management offered by volunteers, the Service Corps of Retired Executives (budgeted at $2.5 million). Another is the Small Business Development Centers, mostly located on university campuses, which provide counsel from faculty or students on particular problems, some of which may be technical. There are 53 such centers nationwide, in all but four States; about half their funding comes from the government ($45 million in fiscal year 1989) and the rest from the universities. Useful as these programs are, they are not focused on the choice and use of technology in manufacturing.

Federal programs that concentrate on improving manufacturing fins' use of technology come down to a very few. The oldest and largest is the Manufacturing Technology (ManTech) program of the Department of Defense, funded at $175.5 million in fiscal year 1990. ManTech was created to encourage the development and use of innovative manufacturing technologies, and thus strengthen the U.S. defense industrial base. The program is directed to large companies as much as small ones, and is concerned with production of military goods. Most of the ManTech money goes to large defense contractors, often for rather narrow projects promising near-term savings.[11] However, some ManTech projects have brought forth new manufacturing technologies of broad importance, civilian as well as military. Numerically controlled machine tools were developed in a ManTech project. More recent projects with possible commercial applications include work on near net shaping of metals and computer integrated manufacturing systems.

If the funding for ManTech programs (varying up and down from $130 million to $200 million in the 1980s) seems a minuscule portion of the Defense Department's $40 billion R&D budget, it looms very

[8] The Small Business Innovation Development Act of 1982 established SBIR.

[9] Comptroller General of the United States, General Accounting Office, *Implementing the Small Business Innovation Development Act—The First 2 Years,* GAO/RCED-86-13 (Washington, DC: October 1985); *A Profile of Selected Firms Awarded Small Business Innovation Research Funds*, GAO-RCED-86-113FS (Washington, DC: 1986); *Effectiveness of Small Business innovation Research Program Procedures* GAO/RCED-87-63 (Washington, DC: 1987); Small *Business Innovation Research Participants Give Program High Marks,* GAO-RCED-87-161BR (Washington, DC: 1987).

[10] U.S. Congress, Office of Technology Assessment, New *Development in Biotechnology: U.S. Investment in Biotechnology,* OTA-BA-360 (Springfield, VA: National Technical Information Service, 1988). OTA found that "SBIR funds are one of the few sources of direct Federal support for applied research and development.

[11] Manufacturing Studies Board, Manufacturing *Technology: Cornerstone of a Renewed Defense Industrial Base* (Washington, DC: National Academy Press, 1987).

large compared to Federal spending for manufacturing technology on the commercial side-especially diffusion of technology to small manufacture. Technology diffusion programs include the 28-year-old Trade Adjustment Assistance, and the newly minted Manufacturing Technology Centers (MTCs), created in the 1988 trade act and operated by the National Institute of Standards and Technology (NIST, formerly the National Bureau of Standards).[12]

Trade Adjustment Assistance (TAA) for firms is open only to companies that can show they were hurt by imports.[13] It has usually been funded at about $15 to $16 million per year but in recent years its prospects were uncertain (the Reagan Administration repeatedly proposed to abolish it) and its funding was cut. In fiscal year 1990 it received $9.9 million in new and carryover funds. Nevertheless, until 1988 TAA was the major Federal program giving one-on-one technical assistance to small and medium-size manufacturers. The TAA program also gives advice to its clients on such things as marketing and advertising, inventory control, and financial management. Help is provided by 12 small, regional, non-profit centers that act, in effect, as industrial extension agencies.

The new Manufacturing Technology Centers are charged generally with transfer of advanced technology to industry, with special emphasis on U.S.-based small and medium-sized manufacturers. The law directs the centers to make new manufacturing technology ''usable" to these smaller firms; actively provide them with technical and management information about manufacturing; establish demonstration centers for advanced production technologies; and, for small firms with fewer than 100 employees, make short-term loans of advanced manufacturing equipment. So far, three federally funded Manufacturing Technology Centers (in Troy NY, Cleveland OH, and Columbia SC) have been established in the United States and three more are planned. The three existing centers got a total of $4.5 million in Federal funds in 1989; matching funds from local sources are required.

NIST expects the Manufacturing Technology Centers to serve primarily small firms with 200 or fewer employees, and to concentrate more on off-the-shelf best practice technologies than on high-tech cutting edge systems fresh from the R&D lab. NIST officials also say that the primary service offered by the Centers will be modernization plans, customized to fit the needs of individual firms. However, the language of the law gives NIST latitude to support Centers with varying approaches, and so far it has done so. The Troy MTC is concentrating on transfer of high-technology systems from labs to selected fins, though it also cooperates with State agencies and community colleges in diffusing best practice to a broad range of client firms. Field agents of the Cleveland MTC are knocking on doors of thousands of small companies in a concentrated industrial area and offering those that respond individual business and technical plans. The South Carolina MTC, which is closely linked to the State's technical college system, is installing centers to demonstrate computerized metalworking equipment.

NIST has its own small demonstration center in the Shop of the 90s. This is a working machine shop that fills job orders from government agencies but also serves a technology extension purpose. It is an offshoot of NIST's highly automated, state-of-the-art Advanced Manufacturing Research Facility (AMRF), which was meant to serve in part as a learning center for manufacturers. However, many people from small manufacturing firms found the AMRF entirely too advanced to have any practical application to their businesses. The Shop of the 90s, using off-the-shelf technology, fits their needs and experience better. Because it is a working shop, with 60 employees and a business worth about $4 million a year, the manager has credibility with small manufacturers. State technology agents are brought in for presentations, and the Shop is open for tours and phone inquiries.

One more small NIST program, also created in the 1988 trade act, is intended to provide technical and financial assistance to State technology extension

[12] Neither program is strictly limited to small and medium-size manufacturers, but in practice TM has mostly served small manufacturing firms, and the law creating the Manufacturing Technology Centers emphasizes dissemination of new technology to small and medium-size manufacturers. See the Omnibus Trade and Competitiveness Act of 1988 (Public Law 1O(H18), Subpart B, Sec. 5121(a).

[13] Trade Adjustment Assistance also includes a reemployment and retraining program for workers losing their jobs due to imports; this part Of TAA is far bigger (recently funded at about $200 million per year) and better-known than TM for firms. For a description and evaluation of both programs, see U.S. Congress, Office of Technology Assessment, *Trade Adjustment Assistance: New Ideas for an Old Program—Special Report,* OTA-ITE-346 (Springfield, VA: National Technical Information Service, 1987).

services. This program got no funding until fiscal year 1990, when it received $1.3 million, but NIST had already begun some modest outreach to States. So far, it has mostly been a one-man show—a single NIST official (sometimes accompanied by the manager of the Shop of the 90s) who travels to State technology agencies explaining what resources NIST has to offer, referring them to other sources of Federal help, and helping various State agencies make contact with each other.

Another federally funded technology demonstration center has been in business since 1988. That is the National Apparel Technology Center in Raleigh, NC, an outgrowth of the 10-year-old TC^2 project. TC^2 (Textile/Clothing Technology Corporation) began as a combined government-industry effort to develop a flexible, automated sewing system able to take on a variety of complicated sewing jobs, such as attaching the sleeve in a man's suit jacket. Although it has fallen short of some of its ambitious technical goals, has produced some commercially usable automated sewing equipment. In addition, TC^2 now supports the Raleigh center, which demonstrates a whole range of modern apparel-making equipment to its member companies, large and small, and arranges seminars with apparel engineering faculty of nearby North Carolina State University. The Federal Government's contribution to TC^2 has been $3.5 million per year for the past few years. The Defense Logistics Agency also operates three demonstration centers for apparel technology, each funded at up to $5 million per year, with three-quarters Federal funding. These centers are open to civilian manufacturers as well as defense contractors.

Altogether, these Federal technology extension efforts are scattered and small. Up to now, the emphasis in Federal technology transfer programs for small manufacturers has been much more on pushing out sophisticated new products and processes (as in the SBIR program) than on helping individual firms adopt best practice technology.

State Industrial Extension Programs

Most of the action in industrial extension is in the States, and even there it is limited, though increasing. Exactly how much it amounts to is uncertain, partly because surveys of State programs are incomplete and quickly outdated, and partly because "industrial extension" is not very well defined in the surveys. More than 40 States have programs to ''promote technology," but most of their effort and funding goes for research and development in universities and for aid to high-technology startup ventures-not for help to existing firms in adopting best practice technology. According to a survey of State programs done for NIST in 1988-89, only 13 programs in nine States had technology extension programs whose main purpose was direct consultation with manufacturers on the use of technology .[14] However, this number is already out of date. At least one new program, Nebraska's, was established after the survey was completed.

One of the better recent surveys of State technology programs was done by the Minnesota Governor's Office of Science and Technology .[15] It found that in 1988 States directly spent $550 million on various kinds of technology programs, but only about 10 percent of that—some $57 million—went for technology transfer and technology/managerial assistance (table 7-l). Technology transfer, which got $46 million (8 percent) of the finds, was defined as facilitating "the transmission of new technologies from the laboratory to the private sector. . . for the creation of new businesses, the introduction of new product lines for established firms, or the revitalization of mature industries."[16] Despite this language, some activities that States call "technology transfer" might really be closer to industrial extension services. At a guess, the States are spending some $25 million to $40 million for such services.

As used here, industrial extension means a service something like this: an accessible office staffed with a few engineers or people with experience in industry invites telephone calls or visits from managers of small manufacturing firms seeking

[14] Donald R. Johnson, Acting Director, Technology Services, National Institute of Standards and Technology, testimony before the U.S. House of Representatives, Committee on Small Business, Sept. 28, 1989.

[15] Governor's Office of Science and Technology, *State Technology Programs in the United States, 1988* (St. Paul, MN: Minnesota Department Of Energy and Economic Development, 1988).

[16] Ibid., p. 1.

Table 7-l—Expenditure on State Technology Programs, FY 1986 and FY 1988

	Expenditures				Number of States with programs FY 1988	Average State spending FY 1988
	FY 1986[a]		FY 1988a			
Type of program	$ Million	Percent	$ Million	Percent		$ Million
Technology/research centers	285.6	41.0	226.6	41.2	29	7.8
Research grants	126.7	18.2	150.2	27.3	25	6.0
Venture/seed capital	159.6	22.9	37.4	6.8	18	2.1
Research Parks/incubators	75.6	10.9	36.9	6.7	22	1.7
Technology/managerial assistance	10.5	1.5	11.0	2.0	30	0.4
Technology transfer	8.4	1.2	45.7	8.3	26	1.8
Other technology programs	30.1	4.3	42.4	7.7	41	1.0
	700.0[b]	100.0[b]	550.0	100.0	44[c]	12.5

Notes:
a There are differences in accounting procedures between the 1986 and 1988 reports, For some states, the 1986 figures represented muiti-year appropriations. The 1988 figures are all on an annual basis.
b column sum does not add to total because of rounding.
c Number of States with one or more technology Programs.

SOURCE: Calculated from: Governor's Office of Science and Technology, *State Technology Programs in the United States,* (St. Paul, MN: Minnesota Department of Energy and Economic Development, September 1986); Governor's Office of Science and Technology, State *Technology Programs in the United States, 1988*, (St. Paul, MN: Minnesota Department of Trade and Economic Development, July 1988).

help. Promptly after the first interview, the office sends a technical specialist (either someone from its own staff or an engineer from the State university) to make an onsite diagnosis. Then the extension service produces a customized client report, and its technical specialist or a consultant works one-on-one with the firm to put into effect the improvements recommended by the service and accepted by the firm's manager.

What small manufacturers need more than the newest technologies fresh out of the laboratory is off-the-shelf hardware and software and individual help in choosing and managing them. They need advice on these choices from an independent source with no financial stake in the selection. And they need to understand how much training is involved in adopting new equipment, and where to get it. These conclusions are drawn from the experience of people involved in technology extension, both the agents providing the services and the firms receiving them. In visits and interviews with five State industrial extension programs in 1988, OTA found that the programs were serving genuine needs that were not otherwise being met, and that demand for the services was high.[17] At least two of the States—Georgia and Maryland-do not advertise the services they offer for fear of being swamped with requests for assistance. (Box 7-A lists and briefly describes the programs OTA visited.)

Individual Problem Solving

Everyone interviewed took it as given that one-on-one contact between technical specialists and company managers is the bedrock of industrial extension. A good hard look at the company's individual problems is the starting point for all the programs. This often includes an intensive telephone interview to begin with, followed by a site visit and a diagnostic report. Again and again, company managers remarked on the value of an objective, experienced outsider taking a fresh look at the company's problems—something that managers of small outfits are often too swamped to do. ''I don't have time to do research," said Jerry Lipkin, Executive Vice-President of Moyco Industries, a Philadelphia manufacturer of abrasives and dental products. "I have to do sales, marketing, and personnel. '

Sometimes, the diagnosis may find that a company's efforts to modernize are misdirected, or that real problems have escaped the manager's attention. According to Travis Walton, director of Maryland's Technology Extension System (TES), some companies think they need sophisticated computer equipment when they don't. For example, "If you make the same product year after year you don't need CAD (computer-aided design)—you only need it if you customize. ' One company, Travis added, came to TES for aid in setting up a computer system to

[17] Findings from these visits and interviews are also reported in Philip Shapira, ''Industrial Extension: Learning from Experience,' contractor report to the Office of Technology Assessment, November 1988.

Box 7-A—Five State Industrial Extension Programs

In 1988 OTA visited five industrial extension programs in four States, some with long experience and some just a few years old. Through interviews with program managers, extension agents, and clients, OTA sought information on the kinds of technical assistance small manufacturers need and how the programs are meeting the needs. The five programs, with acronyms and year of origin, are:

Georgia Institute of Technology Industrial Extension Regional Offices (GTRI, 1960) is headquartered at Georgia Tech in Atlanta and supports 12 regional offices, each with a field staff of two or three people giving individual service to client fins, The regional offices also link clients with specialized services at Georgia Tech, including assistance on productivity, energy conservation, workplace safety, hazardous waste management, and training. Funded at $3.8 million in 1988, GTRI had 26 professional employees and served 960 firms. Days of field service averaged 2 to 5 and the average cost per client was $4,000.

Maryland Technology Extension Service (TES, 1983), based at the University of Maryland, offers one-on-one client assistance at five regional offices. Field staff may refer problems to the university faculty. With a full-time staff of seven people, and funding of about $400,000, TES served 250 to 300 clients in 1988, giving up to 5 days of service at an average cost per client of about $1,500.

Michigan Modernization Service (MMS, 1985) is a State-sponsored program, affiliated with Michigan's Industrial Technology Institute. Its services include intensive diagnosis and onsite visits from a field representative, experienced in industry and manufacturing technology, paired with a training specialist. Some 45 people staff the program, but most of the 25 professionals are part-time consultants. The 1988 budget was $2.8 million (expected to rise to $3.9 million in 1989) and 140 clients were served (250 expected in 1989). Cost per client was about $20,000 for an average of 6 days of service.

Pennsylvania Technical Assistance Program (PENNTAP, 1965), a joint program of Penn State University and the Pennsylvania Department of Commerce, provides technical information from faculty specialists and some onsite visits, in response to client requests. Sometimes PENNTAP takes the initiative in acquainting firms with new technologies. Total budget in 1988 (including in-kind facilities and services donated by the University) was about $1.3 million and the staff was equal to 12 1/2 full-time slots. Some 850 firms and 450 local government bodies received services; cost per industry client was $1,100 to $1,500. The length of service was not reported.

Pennsylvania Technology Management Group (TMG, 1984), a nonprofit corporation sponsored by the State, concentrates on bringing best practice technology to small manufacturers (defined as having fewer than 250 employees, but in practice usually in the range of 20 to 40 employees). One of the small core staff (6 people) evaluates the client's problems, and TMG then shares the cost of a consultant, if needed. With a budget of $350,000 in 1988, TMG served about 40 clients, at an average cost of $8,800. The length of service averaged 8 days.

track inventory, but the real problem was that the inventory was "totally chaotic" and far too big, tying up capital in unneeded items.

Another example comes from the Tnemec Co., Inc. of Baltimore. This branch plant of a small company ($1 3 million sales per year) makes industrial protective coatings for water towers, wastewater plants, and the like. Tnemec wanted to expand to handle a growing business, but the plant manager, Frank Lavin, recognized that he needed help in planning the expansion. "I'm in a small business with a busy day-to-day routine, ' he said. ''I don't know how to build a new plant, ' He called on TES. In a site visit, the TES engineer found that a complicated, inefficient flow of materials had developed over the years in the old plant, and suggested a wholesale rearrangement. The result was that the company got the space it needed in only 25,000 square feet, not *40,000* square feet as originally planned. ''At *$25* a square foot, we saved a lot of money," Lavin said. He added that if he had asked a consulting firm for 40,000 square feet, they would have built it without question. "Consulting engineers and architects build what you ask them to.

Trust

Lavin, like other company managers, praised the ''objectivity and the expertise of the State extension service. Trust in the services' impartiality-the fact they are not trying to sell the companies anything or collect big fees—is a key element in their success. This was the reason several plant owners and managers gave for turning to a State agency instead of a private consultant. Besides, they said, small firms have trouble getting competent service from consulting engineers. One said bluntly: "They are a waste of time and expensive."

Brooks Manufacturing is one company that struck out in trying to find the right private consultant. This Philadelphia firm has a $6-million-a-year business making electrical outlet strips, but it faces growing competition (especially from Taiwan) in its basic product line. Brooks is trying to build up its business in more specialized, higher value-added items—electrical outlet strips for medical carts, for example and is developing a special power strip that is compatible with sophisticated communications equipment. But the company is too small to support a research and development department to design its new products, and it failed to get what it needed from three different consulting engineers. "The engineering service consultants usually send out the new guys to small fins, " President Gary Brooks said.

Pennsylvania's Technology Management Group (TMG) stepped in and helped Brooks find a capable engineering consultant, who developed new product designs and made blueprints for the company. TMG also funded an evaluation of the company's operations to see whether it needed and could handle a Materials Requirements Planning (MRP) system, which takes an order and breaks it down into the individual components and material needed to fill that order. On the basis of the evaluation, Brooks adopted the system. TMG also found a qualified consultant to help the firm tailor the system to its needs.

At Moyco Industries in Philadelphia, Jerry Lipkin remarked that the intervention of TMG in finding a consultant meant that the fees were predictable and there was a cap on final costs. "We have been burned by consultants in the past, and the program's involvement helps reduce the risk of this happening." That TMG puts up a little money (maximum of $1 ,500) toward the consultant's fee reassures the company that TMG too has a stake in the outcome, and that the consultant is qualified. For their part, consultants seem to welcome referrals from State extension services since this adds to their credibility and opens doors to new business.

Extension services operating out of university engineering departments can use members of their own departments for consultations. For example, when American Bottlers Equipment Co. (Ambec) of Owings Mills, MD, came to Maryland's Technology Extension Service for help in computerizing its parts list and linking the list with computerized drawings, the service used its university connection. TES works out of five regional offices but is based in the Engineering Research Center of the University of Maryland; it calls on engineering faculty members in nearly half its cases. Travis Walton, director of the program, says TES has a "visiting nurse" approach—the engineers who staff the regional offices do what they know how to do and call for help when the problem is beyond them.

Ambec is a small company specializing in the manufacture of stainless steel conveying and handling equipment for customers in the food and beverage, pharmaceutical, electronics and other industries. It has sales of $10 million per year and about 100 employees. Essentially a job shop, Ambec works to customer specifications, using families of parts which it assembles to meet a particular customer's needs. Before consulting TES, Ambec had gone through a bad experience with a private consulting firm, which sold it a Material Resource Planning software system that was supposed to keep track of orders and parts, but never worked as promised. Instead of trying that route again, the company called on the State extension service. TES linked Ambec with a University of Maryland engineering professor and a student with good computer skills. The student developed the program Ambec wanted and later went to work full time for the company.

Confidence in an extension service's competence is as important to a company as trust in its objectivity. Connections with an institution that is already well respected throughout the State help to establish that confidence. In Maryland, for example, that institution is the University's highly regarded engineering department. In Pennsylvania it is Penn State University, in Georgia it is Georgia Tech, in Michigan it is the Industrial Technology Institute in Ann Arbor.

Sometimes, only experience will instill confidence. Terry Brady, president of Bradhart, Inc. of Howell MI, consulted the Michigan Modernization Service--MMS) only as a last resort. Bradhart is a small but top-of-the-line job shop, machining high-quality metal parts, especially bearings, to the specifications of its customers in the aerospace, ordnance, and oil industries. To stay competitive in the new global economy, the company decided to modernize. Moving to larger quarters, it installed several computer numerically controlled (CNC) machine tools and a computer system to integrate orders and office processing with production. This investment cost half a million dollars-a lot for a company with sales of $3 million per year. Unfortunately, the company's managers soon discovered that they had seriously underestimated the startup costs for training workers to use the new tools. Further, the software for the computer system did not run properly. The company had run out of credit. It was in a make-or-break position.

At this point, Brady called MMS, but without much hope of real help. He was surprised, frost at getting a prompt businesslike response, and still more so at the quality of training and other assistance MMS was able to provide. Finally, MMS gave Brady a vital boost in confidence when its evaluation confirmed that the company was right to invest heavily in modern equipment, and was headed in the right direction. Brady remarked appreciatively on the way MMS staff had served as a "sounding board," providing advisors who were not competitors but still had an understanding of business and technology. "I still don't believe," he said, "that someone would want to help the little guy. "

Training

Nothing could better illustrate the importance of training on new equipment than the Bradhart story. Because the managers did not appreciate how much training would cost, the company almost went under in an otherwise sensible move to modernize. Fortunately, MMS was able to help Bradhart get State training funds and find good training programs. (As discussed below, MMS also helped the company get a bank loan to tide it over the crunch, before the investment in equipment and training began to pay off.)

With help from MMS, Bradhart set up training programs for employees, both in-house and at a local community college. Shopfloor employees received training on the CNC tools and in quality control techniques; the office staff was trained in spreadsheet and database programs and job costing. In addition, the company sent four or five employees at a time through a local community college to learn basic mathematics, quality control, and supervisory skills. MMS also helped Bradhart untangle its software.

Although the directors and staff in all five industrial extension services stressed the importance of training, MMS was the only one with a training element routinely built into its services. It took time for MMS to recognize the merits of marrying training with technology. In its early days (perhaps influenced by General Motors, which was then trying to automate everything it could in auto assembly) the program concentrated on hardware, and training to use the hardware was not much emphasized. Today, MMS takes care to emphasize that it is not hawking technology per se but is helping firms use technology, which means developing management and training. On every site visit, MMS sends pairs of training and technology specialists to make the diagnosis and write the report, which includes an assessment of training needs and options for every client and actively helps clients design or procure training. The Michigan program spends roughly $1 dollar on training assistance for every $2 dollars it spends on technology deployment.

Other industrial extension services, though less systematic about training than MMS, also know where to refer clients for training advice and assistance. For example, Pennsylvania's TMG linked Brooks Manufacturing with a community college to get training in quality control, statistics, teamwork, and basic math for its workers. However, some of the services have a harder time finding adequate training. Georgia Tech has a small industrial training unit able to provide limited training, mostly for frost line supervisors. But in some of its cases, training that extension agents recommend, and companies are eager to get, is not available.

For example, in a productivity audit of Imperial Cup's paper and plastic cup manufacturing plant in La Fayette, GA, the Georgia Tech engineer included several recommendations for improved training. She found the current training-2 days under a fret-line supervisor-inadequate for working with the sophisticated machinery in the company's paper department. Imperial tried to get a local vocational-technical school to train workers on the shop floor, but the school offered only classroom training. The company also had trouble finding workers with the skills needed to maintain the machinery. The local voc-ed school turned out electronics and auto technicians, but not machinery repairers. In the past, the company sent small groups of workers to the machinery manufacturer in Wisconsin for training, but the manufacturer recently expressed reluctance to continue it. At the time of OTA's visit, no solution to Imperial's training needs was in sight.

Financial Aid

Industrial extension services do not provide funds for capital investment or operating expenses. They are in the business of giving technical, not financial, assistance. However, they can help small firms coming to them with financial problems in two ways. First, their diagnosis may reveal that what the firm's manager thought was a need for funds is really more a problem of management that can be solved, say, with a better use of space, flow of materials, or control of inventory.

Second, the State agency can be very useful in directing firms to sources of funds, and supporting them in dealings with banks. For example, the Michigan Modernization Service not only pointed the Bradhart company toward State funds that could help pay the big bills for their training needs. MMS also helped the company get a bank loan, using State economic development funds as equity (the funds came from Community Development Block Grants, contributed by the Federal Government to the States). "This lessened the financial pressures," said Terry Brady, Bradhart's president. "We would have gone down without the State's help."

Besides the block grants and other economic development funds, many States have special loan programs for small businesses that extension services can tap. The extension services can also plug into the Federal program of small business guaranteed loans. It is safe to say, however, that finding the money to modernize a factory is a serious hurdle for many small manufacturing firms in the United States. They do not have the many options of the small Japanese firm, which can afford to pass up a low-interest government loan in favor of a bank loan at a slightly higher rate, because the bank takes just one day to consummate the deal, while the government loan might take a whole month (see box 6-A, ch. 6).

Staff, Fees, Intensiveness, and Cost of Services

All the State agencies interviewed by OTA reported that they had found ways of getting good staff-even though most pay their engineers and other technically trained people below-market salaries. For their small core staffs, they look for people with broad technical competence (rather than depth of knowledge in a narrow field) and an interest in working with people as well as things. The Technology Management Group in Pennsylvania calls the kind of person they look for NYTE--not your typical engineer. TMG reports no trouble attracting and keeping staff, even though the pay (on average, $35,000 per year in 1988) is well below the median for engineers. The pay in the Georgia Tech extension service is higher (averaging in the mid-$40,000s), but the program's directors say the satisfaction of the job is at least as important as pay in attracting good people. Most of the extension offices are in rural areas where the agents get plenty of local recognition, both for the job they do and as representatives of prestigious Georgia Tech.

The Michigan Modernization Service relies mostly on part-time consultants for its field representatives, and has been through some periods of high turnover. The program directors say that although it is a challenge to get good people, it can be done. The pay is pegged at the State rate for consultants—$250 per day, which compares with $800 to $1,000 per day for private engineering consultants. The field reps take the work despite the uncompetitive rate, partly because it opens the door for more contracts later, partly because the State does much of the preliminary work—and also partly because they enjoy it. Some of the field reps are retired industry engineers (often from the auto industry) and they are enthusiastic about helping small firms learn how to solve problems for themselves. The MMS has changed its ideas about what makes a good field representative. At first, they looked for people with specific technical qualifications. Now they look for breadth and the ability to establish trust, listen, and write a good analytic report.

With its large roster of part-time field representatives (25 in 1988), MMS does not often need outside consultants, but other programs (TMG in particular) use private consultants quite regularly. TES relies heavily on its faculty connections (using them for 45 percent of clients), and the Georgia Tech extension offices taps the resources of the Georgia Tech Research Institute in Atlanta for about 30 percent of its clients. Thus, these programs are able to tackle a shifting variety of technical problems while keeping only a small permanent staff for continuity and a sense of mission.

None of the State programs charges a fee for its initial assessment. Only one, TMG, charges any fee at all; in this program, firms pay apart (usually about two-thirds) of the fee for consultants. The fact that the firms pay nothing for the diagnostic assessment makes it easy for them to enter the program, even when (like the Bradhart company) they don't have very high hopes for it. Many of the company managers interviewed by OTA said they would be glad-next time-to pay for services they got from the extension agencies. The problem with paying up front is that they have no idea whether the agency will deliver professional level services. In the case of TMG, firms get their diagnosis before they are asked to share payment for a consultant. And about 60 percent decide not to go ahead (though many of these are able to make improvements on their own, based on the diagnosis). Those that choose to go forward know what their cost will be, since TMG takes responsibility for dealing with the consultant. The Michigan program is considering a second phase of service that might charge user fees, but this would follow the first, no-charge phase.

The cost per client of the five programs ran from about $1,000 to $20,000 in 1988 (box 7-A). There seemed to be a rough correspondence between the cost and the intensiveness of the services clients receive, although it is hard to say this definitively because definitions of services differ, and so do allocations of cost. MMS and TMG, both of which emphasize field visits and individual consultations based on a written diagnostic assessment, are at the high end. MMS reported an average of 6 days of service and a cost of $20,000 per client. TMG said it gave an average of 8 days of service, at a cost of $8,800 per client—but the cost rose to $19,400 for those clients (40 percent) who elected to use a consultant.

Maryland's TES and the Georgia Tech extension service both give up to 5 days service to their clients, though neither is rigid about "setting" the clock running.' TES ' 'usually' makes field visits, though not always. Georgia Tech may or may not; one regional office reported having contact with 200 companies in a year, helping 100 in depth, and making about 50 site visits. Another said that some field officers are so familiar with a firm after dealing with it over the years (Georgia Tech has been in the industrial extension business since 1960) that a site visit isn't necessary. Both tend to give their clients oral, not written reports. And both rely for specialized technical help on their university connections, not private consultants. TES pays its faculty advisors for their time only when asked, and then at their university salary (not private consultant) rates. The faculty advisors may then use the money for professional purposes such as travel or research support. Georgia Tech can call on its parent organization for extra services to its clients-for example, a productivity audit from the State-funded Georgia Productivity Center program. The TES cost per client is nominally $1,500, but most of the cost of consultation with engineering faculty at the University of Maryland is not included in this figure. Georgia Tech reported a cost per client of $4,000.

The least expensive of these programs, PENNTAP, generally offers the least intensive services. Often, the problems that companies bring to it are narrowly technical and can be handled by a telephone call, a fax message, or group meetings. PENNTAP's eight staff specialists (mostly engineers) do make site visits as well, however, and they tailor responses to clients' individual problems. According to the program's director, human contact is the key to technology dissemination. PENNTAP reported spending about $1,100 to $1,500 per client firm, with no estimate of the days of service rendered.

Improvements in Services Offered

Most of the people OTA interviewed, including the staffs of the five extension services and their clients, thought the programs were doing a good and much-needed job. If there is one change they all want to make, it is to expand the programs and serve more firms, Two of the extension services, Georgia Tech and Maryland's TES, specifically stated that they don't advertise for fear of attracting too much business. Georgia Tech asked the State legislature for funds to open five more regional offices. Michigan's service was expanding in 1989, and Pennsylvania established a new $10 million-a-year program of Industrial Resource Centers, replacing the much smaller TMG, which will serve as advisor to the new centers.

At one of the programs, MMS, the staff had given serious thought to expanding services to individual companies, as well as extending service to more companies. MMS staff members believe that the average of 6 days of service they now give clients is about right for a first bite. "Small and medium-size firms face a digestion issue," said Alan Baum, director of research and analysis. "They can only deal with so much at a time. " But the staff is seriously considering offering a second phase of assistance of up to 20 days, with the firm paying for some or all of the costs (the first phase, as noted above, is free).

MMS has another idea in mind as well. That is to strengthen horizontal links between small firms in the same or closely connected businesses, freeing them from too-great dependence on the larger firms that are their customers. Interestingly, managers of Japanese Government programs for small manufacturers are promoting more independence in much the same way, through networks that provide cooperative product development and marketing services (see ch. 6). Michigan's Industrial Technology Institute, of which MMS is now a part, has made some preliminary moves in this direction. Its PRIME project (Program of Research in Modernization Economics), started in 1985, is helping Michigan auto parts and components suppliers meet new demands from the Big Three automakers—especially the demand for complete subassemblies rather than disparate parts. For example, PRIME might link a small foundry with a machine shop so the two together could make a complete camshaft subassembly.

Finally, some of the extension services-notably Georgia Tech-would like to do more with training. They believe that the training programs they currently offer are too "off-the-shelf" and depend too much on the classroom. And they think that closer links between industrial extension and State vocational educational systems are a must.

It would be a mistake to consider the examples discussed above as typical of industrial extension services in the United States. They are not. OTA chose these five programs to examine not because they are typical but because they are among the most active and the best. The purpose was to suggest what *can be* done with technical assistance to small manufacturers, not to suggest that it *is* being done nationwide. The situation is patchy. Several States besides the four mentioned here also have active programs, others are following the leaders and establishing industrial extension services, and some are doing little if anything. An accurate count is not available, but it is likely that the State and Federal programs combined are spending no more than $40 to $50 million per year on industrial extension. If just 24,000 small American manufacturing firms were to receive industrial extension services each year (about 7 percent of small manufacturers roughly similar to the proportion that is served in Georgia by the Georgia Tech extension service), the total cost would be $120 million to $480 million per year, depending on the level of service.[18]

COMMERCIALIZING TECHNOLOGY FROM FEDERAL LABORATORIES

During the 1980s, the government has tried to encourage the commercialization of technology from the Federal labs by private industry, Congress has passed several laws to promote it; scientific advisers to the President and executive agencies have strongly urged it; and President Reagan signed an Executive Order laying out guidelines to accomplish it.[19] The effects have been positive but modest. The Federal labs still have a long way to go before realizing their potential as a source of new ideas for industry.

When the interaction works, lab-generated technologies can have an impact. For example, although it focuses on nuclear weapons research for the U.S. Department of Energy (DOE), Sandia National Laboratories has also made contributions to civilian industry. Sandia helped to develop important clean room technology and the hot-solder leveler, used in electronics manufacturing. Each was worth over

18See ch. 2 for more detail on these estimates.

19The laws promoting technology transfer include the Stevenson-Wydler Technology Innovation Act of 1980, the Patent and Trademark Amendments Act of 1980, the Bayh-Dole Patent Amendments of 1984, the Federal Technology Transfer Act of 1986, the Omnibus Trade and Competitiveness Act of 1988, and the National Competitiveness Technology Transfer Act of 1989. Also, during 1988-89, subcommittees of the House Committee on Science, Space, and Technology and of the Senate Committee on Energy and Natural Resources held hearings on technology transfer. Major reports to the executive branch include *Report of the White House Science Council Federal Laboratory Review Panel, Office* of Science and Technology Policy, Executive Office of the President, 1983; Energy Research Advisory Board, ***Research and Technology Utilization: A Report*** *of the* ***Energy Research Advisory Board to the UniteStates Department of Energy,*** DOE/S-0067, ***1988; and The Federal Technology Transfer Act of 1986: The First 2 Years,*** Report to the President and Congress form the Secretary of Commerce, July 1989. President Reagan's order establishing guidelines for the Federal labs on technology transfer was Executive Order 12591, Apr. 10, 1987.

$100 million to industry by 1987 according to Sandia's estimates.[20]

Technology transfer is increasing, albeit slowly. Quantitative measures are elusive and fail to capture the key ingredient of personal interaction. Nonetheless, some trends are indicative. Active license agreements between DOE's Oak Ridge National Laboratory and industry were up from 2 in 1985 to 33 in June 1989.[21] Industry increased its royalty payments to DOE labs from $297,000 in FY 1987 to $908,000 in the first 9 months of FY 1989,[22] and are likely to rise further.

The labs were set up mostly to pursue missions other than commercially promising R&D-notably, basic research and the development of science and technology related to weapons—so there are limits to the potential for technology transfer. However, there are also barriers that are not integral to the labs themselves. These can be overcome. Changes in the funding, administration, and orientation of the labs are necessary, and should help the labs to increase their potential contribution to increase U.S. competitiveness in manufacturing. The following sections explore how the labs are responding to legislative and executive mandates to improve technology transfer. While progress has been made, more could still be done to make labs' research available to industry.

The Federal Laboratories: An Overview

The Federal Government spends approximately $21 billion on its labs, mostly through: the Department of Defense (DoD), $10.5 billion; DOE, $4 billion; National Aeronautics & Space Administration (NASA), $2.5 billion; and National Institutes of Health (NIH), $1 billion. Various smaller agencies, such as the Agricultural Research Service, account for the remainder.[23] Most of this money is spent on lab work for defense and basic research. Almost all of DoD's money and about $2 billion of DOE's goes to defense-related R&D, largely weapons development. Most of the DOE labs' remaining resources (after defense-related spending) are spent on basic energy research.

Neither of these two predominant missions, defense and basic research, is directly connected to the needs of the private sector. Not only is defense-related R&D designed to produce weapons systems (not usually transferable to civilian manufacturing), there are security-related barriers which tilt the institutional culture of defense-related researchers producers away from technology transfer into the civilian sector. Basic research faces different, but just as significant, problems in forging links to developers and users of its technology. Basic researchers are almost by definition interested in the pursuit of knowledge, not its application. This tends to be true for both the institution and the individual researcher.

Nevertheless, defense R&D and basic research can sometimes be made useful to commercial manufacturing. Labs differ in their potential to help the private sector, and in their success in giving such help; they come in different sizes and with different structures and orientations. It is therefore useful to begin with a brief overview and some central distinctions.

DOE Labs

The DOE labs are key factors in any discussion of the Federal labs. Indeed, the nine multiprogram DOE labs are usually simply called the national labs, even though they account for only about a sixth of total government spending on Federal labs.

The DOE labs are funded primarily through three program areas,[24] which orient the work that they fund in different directions: Defense Programs ($3 billion) supports the DOE's weapons work and nuclear materials production; Energy Research Programs supports basic research in energy, mainly nuclear energy ($2 billion); and the Nuclear Energy, Fossil Energy, and Conservation and Renewable Energy Programs (collectively referred to below as

[20] *Annual Report: Technology Transfer, Sandia National Laboratories, Fiscal Year 1987*, SAND 87-0749, UC-13, April 1988 (Springfield, VA: National Technical Information Service, 1988), p. 7; Robert Stromberg, Technology Transfer and Policy Department, Sandia National Laboratories, personal communication, June 19, 1989.

[21] Donald Jared, Program Administrator, Office of Technology Applications, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, personal communication, June 20, 1989.

[22] Rees L. Dwyer, III, Executive Assistant to the Assistant Secretary, Management and Administration. Department of Energy, personal communication, Oct. 18, 1989.

[23] National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 1987, 1988, and 1989*, vol. 37, Detailed Statistical Tables, NSF 89-304 (Washington, DC: U.S. Government Riming Office, 1989), p. 29 (estimates for fiscal year 1989) (totals of figures shown for intramural research and research in all Federally Funded Research and Development Centers (FFRDCs)). These figures are by agency, not by lab; agencies sometimes spend money for research in other agencies' labs. See ibid., pp. 4, 31.

[24] Some other agencies also fund R&D in DOE labs.

Applied Energy programs) support various projects beyond basic research that are not related to weapons ($1 ***billion).*** Only Applied Energy has commercialization of technology as a specific part of its institutional mission.

These three programs support the work done in three sets of labs: the four big national labs primarily concerned with defense-related work (Lawrence Livermore, Los Alamos, Sandia, and Idaho Engineering); the five medium-sized national labs that focus primarily on basic research in energy (Argonne, Brookhaven, Lawrence Berkeley, Oak Ridge, and Pacific Northwest); and 28 generally smaller labs (e.g., the Princeton Plasma lab). Three of the smaller labs —including the Solar Energy Research Institute (SERI)—are run specifically by DOE's Applied Energy programs. In general, the larger labs do some work for each of the three programs.

DOE labs are unlike nearly all the rest of the Federal labs, in that all except two of the smaller ones are operated by contractors (they are government-owned, contractor-operated, or GOCOs). Almost all other Federal labs are government-owned and government-operated (GOGOs). The contractors who operate GOCOS vary: some are profit-making, others non-profit; some are industrial firms like Martin Marietta, other are universities like the University of California. GOCOS face some specific problems of their own in the transfer of technology, as we shall see later.

DoD Labs

There are some 68 DoD labs, and DoD spent about $10.5 billion on lab R&D in 1989. These labs are run directly by the Departments of the Army, Navy, and Air Force.

Less is known publicly about the DoD than the DOE labs, partly for security reasons. However, the DoD labs have also been under increasing pressure to encourage commercialization of the technology that they develop. The Stevenson-Wydler Technology Innovation Act of 1980, the Patent & Trademark Amendments Act of 1980, and the Federal Technology Transfer Act of 1986 cleared legal barriers blocking transfers from these labs and promoted structural changes (like the delegation of key decisions) that would encourage transfer. Some DoD labs are clearly making a major effort in this field and others have historically worked well with the private sector. However, in October 1989 DoD's Office of the Inspector General published a report that was sharply critical of the extent to which the letter and spirit of the law had been implemented.[25]

Other Labs

NIH spends about $1 billion in Federal labs. All NIH labs but one are GOGOS. NIH has a good reputation for pushing its technology out toward the private sector and encouraging its scientists to do so.[26]

NASA spends about $2.5 billion in the Federal labs. All but one of NASA's seven labs are GOGOS. NASA's labs (and those of its predecessor, NACA) have been productive in collaborating with industry (see box 2-A). Some of NASA's lab work is still useful to civilian aircraft manufacturers, but its main focus today is the national space program.

NIST (the National Institute of Standards and Technology, formerly the National Bureau of Standards) sees its work with industry as part of its primary mission. NIST spends about$110 million in its labs. The NIST labs have long worked closely with industry in the areas of measurement, standards, materials science, and computer systems, and NIST's Center for Manufacturing Engineering (funded at about $6 million) follows the tradition.

This section concentrates mostly on DOE's nine national labs. They are big, they work on a variety of projects that could be of commercial interest, and information about them is readily available. For these reasons, the report uses an analysis of DOE's national labs to illustrate the problems and potential of the Federal labs as a whole. As discussed below, the light cast by the DOE national labs helps to illuminate the positions of other agencies and labs. While some might argue that DoD labs cannot be expected to follow the same path toward the commercialization of technology, there is evidence that the defense-oriented DOE labs provide some commercially important technology.

[25] U.S. Department of Defense, Office of the inspector General, *Report on the Audit of the DoD Domestic Technology Transfer Program*, *No.* 90-006 (Arlington, VA: U.S. Department of Defense, Oct. 19, 1989).

[26] The one area of special interest to manufacturing--biotechnology-is the subject of a separate OTA report, *Biotechnology **in a Global Economy,*** scheduled for release in late 1990.

Commercializing DOE'S Technology: Mechanisms

"Commercialization" here means making technology developed in the Federal labs useful in industry. In the past, that typically meant nothing more than the publication of research results in conferences and journals, after which the results would make their way to industry and eventually find application. Today, such delay is costly, as U.S. firms fall behind in applying the latest technology to manufacturing. In these changed circumstances, faster commercialization takes on more importance, and several useful mechanisms to promote it have emerged. Collaborative R&D is lab-industry teaming to create new technology for industrial use. Spin-offs and startups transfer already existing technology to existing and new firms respectively. Various mechanisms (e.g., personnel exchanges) can prepare the ground for either form of commercialization.

Collaboration

Collaborative R&D-planned, performed, and sometimes funded jointly by the labs and industry—is a powerful means of commercializing technology. It is not entirely new for the Federal labs: NIH and NIST, for example, have done collaborative work with industry for years.[27] However, it is not at all common in DOE's national labs; only 57 collaborative projects were under way in all national labs in 1987.[28]

Most of DOE's collaborative R&D has been carried out by its Applied Energy programs. These have sometimes targeted particular industries for ongoing R&D projects. This continuity allows the labs and companies to get well acquainted with each others' interests, abilities, and needs, and to smooth out ways of working together. For example, SERI, which has worked on solar energy applications for more than a decade, collaborated successfully with U.S. industry in an effort to catch up with Japan in the commercialization of amorphous silicon technology for solar cells. The SERI project lasted from 1984 to 1987 and had a 3-year budget of $19 million; four firms put up 30 percent of the funds. A second 3-year program, lasting through 1990, is now under way, and half of its $40 million funding is industry-supplied. In both programs, the firms are given patent rights and certain proprietary rights to data, enabling them to get a jump on the competition.[29]

DOE's HTS pilot centers, also run by Applied Energy, follow the targeting model. This experiment is discussed in box 7-B.

Until recently, DOE's Defense Programs viewed commercialization as a distraction from its mission of supplying the military's needs, but it has come to believe that the military would benefit from stronger civilian industries.[30] In 1989 it funded two lab-industry consortia for work on dual-use technologies (those having both military and civilian uses). One group, working to improve the quality of specialty metals such as nickel-based or titanium alloys, will use Sandia's specially instrumented research furnaces to monitor and control the production process. During 1989-94, government will provide $2 million and the collaborating companies will contribute $4.75 million. The industry share will increase steadily, rising to 100 percent after 5 years. The second consortium, the Advanced Manufacturing Technology Initiative, will work on next-generation manufacturing technologies such as advanced controller software and artificial intelligence. DOE has funded this project at $500,000 for fiscal year 1990, a level that will be maintained for four more years. DOE funds for the two projects rose from $400,000 in FY 1989 to $1.1 million in fiscal year 1990.

Several other lab-industry collaborations for dual use technologies are under consideration. These include projects on plasma destruction of toxic substances, combustion synthesis of ceramics, and ceramic metal composites. However, the two projects noted above will entirely exhaust Defense Programs' funds for such collaborations for fiscal year 1990.

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[27]U.S. General Accounting Office, *Technology Transfer: Implementation Status of the Federal Technology Transfer Act of* 1986, RCED-89-154 (Gaithersburg, MD: 1989), pp. 29-31.

[28]Energy Research Advisory Board, op. cit., p. 21.

[29]Ibid., pp. B5-B6.

[30]Military dependence on Civilian technology is discussed in U. S. Congress, Office of Technology Assessment, *Holding the Edge: Maintaining the Defense Technology Base*, OTA-ISC-420 (Washington, DC: U.S. Government Printing Office, April 1989).

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Box 7-B—DOE'S HTS Pilot Centers

As part of its research program in high-temperature superconductivity (HTS), the Department of Energy (DOE) started up HTS pilot centers at three of its national laboratories—Argonne, Oak Ridge, and Los Alamos—in October 1988.[1] These centers are planned as new ventures in lab-industry collaboration, a conscious experiment in rapid technology development and transfer.

Each center has government funding of $1,6 million for FY 1989 (total $4.8 million), and $2.0 million per center (total $6.0 million) is planned for FY 1990. In their first year of operation, the pilot centers negotiated 20 cooperative R&D agreements, with costs usually shared equally between the lab and industry. Industry was ready to join in many more projects than the centers could fund.

Several features of the pilot centers are designed to expedite technology transfer. First, the centers have a transfer-oriented mission and funds to accomplish that mission. The funds are spent only on projects requested by industry. The labs and industry plan to collaborate over the whole R&D cycle, from basic research through product development, with lessons from development fed back into research, Each center has an industry advisory board which DOE consults on the substance and procedure of lab-industry collaboration.

DOE has tried to speed up the negotiation process by offering a model collaboration contract, which carries automatic approval with changes requiring varying levels of clearance. At first, many firms found the model contract's terms unacceptable, but DOE has been revising the terms to meet the fins' objectives. DOE also agreed beforehand to waive rights to inventions made in pilot center research, to a greater extent than for cooperative R&D generally. Also, for work funded at least half by industry, DOE allows, on a case-by-case basis, the withholding of technical data from publication for up to 2 years. This delay, not generally allowed in DOE cost-shared research, can give the firm a valuable head-start in the market.

The HTS pilot centers experiment will be evaluated after 2 years. DOE is committed to applying the lessons learned to cooperative R&D in other programs,

[1]Los Alamos National Laboratory had recommended establishing these centers, when asked by DOE to study how to involve industry in developing HTS technology. John T. Whetten, associate director, Los Alamos National Laboratory, testimony at hearings before the House Committee on Science, Space, and Technology, Subcommittee on Energy Research and Development, July 27, 1988, Serial No. 100-122, pp. 90-91.

In some cases of lab-industry collaboration, DOE has put up all the money, with the private company acting essentially as a contractor. This was the case in the collaboration between Cray Research Corp. and Los Alamos National Laboratory. Cray pioneered the development of supercomputers. Its first and crucial customer was Los Alamos, which needed massive computing power to simulate the operation of weapons and nuclear power plants. Although Cray did most of the R&D and Los Alamos paid for it, the lab was more than a passive customer, spending several person-years studying Cray's machines and suggesting design changes to better suit the lab's needs. The lab's purchases were crucial to Cray's early survival. In 1976, when the company was on the verge of bankruptcy,[31] Los Alamos bought the first machine sold by Cray. By 1989, Los Alamos had bought 14 Cray machines, for a total price (net of trade-ins) of about $200 million.

Spin-Offs to Existing Firms

Lab work done for purely research or defense purposes sometimes turns out to have valuable commercial applications. Firms that make a point of staying in touch with the latest developments, in the government labs and elsewhere, can find out early about such promising research results and can adapt them to commercial purposes ahead of the competition. A firm's own engineers are in the best position to glean research results from outside labs, because they know their own product development cycle, and hence the best times for incorporating new ideas. However, monitoring the vast Federal labs system is difficult even for large firms and often impossible for smaller firms with more limited staff, Without help from the labs, they are not likely to benefit from spin-off. The labs can help in several ways.

[31]Cray had applied to the Securities and Exchange Commission in 1975 for permission to go public, but its application was rejected because SEC believed that there was no market for the Cray machine and the company would not survive.

Occasionally, DOE labs have encouraged spin-off by seeking out firms to apply the technology. For example, Los Alamos gave copies of its Common File System, software that lets different supercomputers share the same data, to several other government and commercial labs between 1980 and 1988. To ease the burden of supporting the software and also to reach a wider audience, Los Alamos found a private firm to develop the software into a commercial product, and in January 1989 concluded an exclusive licensing agreement providing for royalties and continued cooperation.[32]

Spin-off also takes place in less formal ways. Firms with technical questions often get modest amounts of free help from government labs. For example, Sandia receives 600 industry visitors per month and believes that its "free, helpful consultation" with industry is "probably the most productive and yet hard-to-quantify source of technology transfer by the laboratory."[33] For example, the lab has helped in designing high-pressure glass columns for liquid chromatography; assisted in testing the strength of metals; and provided manufacturers with new types of glass that it developed for sealing to metals.[34] Sandia staff even make house calls on occasion. In one plant visit, the lab staff showed a firm how to use new equipment to duplicate Sandia's superconductor fabrication process. This help, according to the firm, 'leaped us months ahead of schedule. '[35] In turn, Sandia staff also learn how their technology works in the field.

Startups

A lab's technology is sometimes commercialized not by an established firm but by a new firm started for that purpose. Startups often can get a new technology to market quickly and they may be more committed to the technology than established firms, but they may lack internal funding, experience in manufacturing, plant or equipment, and distribution channels. From 1985 to 1987, 87 startups were formed to commercialize technologies from DOE labs.[36]

Researchers may leave a government lab to head or work in the startups. Some labs encourage this by granting entrepreneurial leave, with the right to return to their old jobs within a stated time.[37] These labs see the movement of researchers into startup firms as a good way to commercialize technology quickly. However, some people are concerned that lab research teams could be depleted and also that labs might improperly favor their own researchers over established firms for commercializing the technology.

Some labs have gone farther in encouraging startups. The Tennessee Innovation Center (TIC) was formed in 1985 with $3.5 million from Martin Marietta Energy Systems, the operator of Oak Ridge National Laboratory .38 TIC provides numerous services to entrepreneurs, including office and lab space and help in forming business plans and incorporation. TIC typically contributes capital of $30,000 to $100,000 in return for a minority interest in the firm. Its stock in its most successful investment was worth about $7 million by June 1989.[39]

Another approach is offered by the non-profit ARCH Development Corp., formed in 1986 as an affiliate of Argonne National Laboratory and the University of Chicago. ARCH is given patent rights to virtually all inventions at Argonne and the University of Chicago.[40] It identifies those worth patenting, bears the expense of obtaining patents, and tries to license the inventions or, where it makes

32' 'General Atomics to Market Los Alamos Computer Software, ' Los Alamos National Laboratory Public Affairs Office, Jan. 26, 1989; Raymond Elliott, Computing and Communications Division, Los Alamos National Laboratory, personal communication, July 3, 1989.

33R. Geer, "Technology Transfer Is a Process of Quiet Matchmaking," *Lab News*, vol. 41, No. 12, June 16, 1989, p. 1; *Annual Report: Technology Transfer, Sandia National Laboratories, Fiscal Year 1987,* op. cit., p. 9.

34*Annual Report: Technology Transfer, San&a National Laboratories, Fiscal Year 1987,* op. cit., pp. 16, 23-25, 28-29.

35Letter from [author is confidential] t. Dr. Dan Doughty, Supervisor, Inorganic Materials, Chemistry Division 1846, Sandia National Laboratories, June 8, 1989.

36Energy Research Advisory Board, op. cit., p. 42.

37U.S. Department of Energy, *Technology Transfer Summary,* July 1988, p. 6; see also David Kramer, "Two Los Alamos Scientists Forma Spin-off To Develop New Cell-Probing 'Tweezers,'" *McGraw-Hill's Technology Transfer Report,* February 1989, p. 3.

38The funding in turn came from the management fee paid by DOE.

39Donald Jared, Program Administrator, Office of Technology Applications, Martin Marietta Energy Systems, Oak Ridge National Laboratory, personal communication, June 20, 1989.

40Since the University of Chicago, which operates Argonne, is a nonprofit organization, DOE waives its patent rights on request, with some exceptions. The waiver process is discussed later in this section.

good business sense, forms a startup firm itself to commercialize the invention. The startup's initial capital comes partly from a $9 million venture capital fund managed by ARCH, but ARCH usually waits to get additional capital from an unrelated party, as an objective check on the proposed company's worth. ARCH is seeking to replicate the environment at MIT and Stanford, which has done well in supporting startup fins. MIT, with its research budget of only $700 million and only seven professional staff working on patents and licensing, produces about the same number of licensing agreements and new firm startups as all of DOE's labs combined, with their government budget of more than $5 billion.[41] The success of MIT and Stanford owes much to the infrastructure of entrepreneurs, venture capitalists, business planners, lawyers, and bankers, which ARCH is seeking to replicate.

Other Forms of Technology Transfer

A common and relatively simple way of making lab technology available for commercial purposes is to let firms use the labs' specialized facilities. This is not a new idea. Before World War II the National Advisory Committee on Aeronautics made its wind-tunnels and other test facilities available to commercial aircraft companies, and NASA continued to do so after the war. Today, DOE's national labs allow private firms to use an array of expensive special-purpose facilities. In 1987, about 185 scientific facilities in the national labs were used by 1,623 industry and university participants.[42] As of March 1989, Brookhaven National Laboratory's two synchrotrons, set up as advanced X-ray sources, were being used by more than 80 American universities, 23 U.S. fins, 14 other government labs, and 22 foreign institutions.[43] The Combustion Research Facility at Sandia National Laboratories offers specialized lasers and computers for studying how fuels burn. Its users include General Motors, Ford, Chrysler, Exxon, Mobil, Conoco, Unocal, Combustion Engineering, AT&T, and GE.[44]

The Federal labs are also putting new emphasis on technology transfer in their formal communications—published papers, conferences, and so on. Several of DOE's national labs, for example, publish semi-technical brochures to acquaint industry with technologies which may be of interest. Meetings and workshops focused on technology transfer are increasingly common.

The Federal Laboratory Consortium (FLC), composed of representatives from Federal laboratories, also promotes communication with industry .45 The FLC guides firms into the Federal lab system, showing them where to go for help on a particular problem--often within a day or so of the initial inquiry. In conjunction with the Industrial Research Institute, the FLC held lab-industry conferences to identify possible areas of collaboration in manufacturing technology (in 1988) and in hazardous waste management (in 1989). The FLC also funds projects to demonstrate technology commercialization. For example, the University of Utah has a database on specific interests of high-technology firms, using it to market the University's own inventions. The FLC paid the university to adapt this database for experimental use by three Federal labs. Finally, the FLC, the Department of Commerce, and DOE all maintain computerized general-purpose databases on technologies of possible interest to industry. Some of the labs also maintain specialized databases, such as one on superconductivity at Oak Ridge National Laboratory.

Many of the mechanisms described above rest implicitly or explicitly on personal contact between lab employees and private industry, and indeed the exchange of personnel between labs and industry offers another mechanism for technology transfer. Lab researchers can take sabbaticals or visiting positions to spend time (perhaps a year or two) in an established company, and vice versa—with benefits both of immediately transferring information in both directions and developing personal contacts for the future. Such formal exchanges have been rare in the

41 John T. Preston, Director, MIT Technology Licensing Office, ''Creating New Companies and Business Units Within Existing Companies via University License Agreements, " presented to the European Venture Capital Association 1987, modified April 1989; Senator Pete V. Domenici, testimony at hearings before the Senate Committee on Energy and Natural Resources, Subcommittee on Energy Research and Development, May 11, 1988, Serial No. 100-602 (Part 2), pp. 3-4.

42 Energy Research Advisory Board., Op. cit., pp. 21, 61.

43 David Kramer, "For Hire: Lab Facilities," *McGraw-Hill's Tech Transfer Report*, March 1989, p. 1

44 Ibid.; *Annual Report: Technology Transfer, Sandia National Laboratories, Fiscal Year 1987*, op. cit., p. 8.

45 Originally established by the Defense Department in 1971, the FLC evolved as an informal coordinating group until it was given an official mandate by the Federal Technology Transfer Act of 1986 (see 15 U.S.C. 3710(e)).

national labs. In 1987 just 19 industry researchers came to them, and 4 lab scientists went to companies, in an exchange program underwritten by DOE. However, about 400 more industry scientists and engineers worked less formally at the national labs at some time in 1987, using funds from industry and DOE R&D programs. Lab researchers can also serve as consultants to industry-a practice that increased in the 1980s (from 266 consulting projects in 1981 to 697 in 1987).[46]

Barriers to Technology Transfer

A number of factors limit the Federal labs' transfer of technology to industry. There are problems related to the labs' historical mission, the bureaucracies that run the labs and supervise them, and the nature of technology transfer itself (especially in the area of exclusive rights). Industry itself is not blameless: for example, both U.S. universities and foreign corporations send more visitors to the labs than does U.S. industry .47

Mission--The lion's share of DOE labs' funding comes through the Defense and Energy Research Programs. For these programs, commercialization tends to be low priority. In contrast, DOE's Applied Energy projects are usually planned with commercial application as an integral part of their mission, and it is on the whole accomplished effectively. However, Applied Energy has a small and declining share of DOE lab funding.

Funding-Technology transfer does not come cheap. Identifying technologies with commercial possibilities, finding firms that might be interested, and exchanging information with those firms take time and effort, but are necessary parts of aggressive technology transfer. Negotiating terms with firms interested in licenses—and fighting through red tape back at the lab or agency—takes still more effort, indeed probably requires some full-time technology transfer staff. Encouraging startup firms can also be expensive. Patenting is also expensive, especially outside the United States. And if the labs go in for collaborative R&D projects with industry, the labs' share must be funded--often a a level greater than could be justified by the labs' defense or basic research missions.

On the whole, DOE's technology transfer effort has been underfunded. Collaborative R&D has rarely been funded outside the Applied Energy programs and technology transfer offices have been thinly staffed. DOE is not alone in this. DoD, for example, has required its labs to fund technology transfer activities out of overhead.[48]

Lab directors and agencies can hardly be expected to embrace technology transfer enthusiastically if they have no money to pay for it, or have to rob Peter to pay Paul. Low spending is also a signal. Skimpy funding leads companies to question the labs' commitment.[49] Dependability is important too. Delays in expected funding have caused industry to view the labs as unreliable collaborators.[50] In addition, firms may hesitate to pledge themselves to multi-year projects when the government will commit funds only year by year.

Incentives—Incentives for collaboration in the labs are sometimes weak or even negative. Time spent answering a fro's questions is usually time spent away from research; and help to industry does not always count in a researcher's performance evaluation, even though the law specifically directs

[46]Energy Research Advisory Board, op. cit., pp. 21-22. Only 45 industry researchers visited the DoD labs in 1986, while 291 visited the much smaller NIST (then called NBS) labs; U.S. General Accounting Office, Technology Transfer: U.S. and Foreign Participation in R&D at Federal Laboratories, RCED-88-203BR (Gaithersburg, MD: U.S. General Accounting Office, 1988), p. 20.; Rees L. Dwyer, III, Executive Assistant to the Assistant Secretary, Management and Administration, Department of Energy, personal communication, Jan. 4, 1990.

[47]David Kramer, "Trivelpiece: Visits Give Rise to Tech Transfer," *McGraw Hill's Tech Transfer Report,* March 1989, p. 5.

[48]U.S. Department of Defense, Office of the Inspector General, Report on the Audit of the DOD Domestic Technology Transfer Program, Report No. 90-006, Oct. 19, 1989, pp. 8-9.

[49]John Whetten, acting director, Los Alamos National Laboratory, testimony at hearings before the House Committee on Science, Space, and Technology, Subcommittee on Energy Research and Development, July 27, 1988, Serial No. 100-122, p. 90.

[50]William Black, Jr., Senior Vice President, Biomagnetic Technologies Inc., testimony at hearings before the House Committee on Science, Space, and Technology, Subcommittee on Energy Research and Development, June 23, 1988, Serial No. 100-118, pp. 79-80; William Gallagher, manager, Exploratory Cryogenics, Thomas J. Watson Research Center, research division, International Business Machines Corp., testimony at hearings before the House Committee on Science, Space, and Technology, Subcommittee on Energy Research and Development, June 23, 1988, Serial No. 100-118, p. 156; Harold Hubbard, Director, Solar Energy Research Institute, testimony at hearings before the House Committee on Science, Space, and Technology, Subcommittee on Energy Research and Development, July 27, 1988, Serial No. 100-122, p. 97.

that it should.[51] Collaborations with industry maybe unattractive if the work is proprietary and the researcher cannot publish his results. In addition, time that researchers spend on sabbatical in industry is often not counted as pensionable.

Recently, researchers and their labs have been permitted to keep portions of patent royalties paid for their inventions. While the amount of money is often modest, it does offer recognition for work that is useful to industry .52 Some agencies and labs provide added incentives. At least one lab (Oak Ridge National Laboratory) sets aside an extra 4 percent of royalties to reward lab researchers other than those named as inventors on licensed patents for extraordinary contributions to technology transfer.[53]

Slow ***Negotiations--Speedy*** negotiations for licensing of technology, and also for collaborative R&D (which typically includes licensing provisions), are important to fins. They have to fit innovations into their product development schedules and hold on to earmarked funding (their own or investors'). Delays can cause deals to collapse as the firm's strategic situation changes, or the people involved move on. Startups are especially vulnerable.

Negotiations with labs can often take many months. Some delay may be hard to avoid but some is caused by bureaucratic slowness and government reluctance to grant exclusive rights. Both are largely avoidable. Reviews by agency headquarters that convert two-way negotiations between a lab and a firm into three-way negotiations have often been the culprit.[54] For GOGO labs, agency review of collaborative R&D agreements was in principle short-circuited by the Federal Technology Transfer Act of 1986[55] and an Executive Order in 1987,[56] which respectively permitted and required agency heads to delegate to lab directors the authority to negotiate collaborative R&D agreements, subject to agency veto within 30 days. However, many agencies have been slow to implement this delegation.[57] Moreover, these provisions did not apply to DOE's GOCO labs. After complaints by labs and industry about DOE red tape, Congress in November 1989 amended the law to permit similar delegation of authority to GOCO labs.[58] DOE will probably make such a delegation.[59]

Exclusive Rights—Many delays revolve around the companies' desire for exclusive rights, to help recover the cost of expensive R&D efforts. Exclusive rights may also carry certain social costs, including higher prices and reduced use of the technology by others.[60] These costs and benefits must be balanced case by case.[61] This sort of decision might be made by the labs themselves, subject to agency guidelines and audits. However, in many cases the labs' hands are tied.

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51 The Federal Technology Transfer Act of 1986 directs lab directors to "ensure that efforts to transfer technology are considered positively in . . . evaluation of. . . job performance." 15 U.S.C. 3710(a).

52 The Federal Technology Transfer Act of 1986 allows researchers in GOGOs to collect 15 percent of the royalties from their patents, Up to $100,000 per year. Many agencies, including DoD, voluntarily give inventors a greater share. The lab gets much of the rest. Many of DOE's GOCO labs also give the inventors a share of patent royalties. U.S. Congress, General Accounting Office, Technology *Transfer: Implementation Status of the Federal Technology Act of 1986,* op. cit., pp. 37-38; Energy Research Advisory Board, op. cit., p. 44; U.S. Department of Energy, *Technology Transfer Summary,* July 1988, p. 5.

53 Clyde Hopkins, President, Martin Marietta Energy Systems, Inc., testimony at hearings before the House Committee on Science, Space, and Technology, Subcommittee on Energy Research and Development, Mar. 25, 1988, Serial No. 100-136, p. 45.

54 Joseph Allen, director, Office of Federal Technology Management, U.S. Department of Commerce, personal communication, Mar. 9 and 21, 1989.

55 See 15 U.S.C. 3710a. This authority applies only to projects in which the lab contributes only personnel, services, facilities, equipment or other in-kind resources; the lab cannot pay money to its industrial partners.

56 Executive Order 12591, Apr. 10, 1987.

57 U.S. Congress, General Accounting Office, *Technology Transfer: Implementation Status of the Federal Technology Transfer Act of 1986,* op. cit., pp. 23-30; U.S. Department of Defense, Office of the Inspector General, op. cit., p. 10.

58 National Competitiveness Technology Transfer Act of 1989, Public Law 101-189, Sec. 3133 (amending 15 U.S.C. 3710a).

59 DOE had previously supported a bill which would have made such delegation mandatory for the national labs. (The bill was not enacted.) Letter from John Herrington, secretary, U.S. Department of Energy, to Senator Pete Domenici, Sept. 28, 1988, supporting S. 1480, as reported in Senate Report No. 100-544, Sept. 23, 1988. See Sec. 205.

60 These costs and benefits apply to intellectual property protection (patents, copyrights, trade secrets) in general, not just in lab-industry agreements; see the section below entitled Intellectual Property,

61 Exclusive rights can often be limited to a particular application of the technology. For example, an engine manufacturer might be given the exclusive right to use a patented alloy ***in engines,*** but be given only a nonexclusive right, or no right at all, to use the alloy in other products.

. *Patents.* In order for DOE labs to give firms patent rights, DOE must generally first waive those rights. In the past few years, labs have experienced long waits in obtaining waivers. It appears that it typically took 6 to 12 months from the lab's application until DOE approval. In early 1989 DOE's patent counsel worked to eliminate any backlog of applications over 6 months old, but the waiting times have again grown longer pending resolution of policy issues. Some labs have complained about the paperwork DOE requires for waivers. DOE's view has been that it is required by statute to consider certain factors in granting waivers.[62]

In the Bayh-Dole Patent Amendments Act of 1984, Congress tried to cut this red tape for DOE's labs with non-profit operators. The Act provided that, with certain exceptions, these labs need not apply for waivers but can simply claim the right to government-funded inventions.[63] Congress specifically exempted inventions that are classified for security reasons (for which DOE rarely if ever grants waivers anyway), and also unclassified inventions at defense-oriented labs that relate to weapons or naval nuclear propulsion. Congress also permitted DOE to exempt other inventions under "exceptional circumstances."[64] After DOE implemented this provision in its operating contracts with these laboratories,[65] DOE had disagreements with the Commerce Department and the University of California over the proper scope for DOE's 'exceptional circumstances" exemption.

DOE has supported extending the Bayh-Dole approach to national labs with for-profit operators,[66] and also to unclassified weapons inventions unless they are designated as sensitive technical information-all subject to guidelines and safeguards such as restricting the use the operator may make of royalties.[67] However, this legislation was not enacted.

- *Proprietary Rights.* The right to keep data proprietary may be as important as patent rights to firms. Until recently, the Freedom of Information Act (FOIA) was a major obstacle, at least calling into serious question an agency's ability to keep secret the results of collaborative R&D. This discouraged firms from participating.[68] However, Congress recently largely removed this obstacle, exempting the results of collaborative R&D from release under FOIA for 5 years-usually enough time to get a head start in the market.[69] DOE's organic statute (the provisions that set up DOE and its predecessor agencies) provides that DOE should not hinder the dissemination of technical data.[70] The courts have not ruled on how this might apply to results of collaborative research. DOE believes that the Act might apply, but only to data actually in the custody of DOE or the lab.
- *Copyright of Software.* Firms that develop government software into a commercial form or who collaborate with the government to create software are also likely to insist on exclusive rights. Often secrecy is not practical, as software can be duplicated once it exists. Copyright could provide effective protection. However, it is generally not possible in collaborations with or licenses from a GOGO, because material developed in whole or part by govern-

62The law instructs DOE t. follow the goals of promoting Commercialization, fostering competition, making the benefits of R&D widely available in the shortest possible time, and encouraging fiis' participation in DOE research, and to consider such factors as the firm's investment, ability to contribute to research or commercialization, and the need to grant rights as an incentive to participation. See 42 U.S.C. 5908.

6335 U.S.C. 202(a). Although AT&T Technologies, the AT&T subsidiary that runs Sandia, takes no management fee, it is considered a for-profit firm for this purpose.

6435 U.S.C. 202(a); see also 35 U.S.C. 200.

65See Energy Research Advisory Board, Op. cit., p. 49.

66These include Martin Marietta Energy Systems, Inc., which operates Oak Ridge; AT&T Technologies, which operates Sandia; and EG&G Idaho, Inc., Westinghouse Idaho Nuclear Co., Inc., and Rockwell-INEL, which operate Idaho National Engineering Laboratory.

67Letter from John Herrington, secretary, U.S. Department of Energy, to Senator Pete Domenici, Sept. 28, 1988, supporting S. 1480, as reported in Senate Report No. 100-544, Sept. 23, 1988. See Sees. 207,209.

68U.S. Congress, General Accounting Office, *Technology Transfer: Implementation Status of the Federal Technology Transfer Act of 1986*, op. cit., p. 49; US. Congress, General Accounting Office, *Technology Transfer: Constraints Perceived by Federal Laboratory and Agency Officials*, op. cit., pp. 15-17.

69National Competitiveness Technology Transfer Act of 1989, Public Law 101-89, &x. 3 133(a)(7) amending 15 U.S.C. 3710a.

70The law states, for example, that arrangements for conducting research shall not "contain any provisions or conditions which Prevent the dissemination of scientific or technical information except to the extent such dissemination is prohibited by law. " 42 U.S.C. 2051.

ment employees is not copyrightable.[71] Hence, officials at several labs and agencies favor changing the law.[72]

This problem does not arise in GOCO collaborations, since GOCO lab staff are not government employees. However, DOE initially permitted firms to copyright software created partly by a lab only if the firm agreed to deposit the source code for public inspection—which firms were sometimes unwilling to do. In 1989, DOE changed its policy to permit fins, on a case-by-case approval, to make public only an abstract of the software.[73]

Additional Concerns—Even if labs and parent agencies make it a part of their mission to put government research at the service of industry, and if they get funds for the purpose, other concerns still can stop efforts to promote commercialization unless a strong voice within the agency favors such efforts. Moreover, balancing other concerns, such as U.S. national security, against the benefits of commercialization is likely to require intra- and interagency coordination and indeed Presidential leadership.

One concern is fairness. In offering licenses to technology and opportunities for collaborative work, labs and parent agencies try to avoid favoring particular fins. The practical matter of avoiding lawsuits or complaints to Congress is involved, as well as the ethical issues of fairness. But attempts to be fair can slow commercialization.[74]

Also, lab-industry collaboration has the potential for conflicts of interest. For example, the collaborating lab researcher may also have done private consulting for the firm, may have once worked for the firm, or may seek royalty payments for himself or the lab from the firm. Guarding against conflicts of interest takes careful planning and judgments. Agencies without a strong commitment to technology transfer might prefer to avoid the whole problem.

Some labs, such as NIH, place a high value on free exchange of ideas within the lab and with people outside. This poses problems for collaborations involving proprietary research with industry .75

National security needs may also clog the free flow of information out of the labs. In response to this problem, DOE's Defense Programs office assigned responsibilities for information security and technology transfer to the same staff, thus helping to ensure that the two concerns are fairly balanced. Sandia did the same.[76]

Finally, there is the tricky double problem of defining a U.S. firm and determining Federal lab policy toward non-U.S. firms.

General Applications

The **story** of the DOE labs has implications for all the Federal labs, despite the differences among them. One is simply that technology transfer can be done. There are some success stories from DOE, most of them rather unpublicized. Technologies did emerge from the labs and were exploited by U.S. fins, often with help from the labs. On the other hand, the story also suggests that even the DOE labs, which have faced considerable congressional scrutiny on this issue in recent years, have a long way to go in improving their performance.

The HTS pilot projects illustrate both sides of the story. DOE took significant steps forward in setting up the projects and committing to apply the lessons that may emerge from them to other lab programs. However, the process is likely to be a slow. The experiment lasts ***2 years,*** evaluation will take time, the development of DOE-wide policy will take longer, and implementation of that policy will take longer still. This is in the nature of the beast, and DOE should not be faulted for working methodi-

[71] 17 U.S.C. 105, 101.

[72] U.S. Congress, General Accounting Office, *Technology Transfer: Implementation Status of the Federal Technology Transfer Act of 1986*, op. cit. > pp. 48-49; U.S. Congress, General Accounting Office, *Technology Transfer: Constraints Perceived by Agency Officials*, op. cit., pp. 11-12.

[73] According t. DOE's counsel, it is possible that a court would nevertheless compel disclosure of the entire source code under the DOE's organic statute. Richard Constant, Assistant General Counsel for Patents, U.S. Department of Energy, personal communication, Feb. 23, 1989. However, DOE's position is that publication of the abstract satisfies the agency's dissemination requirement.

[74] U.S. ConHess, General Accounting Office, *Technology Transfer: Implementation Status of the Federal Technology Transfer Act of 1986*, RCED-89-154 (Gaithersburg, MD: May 30, 1989), pp. 49-50. In general, collaborative R&D agreements contracts are not subject to the stringent fairness requirements of government procurement contracts.

[75] U.S. Congress, General Accounting Office, *Technology Transfer: Constraints Perceived by Agency Officials*, op. cit., p. 17.

[76] *Annual* Report: *Technology Transfer, Sandia National Laboratories, Fiscal* Year 1987, op. cit., p. 9.

cally. However, the process could easily take 4 to 5 years-the equivalent of two generations of products in some high-technology sectors.

Attitudinal barriers need to be further dismantled as technology transfer becomes an organic element of most programs, rather than remaining the province of isolated specialists or even special programs (like Applied Energy at DOE). Commercialization needs to be supported with funding, which includes funds for appropriate people. For example, the recent Inspector General's report on the DoD labs highlights the paucity of patent lawyers, leading to a backlog of applications and hence of technology transfers that cannot be made until applications have been filed. Legal obstructions need to be addressed, such as the problems surrounding software copyrights and DOE's ability to maintain proprietary information. Also, authority must be delegated to levels low enough to get the job done. DOE's labs have suffered long delays at agency headquarters and, according to the Inspector General's report, the DoD has not delegated sufficient authority or given policy guidance to a low enough level in the DoD hierarchy.

There are many reasons-financial, legal, practical, and philosophical-why the gears still grind slowly in bringing new technologies out of Federal labs and into manufacturing companies. It is much easier for both labs and parent agencies to go on doing things the traditional way than to tackle new problems in government-industry interaction— such as justifying extra funding for technology transfer, wrestling with conflict of interest issues, or negotiating collaborative research. It is also evident that real difficulties stand in the way of making the necessary changes. The labs' success in transferring technology will depend very much on funding for this purpose and on the will and attitude of senior lab managers and top officials of parent agencies, along with continued leadership from Congress and the President.

ENGINEERING RESEARCH CENTERS

The idea of creating university-based, multidisciplinary engineering research centers (ERCs) came out of discussions in 1983 between the National Science Foundation (NSF), the National Research Council, and the President's Office of Science and Technology Policy.[77] It was hoped that these center% would help the performance of U.S. industry by strengthening some of the weak links in American engineering: the link between engineering education and the real world of manufacturing, the link between university engineering research and industry engineering problems, and the links between the engineering disciplines.

NSF began to setup the program in 1984, and by 1988 had funded 18 ERCs at an average of about $2 million per center annually .78 (Box 7-C lists the ERCs and their areas of research.) The NSF funds cover about half the costs. Industry contributes about one-third, and the rest comes from university, State, and local finds. Each center gets NSF funding for an initial 5-year period, with a review after the third year. If the evaluation is positive, the ERC gets 5 more years of funding, starting with year four. Another review after the sixth year leads (if it is positive) to a final 5 years' funding from NSF—a total of 11 years, after which the ERC has to compete for new funds with proposed centers or else find some other source of money.

For an innovative n-year program that was deliberately planned with a long time horizon, it is too early to draw definitive conclusions about the program's success in meeting its goals. A few observations based on experience so far are in order.[79]

Overall, the centers have attracted impressive levels of financial support and participation from industry—a crucial element in their success. Individual centers get from 9 to 61 percent of their funding from private companies, and about 420 companies are taking part. However, most of the

[77] Much of the material in this section is drawn from Philip Shapira, "The National Science Foundation's Engineering Research Centers: Changing the Culture of U.S. Engineering?" contract report to the Office of Technology Assessment, March 1989. Additional material is drawn from David Sheridan, "The Engineering Research Centers," contract report to the Office of Technology Assessment, June 1989.

[78] In January 1990 three more ERCs were established.

[79] These observations are based on interviews with NSF officials, and site visits to ERCs at four universities, including interviews with faculty members, students, and industry participants in the ERCS. The universities were Carnegie-Mellon, the University of Illinois at Urbana, the University of Maryland, and Purdue. For more details of the visits and interviews, see Philip Shapira, op. cit.

Box 7-C—The National Science Foundation Engineering Research Centers

In June 1984, the National Science Foundation (NSF) invited proposals for the creation of Engineering Research Centers (ERCs). The Foundation received *142* proposals from over 100 universities. Six centers were selected in 1985:

- Columbia University, telecommunications
- Massachusetts Institute of Technology, biotechnology process engineering
- Purdue University, intelligent manufacturing systems
- University of California-Santa Barbara, robotics systems in microelectronics
- University of Delaware, composites manufacturing
- University of Maryland/Harvard University, systems research

Another round of 102 proposals was evaluated in 1986; NSF awarded five additional ERCs:

- Brigham Young University, University of Utah, advanced combustion
- Carnegie-Mellon University, engineering design
- Lehigh University, large structural systems (for construction)
- Ohio State University, net shape manufacturing
- University of Illinois, compound microelectronics

In 1987 three more centers were designated:

- Duke University, emerging cardiovascular technologies
- University of California-Los Angeles, control of hazardous wastes
- University of Colorado/Colorado State University, optoelectronic computing systems

in the fourth round, 1988, four more centers were awarded:

- North Carolina State University, advanced electronics materials processing
- Texas A&M University, University of Texas-Austin, offshore technology for recovery of oil and other resources
- University of Minnesota, interracial engineering
- University of Wisconsin—Madison, plasma-aided manufacturing

In 1988, the third year review of the first generation of ERCs resulted in decisions to phase out two centers-Delaware and Santa Barbara--over the following 2 years. The other four original centers were continued for another 5 years.

And in January 1990, three more centers were added:

- University of Montana, interracial microbial proves engineering
- Mississippi State University, geometrically complex field problems
- Carnegie-Mellon University, data storage systems center

companies are large (over 500 employees). The program does not reach many small or medium-size firms.[80]

Industry participation ranges from short-term help with specific problems, to recruitment of well-trained engineering graduates, to collaborations in long-term strategic research (e.g., several firms are participating in the optoelectronics program with the two Colorado universities, as a way of getting into future generations of semiconductor manufacture and application). The centers that have been in operation for more than a couple of years can all cite specific examples of technology transfer to industry. For instance, an advanced engineering design system developed at the Carnegie-Mellon Center is now being used by General Motors. Most of the technology transfers so far. though, have tended to be highly specific technologies. For example, a performance analysis workstation developed at the University of Maryland center has been commercialized by AT&T-SUN. NSF hopes that the centers will develop ''whole new technology systems rather than pieces of systems. '

[80] An exception is MIT's biotechnology program, In this field, many of the leading companies are small

While comments by industry representatives on the ERCs were nearly all favorable, observations by university faculty members on industry's involvement were more mixed. Many faculty members emphasized that contacts with industry had a positive influence on their own research, and that the program had established new relationships or enriched existing ones. On the other hand, some faculty members criticized industry's short-term outlook and unstable participation. Some (not all) companies seemed interested only in getting immediate answers to particular problems and avoided risky or long-term research. More generally, ERC faculty were concerned about the constant turnover of industry representatives, which obliges them to keep training new industry people. Said one: 'There is a constant educational process. '

The evidence so far shows the ERCs are making good progress in educating engineers in new ways. They are giving students opportunities to work with industry while they are in training; exposing them to an array of engineering disciplines and methods; giving them access to sophisticated research facilities; and fostering an interest in manufacturing. ERC graduates seem to have little trouble finding jobs, and in several cases corporate sponsors have actively recruited students before they graduated. Some of the students fear, however, that they will not be properly recognized by industry since their education has broken the mold of traditional disciplinary boundaries.

The number of students affected by the program is still small. In most of the universities with ERCs, only about 1 percent of engineering undergraduates are taking part in the ERC program (MIT, with nearly 14 percent undergraduate participation is a notable exception); between 2 and 14 percent of engineering graduate students in universities with ERCs are participating. And only 18 of the 280-plus U.S. colleges and universities offering engineering education have ERCs.

The ERCs have far less funding from NSF than originally planned, and this has caused problems for some of the centers. Individual ERCs are getting $300,000 to $1 million less per year than expected. Some have been able to makeup the difference from industry contributions, but others have had to reduce the scope of research and cut funds for equipment and students. One ERC director said that the shortfall in funding had curtailed efforts to build relationships with smaller businesses, and forced him to spend more time in fund-raising and less in research. It is possible that the industry share of ERC funding will continue to rise. However, companies tend to emphasize short-term projects, and their support over the long term is uncertain. In a survey by the General Accounting Office of companies sponsoring ERCs, 85 percent of respondents said they would continue support for the following year, but only 41 percent were willing to commit support 4 years in the future. Thus, it is likely that with greater industry funding would come less stability and more pressure for short-term results.

The ERC program is mostly at the research end of the R&D spectrum in industry. Whether it will lead to successful commercialization of new products or manufacturing processes is unknown. On this point, there is some skepticism within the program itself. As one ERC program manager with NSF said: "I think the ERCs will make clear the next generation of technology systems in their particular areas of research, but who in the United States will be capable of manufacturing those new technologies?' A faculty member at the University of Illinois ERC said: "It will be Sony, Toshiba, and other Japanese companies that will commercialize it. '

Possibly the ERCs' biggest impact on industry will be the caliber of the engineering students turned out. ''When they move into industry," said one NSF official, "those engineering students will be well prepared to take on the engineering problems of industry in a real world industrial context. " He added: "I look for them to move into management eventually where they will make their greatest contribution. About half the managers in Japan have a technical background, but the proportion in the U.S. is much lower. I'm hopeful the ERCs will play an important role in correcting this imbalance. '

TAPPING INTO JAPANESE TECHNOLOGY

Until recently, U.S. industry gave rather scant attention to research results and new technologies developed in Japan, for several reasons. First, many people in U.S. industry were hard to convince that Japanese technology had much to offer. This skepticism is now rare. Second, much of the Japanese superiority stems from excellence throughout the manufacturing process, and this involves things that are hard to copy. It is no easy matter to imitate a whole interrelated system of organizing work and managing people. However, many U.S. managers are trying to adopt various aspects of Japanese manufacturing practice, and some are making headway.

Today, interest in Japanese technology goes beyond the factory into the laboratory. Japanese engineers and scientists are adding strength in research to their proven abilities to adopt foreign technologies and improve on them. Thus, keeping up with research results from Japanese labs is taking on new importance.

People-to People Technology Transfer

The Japanese have long been adept at keeping up with foreign scientific and technological research by sending people to study in other countries. For years, a great many Japanese scientists and engineers have undertaken graduate studies in American universities, attended scientific meetings in the United States, visited U.S. national laboratories, and won fellowships in U.S. Government laboratories. But the flow has mostly been one way. For example, in 1988 there were over 6,700 Japanese scientists and engineers working in U.S. Government and university facilities. The number of Americans working in Japanese labs was probably 800 at most.[81]

Several factors account for the meager presence of technically trained Americans in Japan. First, U.S. engineers have not been particularly eager to work in Japan. Not many speak Japanese and until quite recently, few were interested in learning it. For those engineers and scientists who do want temporary assignments in Japan, high living costs and the difficulty of finding jobs for spouses are other important obstacles. Moreover, very few U.S. companies or institutions have wanted to send technical people to Japan for extended stays, nor do they especially reward scientists and engineers who have experience in Japan. For example, MIT graduate engineers who take MIT-sponsored internships in Japanese Government, industry, or corporate labs usually find on their return that they are hired on much the same terms as engineers with no Japanese experience or Japanese language.[82] However, the personal relationships the interns form in their year or two in Japan may prove of great importance over the years in learning about the latest Japanese advances in technology. One company manager said that these young people may well turn out to be the industry leaders 25 years later.

The nature of Japanese institutions also deters U.S. researchers from doing work there. Much R&D in Japan—including some of the best—takes place in private industry, and since a good deal of this work is proprietary, acceptance of outsiders in corporate labs can be difficult. In government and university labs, the quality of basic research has been uneven, very good in some fields but less so in others. Furthermore, foreign researchers' access to government labs was rather limited until recently. In the United States, university and government labs have the reputation for consistently high-quality work. Positions in the United States interest foreign researchers, and foreigners are generally welcome. Japanese scientists win many of these positions on merit, often drawing stipends from the U.S. Government.[83]

Since 1962, the United States and Japan have had bilateral exchange programs in the field of science and technology. The U.S.-Japan Cooperative Science Program, established by executive agreement that year, has supported hundreds of joint seminars and short-term cooperative research projects ever since. In the late 1980s emphasis in these bilateral exchanges shined to longer term projects and more research by American scientists and engineers in Japan. A new agreement signed in 1988 reflected this changed emphasis.[84]

[81] National Science Foundation, Statistical Research Services.

[82] Under its Japan Science and Technology program, the Massachusetts Institute of Technology has sponsored 1-or 2-year internships in Japan since 1983. Returning interns reported to an OTA-MIT workshop in 1988 that, while employers took a positive view of the interns' Japanese experience, they were not always interested in making immediate use of that experience, or able to do SO. Representatives of American companies that support the MIT program confirmed the point; the interns are treated like other newly hired engineers and are expected to fit into existing patterns of work assignment and rewards. (U.S. Congress, Office of Technology Assessment, *Technology Transfer to the United States: The MIT-Japan **Science and Technology Program,*** background paper, April 1989).

[83] For example, 327 Japanese did research at the National Institutes of Health in 1986-87, compared to 72 West Germans and 68 French. Stipends for five out of six Japanese werepaid by the NIH, at a cost of $6,8 million; fewer than half of the Germans and two-thirds of the French got NIH stipends. See Marjorie Sun, "Strains in U.S.-Japan Exchanges," ***Science,*** July 31, 1987.

[84] The Agreement Between the United States of America and Japan on Cooperation in Research and Development in Science and Technology, first signed in 1980 and revised in 1988.

One goal of the U.S. negotiators in the new agreement was "equitable contributions and comparable access to each Government's research and development systems."[85] In 1988, the Japanese Government established two award programs to bring as many as 100 young (under 35) post-doctoral or master's-degree American scientists and engineers to Japan each year for research lasting 6 to 24 months. Placements are in university and government labs, some of which rank as world leaders (e.g., the Institute for High Energy Physics at Tsukuba). The awards pay for airfare to Japan, travel within Japan, a stipend, housing and family allowances, medical insurance, and Japanese language instruction. Each award is worth about $50,000 per year; 100 awards would amount to about $5 million per year.

In addition to founding these two programs, the Japanese Government also made a one-time gift of $4.8 million in 1988 to enable U.S. investigators to do research in Japan.[86] The National Science Foundation administers the fund, using it mostly for long-term visits for U.S. researchers (of any age, not limited to post-docs) in all kinds of Japanese labs—university, government, or corporate-with whom NSF concludes agreements. For example, NSF has an arrangement with the Japanese Ministry of Industry and International Trade (MITI) to offer U.S. applicants up to 30 research spots per year in the 16 laboratories directed by MITI's Agency of Industrial Science and Technology.

NSF also provides awards covering tuition, fees, and a stipend for researchers undertaking intensive study of the Japanese language. The program is primarily for graduate or post-doctoral scientists and engineers, but is also open to senior researchers, including people in industry; it can accommodate about 50 people per year. In addition, NSF supports programs at four universities to improve the teaching of Japanese, and about 50 more individual students get tuition and stipend awards in connection with these programs. Altogether, NSF set aside $800,000 in fiscal year 1988 for its Japanese Initiative programs, and $725,000 in 1989; spending in 1990 is expected to stay at the 1989 level. Most of the NSF funds are spent for bilateral seminars, short-term visits, and the Japanese language programs.

In late 1989, NSF spokesmen said that the Japanese language programs were oversubscribed and ''competitive, '' and that qualified people are being turned down. Participation in the new programs for long-term visits and research in Japan was spottier. NSF estimated that of the 100 places available from April 1989 to March 1990 in the two Japanese Government programs, about 60 to 65 would be filled. NSF's own program supporting long-term visits to Japan has had 18 participants since May 1988, but some seemingly attractive spots have had few takers. For instance, only one of the 30 slots offered in the MITI labs was occupied in 1989. None of a possible three posts in the Fifth Generation project was filled (one was the previous year). Only one researcher so far has been posted to a Japanese corporate lab.

The reasons mentioned above—the high cost of living in Japan and ignorance of the Japanese language—are still important deterrents to many potential candidates. The age limitation may be another; American researchers find it easier to take a year abroad when they are already established in academic or research positions than when they are just starting out. But a major factor may be unfamiliarity. These programs are barely more than 1 year old. As their reputations grow, they could fill up, as have some of private programs that sponsor placement of U.S. engineers and scientists in Japan. One of these is the Japan Science and Technology Program of the Massachusetts Institute of Technology, which sends MIT graduate engineers and scientists to corporate, government, or university labs in Japan for 1- or 2-year internships. In its first 6 years, 1983-89, the MIT program had 53 participants (an average of fewer than 10 per year). In 1989-90, it sent 47 interns to Japan.

Even assuming fairly rapid growth, all these programs together, public and private, will send only a few hundred researchers to Japan per year. Adding in those who go on their own, the numbers are still small compared with the thousands of Japanese

[85] Letter from the Honorable George P. Shultz, Secretary of State of the United States of America, to His Excellency, Sousuke Uno, Minister for Foreign Affairs of Japan, June 20, 1988; letter from Mr. Uno to Mr. Shultz, June 20, 1988. See also the Omnibus Trade and Competitiveness Act of 1988, which directed that federally supported international science and technology agreements should ensure "equitable and reciprocal" access to technological research, to the maximum extent practicable (Public Law 1O(M18, Part II, Sec. 5171, "Symmetrical Access to Technological Research").

[86] The gift was arranged by then Prime Minister Takeshita.

scientists and engineers who study and work in the United States. Moreover, relatively few Americans in other fields related to industry and technology—economics, business administration, current business experience-spend time in Japan acquainting themselves with Japanese management and business practice. A few university programs (e.g. Stanford's) encourage exchanges of this kind by offering intensive training in the Japanese language.

Scanning Japanese Technical Literature

U.S. acquaintance with written research results from Japan does not begin to match Japanese knowledge of U.S. research. One reason is the idea, still current in some companies, that anything important will be published in English.[87] A more important reason is the scarcity of technically trained Americans able to read Japanese. Companies that want to keep up with Japanese research often cannot find someone to do it.[88] Job-seekers who offer this skill may be highly valued. For example, one American specialist with experience in scanning Japanese journals, translating titles and abstracts, and using on-line Japanese databases was hired by a high-technology company that told her to name her own price. The experience of this information specialist contrasts with that of the MIT engineers returning from Japanese internships, whose experience in Japan and knowledge of Japanese were usually not much used or specially rewarded in their first jobs back home. Companies may set a higher value on knowledge of Japanese in a full-time information specialist than in a freshly minted engineer, whose main value to the company is technical competence.

Government and private efforts to provide services that scan and translate Japanese technical literature have been only modestly successful so far. In the Japanese Technical Literature Act of 1986, Congress directed the U.S. Department of Commerce to set up an office to provide such services. The office established to do the job is small, staffed by two people and funded at less than half a million dollars per year, reprogrammed from other department funds. Initially, the office arranged for translations, but the service was so expensive ($60 per page) that there was little demand for it. Services still provided by the office include a directory of translation and monitoring services, a listing of important Japanese documents available in English, and a yearly report on important Japanese advances in science and technology.

A more direct and focused effort to learn about Japanese accomplishments in high-technology fields is JTECH, managed by the National Science Foundation in collaboration with other Federal agencies and funded at $600,000 in fiscal year 1990. JTECH sends teams of leading scientists and engineers to Japan to evaluate R&D in areas such as computer-assisted design and manufacturing of semiconductors, complex composite materials, and supercomputing. Workshops at NSF discuss the teams' preliminary findings, and the panel reports are distributed by the National Technical Information Service. In 1989, JTECH published reports on the much-discussed topics of superconductivity applications and high-definition television.

Learning the Japanese Language

For the long run, broader knowledge of Japanese among Americans is the best assurance that scientists, engineers, and business managers will be able to keep up with technological advances in Japan. And the best way to learn Japanese is to start early. Japanese school children get 10 years of instruction in English, from the elementary grades through high school. (Though the instruction is weak in conversational skills, most Japanese professionals learn to read some English.) It is the rare American high school that offers Japanese courses, and instruction in the elementary grades is practically nonexistent.

R&D CONSORTIA

Traditionally, consortia have played a much greater role in technology development in other countries, such as Japan and Korea, than in the United States. Antitrust law and the prevailing free

[87] One young engineer, a former AEA Japan fellow who now works for Hewlett-Packard, told the OTA-MIT workshop that he reads Japanese technical articles on his own, but few of his colleagues see the need. The company does not use his Japanese beyond asking him to translate occasional messages. U.S. Congress, Office of Technology Assessment, Technology *Transfer to the United States from Japan,* op. cit., p. 11.

[88] It might be thought that some of the Japanese scientists and engineers who study in the United States would stay and work for U.S. firms (as Korean and Taiwanese researchers have done in large numbers), thus providing a source of technically trained people able to read Japanese. However, most Japanese have been little inclined to stay in America and work for American companies, and some Korean and Taiwanese are returning to their home countries even after many years of working for U.S. firms.

market ethos combined to make cooperative research appear inefficient or even illegal.

When American technology led the world, means of improving not just the technology but the process for creating it had little place in the public policy agenda. Yet as America's competitive position has deteriorated, and a state of crisis has emerged, especially in certain high-technology sectors like semiconductors, some now argue that R&D consortia are a critical element in the return to international competitiveness. The argument contains the following points.

First, as manufacturing processes become more complex and the technology more sophisticated, the cost of R&D rises. In particular, the sheer size of the investment necessary to advance to new generations in microelectronics implies risks unacceptable to all but a few large firms. For example, developing X-ray lithography technology runs into hundreds of millions of dollars. Such investments are beyond the reach of smaller firms, and even IBM is balking at that on its own. Consortia can allow the maximum leveraging of resources, by giving a company access to substantial R&D returns for a relatively small outlay. Companies can also ensure that they are in a position to appropriate the results of the research in that field-reducing a different risk, that they will be frozen out of a key development.

Second, U.S. industry is known for short-term thinking-which is a particular handicap in developing new technology. Consortia can reorient the perspective of participants toward longer term investment.

Third, there are externalities. Single firms may not be able to capture benefits from research that would nonetheless benefit the community as a whole. If a number of firms join together to do the research, the risks are spread and diluted.

Fourth, research consortia often have an important training function, even when they do not reach the technological goals they originally aimed for.

Fifth, consortia may improve the diffusion of new technologies by increasing the speed or the breadth of diffusion or both, a very important attribute. This may be especially true for consortia designed to help companies to catch up in areas of technical weakness.

Sixth, the creation of significant alliances and even a consensus among participants in the face of foreign competition can be useful. In textiles, for example, the Textile and Clothing Technology Corporation (TC^2) is credited with developing inter-and intra-industry linkages that have strengthened the domestic industry, even though the original technological goal of the project was not achieved.

All these benefits are important. If they were the only side of the story, strong backing for R&D consortia would bean obviously appropriate goal for public policy. But three main sets of drawbacks have been put forward. Some have stressed an anti-competitive and hence antitrust element of cooperative R&D; this argument becomes more telling for consortia that are further downstream toward manufacturing. Alternatively, some argue that R&D consortia have minimal effects-they simply don't work and are not a useful means of furthering competitiveness. Finally, there are questions about the relationship of the government to R&D consortia.

The problem of antitrust is discussed in the last section of this chapter and in chapter 2. However, since R&D consortia are under discussion here, the antitrust argument is not very relevant; few people see antitrust problems in nonproduction cooperation.

The second criticism is more cogent. Not all consortia are successful, but some are. The problem is to identify the circumstances that make for success, rather than offering simplistic generalizations. Some of the key questions are:

- *Goals. Are* consortia designed to attain some goals more successful than those aimed at others? For example, is basic research a more appropriate goal than research closer to commercial application? Does a consortium do better trying to produce new technology or should it simply focus on catching up with technology that exists elsewhere?
- *Players.* Who needs to be involved? Must the biggest firms in an industry be part of the consortium? Should all participants be roughly the same strength or size? Should the industry's technology leader participate? Do consortia with vertical participation fare better than those involving only firms from a single stage of the production process?

- *Financing. Are* there optimum forms of financing? Should the government help? How much?
- ***Technology transfer strategies.*** R&D consortia have two primary purposes-the creation of new technology, and the diffusion of technology. Can successful diffusion strategies be defined?
- ***Personnel.*** Firms are typically reluctant to send their best people to consortia. Does this matter, given that in some consortia most scientists are hired directly rather than being seconded from participants? How does this affect technology diffusion to participating companies?
- *Structure.* Does the structure of the consortium—timeframe, forms of participation, location of research labs, accrual of patent rights to insiders and outsiders, etc.-affect its success?

The third set of criticisms concerns the role of the government. In particular, the use of government money for R&D inevitably means that the government will have a say in which technologies to support. Critics argue that the U.S. Government in particular lacks the institutional capacity to make such choices.

This section examines some of the more important cases involving R&D consortia, focusing on the United States and Japan. It then offers some possible guidelines for cultivating successful consortia.

Collaborative R&D in U.S. High Technology: Electronics

The electronics industry accounts for the majority of joint R&D activity in the United States as well as in Europe and Japan. In the United States, most joint activity has occurred in the last 10 years. Early joint R&D efforts in this country were centered in universities, mainly because of antitrust concerns. Over time, and with relaxation of antitrust prohibitions, more joint efforts have been undertaken by private companies and those tend to be targeted further downstream.

This section looks at three different types of joint R&D in electronics: basic research (industry-university collaboration), long-term strategic research (MCC), and manufacturing R&D (Sematech). The following section looks at collaborative R&D more generally in Japan.

Basic Research: Industry-University Consortia

This form of research collaboration has grown rapidly in the microelectronics industry during the 1980s.[89] Usually, the projects focus on basic research and on training students in subjects that fit the industry's needs. Member firms are granted access to all research findings. They are also encouraged to send technical people to the university to do research for extended periods. They often use their university access for recruitment; this may be the most important aspect of cooperation for the firm. Universities benefit because the extra research funding helps them to attract and keep faculty and graduate students and to upgrade their laboratories and equipment. Also, it encourages interdisciplinary teaching and research-something that is hard to accomplish with the university's own resources.

Some programs are designed to promote regional development. An example is the North Carolina Microelectronics Center (NCMC), which draws on university faculty from the Research Triangle to conduct R&D in a center constructed and operated in part with State funds. Member firms work together in vertically integrated teams: NCMC's initial sponsors included a semiconductor manufacturer (General Electric), a telecommunications equipment maker (Northern Telecom), a semiconductor manufacturing equipment firm (GCA), and a supplier of manufacturing process gases (AIRCO). Although NCMC's success at economic development has been questioned, it appears to have been effective in achieving technical goals.[90]

In microelectronics, the Semiconductor Research Corp. (SRC) is a key case.[91] It plays the role ‘‘ broker for the semiconductor industry's basic research activities. An early goal was to stem the proliferation of expensive and duplicative university facilities for R&D on integrated circuits, and in this SRC had some success. Through the SRC's technical advisory boards, member firms have also approached some consensus on the main technologies to push for rapid advance. In addition to shaping the research agenda in microelectronics, this team-

[89] Much of the material in this section is based on David C. Mowery, ‘ ‘Collaborative Research: An Assessment of Its Potential Role in the Development of High Temperature Superconductivity, “ contract report prepared for OTA, January 1988.

[90] Dan Dimancescu and James Botkin, *The* New *Alliance: America's **R&D** Consortia* (Cambridge, MA: Ballinger, 1986), pp. 9-10; 75.

[91] In 1989, SRC had 28 member companies and a budget of about $30 million, $20.4 million of that from industry.

building exercise helped lay the groundwork for Sematech.

SRC has had less success in transferring results of the research it funds to member firms. The reasons are not altogether clear, but a likely one is the typical difficulty companies find in making immediate use of basic research. Another is the separation between R&D and manufacturing in many member companies, and a third is the lack of a reward system within companies for adopting ideas developed outside.

Long-Range Strategic Research: MCC

The Microelectronics and Computer Technology Corp. (MCC) was founded in 1982 by leaders of the computer industry, galvanized by the threat of Japan's Fifth Generation computer project.[92] The idea was to share resources and risks, and to undertake mid to longer term R&D where individual companies might not venture. More than at its founding, MCC today conducts numerous specialized projects tailored to the needs of its members, and it is putting more effort into meeting the needs of smaller companies and into technology transfer. However, it has so far kept the ability to do some core, longer range R&D projects.

MCC funding is almost entirely private. It was the first U.S. industry consortium in a non-regulated industry, and is a large one, with a staff of 430 and an annual budget of around $65 million. It currently has 20 member firms (shareholders), drawn largely from the computer, semiconductor, and aerospace industries.[93] MCC's five research programs are application-driven; they are in advanced computing technology, computer-aided design, packaging and interconnect, software technology, and high-temperature superconductivity. They operate on 6-to 10-year horizons, with an increasing emphasis on spinning off interim products.

MCC originally expected to draw staff from its shareholders but the firms were reluctant for competitive reasons to assign their best people. Admiral Bobby Ray Inman, the first CEO of MCC, initially rejected 95 percent of the researchers sent by the member companies, instead hiring highly respected outside scientists who were attracted by the large R&D budgets, high wages, and the central mission of long-term R&D.[94] These direct hires now comprise 85 percent of MCC's staff.

The structure of MCC is also an accommodation to competitive rivalries. Each of the five main research programs is operated independently, and there have been strict rules (recently somewhat loosened) about information exchanges among scientists across programs. Shareholders can pick from among the programs, joining as few as one. This cafeteria structure allows member firms to work in areas where they are weak and keep their strengths to themselves.

Both MCC's structure and the large percentage of directly-hired staff have impeded the transfer of technology, particularly within the consortium. Inman noted that although these factors made managing MCC much more difficult, they also helped MCC to attract and maintain a sufficient number of shareholders.

The ***Six-Year Mark—As*** MCC ended its sixth year, evaluations were mixed. Membership was holding steady, and MCC managers believed that existing shareholders represent a generally solid core of supporters. But shareholders continue to withhold their best people and their best ideas from MCC: virtually every good research idea pursued by MCC has come from within the consortium. Moreover, member firms are demanding a more immediate bang for their buck, and some have said they are looking to lower their contribution to MCC. (Most of the shareholders pay at least $1.5 million per year; some 20 associate members pay annual dues of $25,000 for limited access to MCC research.)

For members, a basic problem is the dearth of clearly usable research results. Only three commercial products have resulted from MCC technology.[95] However, some firms also use MCC technology less directly, as Honeywell did to develop an internal product designed to place components on a multilay-

92 The industry giants, IBM and AT&T, did not join, possibly for antitrust reasons.

93 Member account for one-half to two-thirds of all firms in those industries, and most have R&D budgets of $100 million or more. Merton J. Peck, "Joint R&D: The Case of Microelectronics and Computer Technology Corporation," *Research Policy, 15, 1986,* pp. 224-225.

94 Interview with Inman, Nov. 1, 1989.

95 NCR Corp. recently introduced Design Advisor, an expert system for integrated circuit designers based on MCC's work in artificial intelligence. The consortium has also licensed its laser bonding technology, a technique for connecting the leads of semiconductor chips to the circuit board. Most recently, the Digital Equipment Corp. (DEC) announced plans to use MCC's tape-automated bonding technology in one of its VAX computer systems.

ered printed circuit board. Boeing has set up four labs in Seattle to develop technologies that it takes from MCC.[96] Other benefits are apparent but hard to measure. For example, access to MCC has allowed member firms to delay capital investments and then make the right ones when the time comes. And even negative results help shareholders to avoid blind alleys.

Nevertheless, MCC members and executives alike feel that the consortium should be spinning off immediately usable technology even as it pursues long-term projects. This pressure for results has been intensified by a change in the corporate level of interaction with the consortium; MCC executives refer to this as the ''kings, dukes, and barons progression. In place of CEOs with long-range visions (the founding members, or kings), responsibility for interacting with MCC has migrated downward to the managers of profit-and-loss centers (dukes and barons) in many member firms. These managers have much more immediate needs, and generally press for nearer-term payoffs.

A few shareholders--Digital Equipment Corp., Control Data Corp., and Boeing, for example-have made major technology transfer efforts. DEC spends half again its investment in MCC seeking ways to use the consortium's results.[97] But others largely ignore MCC. Scientists at MCC describe some shareholders as "black holes' because of the difficulty of locating-and then maintaining contact with-the appropriate recipient for a particular technology. "Too many [shareholders] are waiting around for a virtual product design to emerge before they examine what's happening and why they might use it, " Inman observed after he left MCC.[98] In addition to diverting MCC resources away from long-term research, this demand for neatly packaged results creates tensions, according to one program manager, because 'the weak sisters want us to bring the technology damn near to market," while the strong ones don't.

Some technology transfer problems arise in strong firms as well as weak ones. For example, MCC's CAD program serves a group of semiconductor manufacturers who have become increasingly dependent on the emerging software vendor industry. When MCC gave CAD members research algorithms instead of completed software tools, it was "like feeding grass to tigers," according to MCC's chief scientist, John Pinkston.[99] The CAD program director stepped down and the program was substantially reorganized. A similar problem occurred with MCC's much-praised laser-bonder. Most MCC shareholders could not use the technology in 'raw' form. It was eventually licensed to a non-member firm with the sophisticated capacity to make use of it.

Mid-Course Corrections-MCC has changed its structure to combine shorter with longer term projects.[100] The CAD program and two others were each reorganized into a core unit working toward long-range goals, plus several satellite projects, designed to produce ongoing results for shareholders. In these programs, shareholders must buy into the core project and at least one satellite. However, MCC's Advanced Computing Technology (ACT) program (by far the largest) recently eliminated the core structure altogether. A shareholder can now select from 12 medium-term projects—including neural networks, optical computing, and artificial intelligence—at an annual price of $125,000-$700,000 apiece plus a one-time fee of $250,000 for access to the program. Although some of ACT's $1.5 million contributors are sure to trim their investment, MCC hopes that new participants will more than offset that loss.

MCC has begun to seek government money in cases where shareholders fail to exploit its research or where the government funds complementary research. For instance, the shareholders did not pick up the parallel processing work of the advanced computing program, so MCC instead attracted a $6 million DARPA contract. Toward the end of 1989, MCC estimated that government contracts would

96 *Management Review,* February 1989, p. 26.

97 Among other things, DEC requires that every MCC project it supports have an individual sponsor within the company. By including the funding for external R&D in the budget for internal research projects, DEC encourages managers to pay close attention to the work of consortiums. *Scientific American, May 1989,* p. 100. DEC also works hard to put researchers returning from a tour with MCC into positions where they can help the company the most.

98 Fred Guterl, ''MCC: The Dilemma of Joint Research," Business *Month,* March 1987, p. 50.

99 Interview with Pinkston, MCC, May 12, 1989.

100 For a discussion of MCC's reorganization, see J. Robert Lineback, ''MCC, After Five Years of R&D, Refocuses To Earn Its Keep,'' *Electronics,* December 1988.

grow from 2 or 3 percent of its budget to 10 to 15 percent in 1990. MCC now also does proprietary work for individual member firms. The packaging and interconnect program (MCC's most successful) runs such projects for five of its seven shareholders. These projects exploit other ongoing research and currently total less than 20 percent of the program's effort.

MCC is putting more resources into transferring its results. In 1988, for example, there were some 80 technology transfers to shareholders compared to a handful in 1985. Fully a quarter of MCC's budget now goes into technology transfer activities. Other, more qualitative changes include relaxing the barriers between programs, formal voting on program research to increase shareholder commitment to MCC's work, and attempting to increase the shareholder portion of MCC's staff to 35 percent. On the members' side, most do keep some people on the premises in Austin-and not just to see what other shareholders are up to, as in the early days, but to do real work. Although staff seconded from shareholders are still a small minority, those who are assigned there could be used to transfer technology back to the company.

MCC's ***Future—The*** shift in MCC toward more client-centered and more immediate results is in part a response to the needs of weaker members. One function of MCC is to help C companies become B companies, or help A and B companies strengthen weak areas. Thus the trend toward shorter term, more specialized R&D has positive aspects. At the same time, the trend could upset the balance between MCC's original goal, to take on long-term and relatively risky research, and the need to generate products that are more immediately or more narrowly useful to members of the consortium. It is this balance that distinguishes MCC from institutions that are devoted mostly to serving individual customers with proprietary R&D.

Manufacturing R&D: Sematech

SRC and MCC notwithstanding, microelectronics industry observers were skeptical about the 1987 announcement of a proposed manufacturing research consortium to be funded equally by industry and government. Twenty years of intra-industry competition would not be easily set aside. The newfound cooperation was partly based on fear, as Japanese inroads into the market for dynamic random access memory (DRAM) chips—the workhorse of the chip business—threatened U.S. firms' very existence.

Despite the similarities between MCC and Sematech, including a handful of common members, there are major differences. The Federal Government, consciously excluded from MCC, is a full partner in the 5-year chip consortium: DARPA is contributing $100 million per year, roughly half of Sematech's budget.[101] More important, Sematech's focus is narrower and more applied; it goal is to develop 0.35 micron manufacturing technology by 1993. Sematech's membership is relatively homogeneous: 14 semiconductor manufacturers, both merchant and captive, which together represent 80 percent of U.S. chip production capacity. Sematech's 15th member is Semi/Sematech, an organization of U.S. equipment and materials producers.

Sematech's members include IBM and AT&T, the industry giants that have stayed away from MCC. Sanford Kane, then IBM's vice president for industry operations, explained his company's rationale for supporting Sematech:

> The survival of the U.S. semiconductor industry was critical to us for several reasons. Number one, we were one of the largest purchasers of chips in the world. We liked to source locally, and we didn't want to be in a position where we had no choice but to be dependent on our competitor. Second, IBM was the largest manufacturer of chips in the world. We produced in-house those chips that gave us a technological edge. In order to stay state-of-the-m% we needed to have sophisticated equipment to make the semiconductors. If the U.S. chip makers go, so would the U.S. equipment companies. We knew it would be difficult to establish close relationships with the Japanese, especially since most of their firms are associated with chip companies. We would be forced to share information and it would be doubtful whether we could get access to state-of-the-art equipment as quickly as our Japanese counterparts.[102]

[101] DoD's support is scheduled to end in 1993. Robert Noyce anticipates that, if Sematech is successful, industry will continue to fund the effort without government support, albeit on a smaller scale. If industry is unwilling to fully fund Sematech after 1993, he maintains, it should be ended. "I'm a firm believer in sunset provisions,' says Noyce. Interview with Noyce, May 11, 1989.

[102] "Sematech," Harvard Business School Case #N9-389-057, 1988, p. 10.

So important is Sematech's success to IBM and AT&T that the two firms shared their respective 4 megabit (M) DRAM and advanced 64 kilobit (K) SRAM processing technologies to the consortium, along with the engineering support necessary to get them into operation. These contributions have allowed Sematech to establish baseline manufacturing with 0.7 and 0.8 micron technology less than a year after moving to its Austin facility. Although Sematech's fabrication facility (fab) will turn out only a few hundred wafers a day, just a fraction of a commercial fab's output, the consortium considers that sufficient to achieve rapid process learning. Sematech's strategic plan calls for high-yield, pilot application of 0.35 micron processing technology an estimated 6 to 18 months ahead of leading foreign chipmakers.[103]

Three strategic objectives are central to achieving this goal: 1) improving suppliers' technologies, 2) improving chip makers' manufacturing skills and techniques, and 3) strengthening the manufacturing technology base for semiconductor production.

Objectives-First of all, Sematech must strengthen U.S. materials and equipment suppliers. The industry includes hundreds of small supplier fins, most with sales of less than $10 million per year. These firms have traditionally had an arm's-length, and often adversarial, relationship with semiconductor producers, who preferred to keep their chip designs and manufacturing processes secret. A recent report describes the industry's situation:

> Compared with captive equipment makers in integrated Japanese and European electronics firms, U.S. equipment makers lack the advantages of predictable internal markets, access to broad scientific expertise, and deep pockets for high-cost R&D. They also lack the opportunity for joint development and internal site testing of new equipment, and the benefit of systematic high-quality feed-back on product performance.[104]

Sematech represents an attempt to overcome some of these structural handicaps. Through competitive R&D contracts to selected suppliers, it will try to promote long-term alliances between chipmakers and suppliers. Although chip producers are the source of two-thirds of the innovations in semiconductor equipment, they have traditionally kept these innovations secret, so as to preserve their competitive advantage in process technology.[105] The consortium structure encourages chipmakers to reveal their secrets to equipment producers.

By awarding contracts to multi-company teams, the consortium is also trying to promote cooperation and consolidation among suppliers. For example, a team composed of three rivals in high purity gas technology was recently awarded a contract to develop gas pipelines, filters, and other technology for Sematech.

The R&D funds awarded to selected suppliers will also be important, although probably less so than the knowledge it generates and improved relationships with chipmakers. Sam Harrell, president of Semi/Sematech, expects over half of Sematech's budget to filter down to equipment and materials firms in the first few years of the consortium.[106]

Finally, Sematech will provide a high-quality beta test site, where suppliers can test run their new equipment and processes under realistic manufacturing conditions. Currently, a supplier firm must test its equipment on an actual production line; since it can take weeks to debug a new piece of equipment, chipmakers are understandably reluctant to act as guinea pig. This test facility will also serve to certify the quality and composition of chemicals and other inputs.

Sematech's second objective is to improve manufacturing skills and techniques among chipmakers themselves and, in so doing, to change the very culture of semiconductor manufacturing in the United States. Sematech's director of strategic planning, A. S. Oberai of IBM, describes the problem this way:

> In Japan, engineers spend 70 to 80 percent of their time on "continuous improvement programs." The process operator is king-the first line of attack. It is he who keeps the equipment in order and decides when to call in the engineers. In the United States, engineers spend 70 to 80 percent of their time on crisis management as opposed to crisis avoidance.

103 The consortiums interim goal is to apply 0.5 micron manufacturing technology by 1990, roughly even with leading foreign chipmakers.

104 "Sematech: Progresses and Prospects," Report of the Advisory Council on Federal Participation in Sematech, 1989.

105 Eric von Hip@, The *Sources of Innovation* (New York, NY: Oxford University Press 1988).

106 "Sematech," Harvard Business School, op. cit., p. 12.

> The system encourages that by rewarding doers—problem solvers—rather than problem avoiders. [In contrast to Japan, in the United States] process operators do no maintenance or planning-they just push wafers.[107]

Sematech should also provide an arena for the cooperative development of standard equipment interfaces-a key problem up to now—and members will be able to use their substantial market power to get those standards accepted industry wide. The ultimate goal is a computer-integrated manufacturing system, which will provide diagnostic information about chip manufacturing to a computer in a standardized format.

Sematech's third objective is to strengthen the manufacturing technology base. Through expert workshops, the consortium tries to identify the most promising paths to its various technical goals. In addition, 10 percent of Sematech's budget is going to 11 university centers of excellence,[108] whose activities are being directed by the SRC. The centers are conducting research in a limited number of areas that will be critical to Sematech's post-1990 activities: for example, contamination/defect assessment and control, and advanced plasma etch processing technology.

Preliminary Assessment—Sematech got off to a rocky start. Member firms clashed over the kinds and volumes of chips to produce.[109] There were problems in recruiting a CEO, and DARPA rejected the consortium's first operating plan. However, after a year-and-a-half of operation, Sematech has made significant progress. It has built a world-class clean room and fab in less than half the normal time and at lower cost. In March 1989, several days ahead of schedule, the consortium produced its first chips, using AT&T's SRAM technology.

Member company assignees to Sematech are generally high caliber, and the consortium has, unlike MCC, achieved its goal of balance between assignees and direct hires.[110] There is other evidence of members' commitment. National Semiconductor has built a pilot production line to apply the tools that Sematech is developing.[111] And some supplier firms appear to have made preliminary plans to locate R&D and production facilities in Austin.[112]

According to Sematech officials, members' commitment went 'from casual to urgent" following the Federal Government's decision to participate.[113] Whether or not DARPA's financial contribution is critical,[114] Federal participation is certainly important symbolically: it gave Sematech credibility and encouraged industry members to believe that government officials will take seriously their concerns about unfair Japanese trade practices.

The participation of IBM and AT&T is at least as important. Their contribution of leading-edge technology represents an enormous benefit to merchant firms-one that has probably outweighed any costs to them of Sematech membership. However, the real test of commitment will come only later, when merchant firms will receive much less relative to their contributions, financial and otherwise.

Even now, not everyone would agree that Sematech is a conditional success. One concern is with Sematech's decision to limit actual production of chips in its fab, in keeping with strong opposition from IBM and Texas Instrument to high-volume

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107 Interview with A. S. Oberai, May 10, 1989.

108 As of January 1990.

109 Some analysts argue that, in choosing high-volume Chips, Sematech is attacking the wrong problem. They see the industry's future in application-specific integrated circuits (ASICs), which are custom-made in small quantities.

110 According t. Larry Novak, a Texas Instruments assign= and Sematech's director of technology transfer, an assignment to Sematech is seen as "career enhancing. Slow growth of the industry has kept many employees from moving up the career ladder in their home companies. Sematech provides an alternative ascent route.

111 *New York Times*, July 2, 1989.

112 "Sematech: Progress and Prospects," Op. cit., p. ES-4.

113 Ibid.

114 Claude Barfield, American Enterprise Institute, in testimony before the Joint Economic Committee, June 8, 1989, argued that industry was prepared to fund Sematech on its own. However, Robert Noyce argues that semiconductor companies can ill afford the $100 million per year they contribute, since their profits are among the lowest in manufacturing.

production.[115] Some critics believe that a high-volume operation is essential for testing yield and reliability, and that frictions between design and manufacturing teams can otherwise be swept under the rug.

High-volume production would require attention to every step in the process chain instead of the current selective emphasis, principally on lithography. That would cost considerably more money than Sematech has available. Some believe that the consortium's budget is too small to ensure success. Financial constraints do force Sematech to place its bets on a limited number of technologies aimed at achieving 0.35 micron circuitry. If those bets prove wrong, as one member company liaison said, "Sematech will have bought the farm."

Even if Sematech's technology wagers pay off, as most experts expect, the consortium still faces major problems. Technology transfer is one: Will member companies actually adopt the manufacturing tools that Sematech develops, let alone the new 'culture' of semiconductor manufacturing? Similarly, will the new closer relations between chipmakers and their suppliers be sufficient or lasting? Finally, will all of Sematech's work translate into significantly greater U.S. market share?

Cooperative R&D Ventures in Japan

In a nation where corporations are famous for the ferocity of their competition, the continued use of cooperative research ventures could not have come about by accident. Several factors have combined to produce the level of joint research activity seen in Japan.[116]

First, the nation has a tradition of government efforts to promote cooperation between competing firms that dates back to the beginning of industrialization in Japan. This history has conditioned firms to accepting joint R&D.[117] Second, the stability of firms within industries fosters the development of a certain level of trust. Wakasugi describes membership in a research consortium as 'effectively perpetual."[118] Third, firms want to participate because they are afraid of letting rivals gain a competitive edge.[119] Companies do not invariably join R&D consortia when invited;[120] however, reluctance to flout powerful, respected government agencies such as MITI, combined with fear of missing the bus, usually win out.

On the government side, Japanese ministries are constantly engaged in turf battles. One way for them to gain size and prestige is to become the promoter of more and more cooperative R&D ventures. The Science and Technology Agency established the Japan Research and Development Corp. in 1961, the same year MITI started the Engineering Research Association program (ERA). When MITI announced a 10-year biotechnology research consortium in 1981, three other agencies responded with their own cooperative biotechnology projects. Government agencies provide substantial financial inducements for joint R&D, including loans whose repayment is contingent on the venture's success, rapid depreciation of equipment, R&D tax credits, and outright grants.

Finally, Japan's legal climate is extremely favorable to cooperative ventures. One of the clearest expressions of Japan's attitude towards antitrust is embodied in the regulation that, even if the Japan FTC feels they have a legitimate case, they cannot act if it would "cause a loss of international competitiveness" for that firm.[121]

Private cooperative research ventures are common in Japan, but they usually do not involve government participation. Although fully one-third of industrial R&D is collaborative, 90 percent of that

115 During the planning stages of Sematech, many industry officials argued that a high-volume production operation was essential foresting yield and reliability, but Texas Instruments did not want competition in the DRAM market. IBM also opposed high-volume production for a variety of reasons. Sematech members eventually agreed on a facility capable of high-volume production but with an actual output of only 200 wafers a day. *New York Times*, Mar. 5, 1987.

116 This section draws primarily on the following sources: Mark Eaton, ''MIT1 and the Entrepreneurial State: The Future of Japanese Industrial Policy,' unpublished monograph, 1987; George R. Heaton, Jr., ''The Truth About Japan's Cooperative R&D,' *Issues in Science and Technology*, fall 1988; Jonah D. Levy and Richard J. Samuels, "Institutions and Innovation: Research Collaboration as Technology Strategy in Japan," MIT Japan Science and Technology Program, WP 89-02, April 1989; Daniel I. Okirnoto, "Regime Characteristics of Japanese industrial Policy," *Japan's High Technology Industries*, Hugh Patrick (cd.) (Seattle, WA: University of Washington Press, 1986); Richard J. Samuels, ' 'Research Collaboration in Japan," MIT Japan Science and Technology Program, WP 87-02, 1987; and Ryuhei Wakasugi, "A Consideration of Innovative Organization: Joint R&D of Japanese Firms," Shinshu University, Faculty of Economics, Staff Paper Series 88-05, March 1988.

117 Levy and Samuels, op. cit. p.%'

118 Rhuhei Wakasugi, 1987, cited in Levy and Samuels, op. cit., p. 38.

119 Kozo Yamamura, ' 'Joint Research and Antitrust: Japanese vs. American Strategies,'' *Japan's High Technology Industries: Lessons and Limitations of Industrial Policy*, Hugh Patrick (cd.) (Seattle, WA: University of Washington Press, 1986), p. 187.

120 Samuels (op. cit., p. 39) offers several examples of leading firms who shunned joint research when they believed they were far ahead of their rivals.

121 Yamamura in Patrick, 1986, p. 196.

is simply two-firm contracts between users and suppliers (i.e., firms that would not compete anyway). Only one-fifth of all joint research----or about 6 percent of total industry R&D-occurs between rival firms. These are the cases in which government participation is most common; because of competitive pressures, such alliances tend to succeed only with government sponsorship.

The typical vehicle for a joint project involving rival firms is the Engineering Research Association (ERA). The ***kenkyu kumiai ho*** (Cooperative Research Act), passed in 1961, gave ERAs the same legal standing as industry associations. Early ERAs were designed to help small and medium-sized firms catch up technologically, and so aimed to import and distribute technology, rather than develop it from scratch. In the early 1970s, ERAs entered a new phase. Although technological catch-up was still the goal, large firms began to play a bigger role and the focus shifted to more advanced research and product technologies. Critical to this change was a new MITI policy encouraged use of ERAs for “large-scale projects” involving research too extensive for any single firm to undertake. The projects (31 to date) were initially designed to meet specific goals, including creation of a prototype in some cases. The risk was primarily financial, since the technologies themselves had almost all been proven in the United States or Europe. A celebrated example of this kind was MITI’s VLSI project (1976-79), which helped Japan’s electronics firms master the manufacture of large-scale digital integrated circuits.

Around 1980, cooperative R&D in Japan entered a third phase, as the Japanese Government began to shift from catch-up to state-of-the-art projects. The Fifth Generation Computer Project, a successor to VLSI, is a 10-year national project focused on artificial intelligence and other leading edge technologies designed to make computers far more accessible to untrained users. Large-scale projects have become increasingly risky: for example, optoelectronic elements had not been proven when the Optical Measurement and Control System Project began in 1979. Similarly, the Next Generation Industries Program has turned increasingly to uncertain technologies such as bioelectronic integrated circuits.

As cooperative R&D in Japan entered its third phase, new vehicles were set up to promote cooperative research, and existing institutions are evolving to meet the new challenges. MITI and the Ministry of Posts and Telecommunications established the Japan Key Technology Center (KTC) in 1985 to fund promising proposals from research consortia. Much like a venture capitalist, KTC buys equity shares in the new firm-up to 70 percent of total capitalization. The research group, not the government, retains all patent rights.

Like ERAs, KTC consortia will have initial terms of 7 to 10 years and budgets for term of around $100 million. Unlike most ERAs, KTC projects must break new ground in basic or applied research, and the work is more likely to be conducted in joint facilities.[122] So far, KTC has provided more than $250 million in capital to 61 research projects. Eaton sees the program as a watershed: “It is difficult to overstate the significance of the KTC . . . It signals a new willingness by the Japanese, led by the state, to risk resources for basic industrial research. ’’[123]

For all its contributions, joint R&D has not been the primary means of technical advance for Japanese industry. It has always complemented rather than dominated the research that companies were simultaneously doing in their own labs. Nevertheless, cooperative R&D ventures have proved technologically significant, especially in electronics. During Japan’s period of catch-up, they provided an efficient way to rapidly raise the overall technological base of Japanese industry. As research consortia shift their activities to more exploratory research, success will be less predictable and more elusive, since uncertainty is the price of doing things that are really new. However, consortia do have the virtue of spreading the risks in uncertain ventures.

R&D consortia have also helped to speed the diffusion of technology between Japanese companies. Getting firms to share technology can be difficult. Though intellectual property laws are weaker in Japan than in the United States, they do provide some protection. The problem of technology sharing can be avoided if all the major player participated in its development in the first place. That way key capabilities are less likely to become proprietary, and the overall level of technological

[122] Eaton, op. cit.

[123] Ibid.

competence rises faster. No major firms are left behind in the technology race, and more firms mean more competition. (For further discussion of competition and technology diffusion, see the section *Intellectual Property.)*

As for the Japanese government's part in R&D consortia, the idea that Japan's technology advance is driven by a massive, government-directed program--a view fairly widely held in the West at one time-is untrue and largely discredited. It is a mistake, however, to underestimate the government's influence. Although government's annual spending per project is typically rather modest (the $300 million MITI spent over 4 years for VLSI was unusually high), the government commitment is steady and long-term, and this counts for a great deal.

Moreover, the fact that the government enters into relatively few R&D consortia should not be taken as a sign that the government's role is insignificant. The projects in which government participates are carefully chosen. Usually they are the upshot of continuing discussions between government agencies and business councils. They are consistent with the "vision," also developed by government and industry, of what kinds of technologies and industries are essential to the Japanese nation. Projects in the 1970s and 1980s were chosen for their contribution to the Japan's becoming a knowledge-intensive society.

Thus, the government's choices are both strategic and symbolic. They also give a signal. Private banks and financial institutions follow MITI's lead. And funding of joint R&D is only one of a whole raft of tools at the government's disposal for supporting strategic technologies. Besides the special loans, grants and tax breaks companies can get as inducements for joining R&D consortia, they may also get similar benefits from government programs in the commercial development that follows.

Making Successful Consortia

The innumerable factors (ranging down to the personalities of key participants) that affect the outcome of R&D consortia prevent the development of a recipe. Nonetheless, it is possible to offer some guidelines.

Because companies in the same industry are primarily competitors, minimizing conflict between consortium participants is critical. It is always difficult to get participants-often with long histories of competitive relations-to work together on anything, although successful cooperative research demands that they do. Consortia which fail to reduce conflicts to workable levels either collapse during the planning stages or find their effectiveness sharply reduced.

Conflicts can be avoided in more than one way. First, the evidence from Japan suggests that cooperation is more easily established when a technology is already known. Catch-up consortia have the advantage of avoiding certain conflicts by definition; for example, the participants need have little fear that any monopoly-creating technological breakthrough is at stake. Catch-up consortia also benefit from their clear goals, which make them inherently more likely to succeed than new technology consortia. This comparison by itself is misleading, however. Catch-up consortia should be compared with other catch-up mechanisms, not with new technology consortia. Likewise, new technology consortia should be compared with other mechanisms of technological innovation.

It may also be easier to avoid conflicts when a cooperative project is aimed at goals far from the competitive arena. For this reason, some claim that R&D consortia should be aimed at basic industrial research rather than applied research. Yet if participants can agree on well-defined areas of precompetitive research, they can overcome the potential for conflict. Indeed, international competitive pressures can be so strong in some cases that participants become exceptionally interested in making major cooperative R&D efforts that go right through pilot production (e.g., Sematech) perhaps even into commercial manufacturing (e.g., Airbus). Moreover, the results of applied research may be more useful to consortium members than yet another increment of basic research-in which the United States is already strong.

Conflict is not the only impediment to success. Ultimately, success comes only when the products of a consortium are adapted and integrated into the mainstream of participating fins' operations. There are several ways of encouraging diffusion of the results from cooperative R&D. Most important, a substantial financing commitment from participants seems to be necessary. Firms pay attention when enough of their own money is at stake. Of course, defining "enough" is possible only case by case;

Sematech defined it as 1 percent of each fro's revenues. Another funding strategy is to make sure that the resources given to the consortium are taken from the budget of the department in the firm that is responsible for using the consortium's results.

Another issue is personnel. Firms do not often send their very best people to R&D consortia. But if they send fourth-best personnel, the consortium will have no credibility within member fins. Firms must recognize the problem and send at least their second-best people, if the consortium's results are to get an attentive hearing. Also, a powerful patron for the consortium within the member firm helps to ensure that the results are exploited; without such a patron, the consortium can easily fall victim to the ''ilot-invented here' syndrome.

To establish closer links between consortia and at least some participants, the EC (almost always) and the Japanese (sometimes) have located their consortia research within the labs of participating firms. In contrast, MCC and Sematech have their own labs. Another diffusion strategy is the promotion of parallel research. Japanese firms taking part in consortia often have entire research labs devoted to shadowing the consortiums results.

On a slightly different point, one key reason why Japanese companies take part in consortia is to keep an eye on what their competitors, domestic and foreign, are up to. Technology diffusion is an acknowledged weakness of U.S. manufacturing (see ch. 6). If R&D consortia succeed not only in transferring their own results effectively to members, but also in raising members' awareness more broadly of technology advances in their field but outside their members' own area of emphasis, then the consortia will have served a useful purpose.

The Role of Government

Government should try to ensure that consortia it supports are designed appropriately, taking to heart the lessons described above. But this is not sufficient grounds on which the government can make a choice of projects. For example, it is necessary but not at all sufficient that the project have enthusiastic participation (including a hefty financial commitment) from industry. The government—with its inevitably limited funding-must also have some notion of the extent to which the projects it supports are important for the economy as a whole.

Some areas of technological advance offer long-term benefit to society but do not attract sufficient private investment because they are high-risk activities with uncertain pay-offs, and are very expensive. In the past, industries and technologies have been supported by the government on the grounds that they were vital for the nation's security. But today other grounds appear more pressing. Certain industries have vitally important spill-over effects: knowledge-intensive industries have ramifications far beyond their own (fast-expanding) boundaries; the whole complex of industries that the Europeans call ''telematics' directly affects the competitiveness of many other industrial sectors. And there are other "key" technologies. It is not an accident that both Japan and the Europeans have targeted the same key industries and technologies.

The notion that some consortia are more worthy of government support than others implies that some government agency must make that determination (see ch. 2). It is fair to argue that any large-scale shift toward cooperative R&D with government support will, in the end, imply the kind of choices that a civilian technology agency would be designed to make. Only such an agency could have the necessary expertise.

This brings up a final important point. While the government must seek to ensure that its support goes to projects that are both valuable and likely to succeed, government support is itself a factor in the equation. In Japan and Europe, government support provides both cash and credibility to a project, and may make the difference between success and failure. That, after all, is why these governments' support for R&D projects can be justified: if government money did not make the difference between success and failure, there would be no need for that spending in the first place.

INTELLECTUAL PROPERTY

Intellectual property rights, once largely ignored in our Nation's trade policy, are now an important issue. Foreign firms skilled at imitation are said to be stealing our inventions, and weak protection of intellectual property is held to blame. The United States is negotiating for stronger rights worldwide (including better enforcement), both bilaterally and in multilateral negotiations of the General Agreement on Tariffs and Trade (GATT) and the World Intellectual Property Organization (WIPO). There is also concern to maintain strong protection in this country-especially against infringing imports.

Attention has been focused on the whole range of intellectual property rights, including (among other things) patents for inventions; copyright for books, records, and computer software; and laws concerning trademarks used to identify a fro's goods.[124] This section, however, addresses only those intellectual property rights that directly protect technological innovation, including patents and software copyrights. Generally, the term "intellectual property" in this section denotes only intellectual property of this sort. (Box 7-D describes those intellectual property rights and explains how their effectiveness can vary.)

Inventors do not always need legal protection to keep imitators out of the market. Sometimes they can keep the new technology secret long enough to get a good lead in the market.[125] For example, it is hard for an outsider to determine the exact composition of many chemicals, and still harder to determine the process used to make them. In other cases, secrecy is not feasible. Many products are rather easily examined and duplicated—machinery, for example. Even computer chips, with their microscopic maze of interconnecting circuits, are surprisingly easy to copy. Information can also leak out through employees switching firms, and through suppliers and customers. In many industries, detailed information about new products and processes often leaks out to competitors within a year after they are developed.[126] When secrecy breaks down, inventors may turn to the legal protection of intellectual property rights.

The U.S. interest in intellectual property rights to protect technological innovation is not surprising. While other countries have surpassed us in implementing some new technologies, the United States is still a world leader—perhaps *the* leader—in discovering new technologies. The inventor of something new has an obvious interest in keeping to himself the right to make and sell the thing-or in extracting royalties if he wishes to sell that right to others.

The case that stronger protection would yield great dividends is not clear, however. Protection of inventions is only one factor—by no means the most important-in competitiveness. Furthermore, the net effect of stronger protection on the advance of technology is uncertain. While it might encourage R&D by rewarding inventors, it can limit the diffusion of the new technology. Finally, it is not easy to persuade less developed countries, where intellectual property protection is relatively weak, to raise their level of protection. While intellectual property protection does matter, even the best foreseeable changes in protection here and abroad will probably have at best a modest positive effect on U.S. manufacturing. The most promising avenues of change are: 1) streamlining enforcement of patent rights in the United States and Japan, and 2) harmonizing patent procedures among different countries.

How Much Can Increased Protection Help?

This section considers whether: 1) stronger protection for technological innovation can prevent large trade losses to imitators, 2) stronger protection would make the U.S. economy (and other economies) more efficient by encouraging research and development, and 3) the United States can convince other countries to increase protection.

Preventing Losses

It is not known how much the U.S. trade deficit is increased by gaps in intellectual property protection. The U.S. International Trade Commission (ITC) estimated that for 1986 these gaps caused U.S. firms to lose revenues of $43 to $61 billion.[127] This figure is extrapolated from survey responses by selected firms with estimated losses totaling $23.8 billion. The sum includes at least $1.8 billion in sales lost directly in the United States to infringing imports, $6.1 billion in sales lost directly abroad because of

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124For a more general discussion of intellectual property rights, see U.S. Congress, Office of Technology Assessment, *Intellectual Property Rights in an Age of Electronics and Information*, OTA-CIT-302 (Springfield, VA: National Technical Information Service, 1986).

125Trade secrets law Cm protect against competitors' use of information gained by unauthorized access.

126Edwin Mansfield, ' 'Ho„ Rapidly Does Technology Leak out?" *The Journal of Industrial Economics*, vol. 34, No. 2, December 1985, pp. 219-221. Mansfield reported on a survey of 100 firms in 13 industries, chosen at random from those industries' high R&D spenders. Ibid., p. 217, fn. 2.

127U.S. International Trade Commission, *Foreign Protection of Intellectual Property Rights and the Effect on U.S. Industry and Trade* (Washington, DC: USITC Publication 2065, February 1988), pp. H-2 through H-3.

Box 7-D-Intellectual Property Rights Protecting Innovation

Intellectual property rights follow national boundaries. They are granted by national (or state or provincial) governments, and apply only within the national territory. A firm that desires rights in other countries can seek such rights from those countries, If a firm's rights are being violated in a foreign country, it must go to that country's courts for monetary compensation or an order stopping future violations.

The most important intellectual property right for protecting technological innovation is the patent. Patents are granted by a national government for inventions of new, useful, and non-obvious products or processes (including new, useful, and non-obvious improvements of existing products and processes). A patent grants the right for a fixed period (in the United States, 17 years) to stop others from doing the following things *within the* national *territory:* making covered products; using or selling covered products, wherever they were made; using covered processes; and (in some cases) using or selling products made abroad by covered processes.

Other rights include copyright, semiconductor mask work protection, and trade secrets+ Copyright is the right for a fixed period (in the United States, the term varies depending on circumstances but is at least 50 years) to control the copying and other dissemination of textual, artistic, or other expressions; it is significant for protecting technology because in the United States and many other countries, copyright protects against the copying of computer programs and data. Mask work protection, a new form of protection created by the United States in 1984 and since adopted by other countries, protects against copying the layouts of semiconductor chips, which involve elaborate interconnections and are very expensive to design. Trade secrets law concerns the stealing of a firm's secrets, including technical know-how. Depending on the law, a firm which has tried to keep its knowledge secret may be able to stop other firms which gained unauthorized access to this knowledge from using it.

The scope and effectiveness of protection varies from country to country. For example, Argentina, India, Brazil, and Mexico do not grant patents for pharmaceutical products, and Brazil does not grant patents for processes for manufacturing pharmaceuticals. Also, the duration of patent protection varies. The United States generally grants protection for 17 years from the date of the patent grant, while in India patents concerning foods, pharmaceuticals, veterinary products, pesticides and agrochemicals last only 5 years from the patent grantor 7 years from the application, whichever is shorter. Some countries require that, when it is in the national interest, patent owners must grant a license to a local producer. If the parties cannot agree on a royalty rate, an administrative or judicial authority will set one.

Thus, the laws vary in scope; but the effectiveness of protection might depend still more on procedures for enforcing legally defined rights. For example, applying for and enforcing patents can be costly, especially in foreign counties where companies have to hire foreign patent lawyers and pay to have documents translated. Application and enforcement proceedings often take several years, during which time others are in most cases free to imitate the invention. Moreover, the rules of procedure and evidence in some countries might make it difficult to prove that a violation has occurred.

inadequate protection, and $3.1 billion in lost royalties.[128] It also includes other items, such as reduced profit margins, business never attempted abroad, loss of manufacturing economies of scale, and the effect of a weakened sales force on other product lines. The ITC's report did not quantify these other items separately.[129]

As the ITC acknowledges, projecting from the 193 companies that estimated lost revenues to the whole U.S. economy is problematic. Even for these 193 companies, the ITC depended on firms' own estimates of their losses. It is hard for a firm to state confidently how much it has lost even in direct sales, and even more so for other items such as hypothetical losses from sales never attempted. The estimates could also be too high if the firms incorrectly believed that certain goods were infringing. In addition, the ITC study concerned infringement of all intellectual property. If losses were restricted to technology-based intellectual property, the subject under investigation here, the ITC's estimate would probably be at least 10 percent lower.[130]

[128] Ibid., pp. 4-5, 4-6. These three figures are compiled from firms that estimated these items separately. Other responding firms may have incurred these losses but did not estimate them separately.

[129] Ibid., p. 4-4.

[130] Entertainment, food and beverages, publishing and printing, and textiles and apparel comprise $2.43 billion of the total losses of $23.8 billion. Ibid., p. 4-3. These particular categories probably involve almost exclusively trademarks and literary or artistic copyright.

More fundamentally, the existing forms of protection cannot always protect against imitation. Even when a firm has a patent, others can often invent around it—i.e., develop alternative technologies to get the same result.[131] The patent does give the original inventor a headstart while others catch up. During this time, the inventor might be able to improve the manufacturing process, expand production to exploit economies of scale, and develop marketing channels ahead of his competitors. If competitors are better at manufacturing or marketing, however, they can overtake the inventor. This has happened many times. A classic example is the CAT scanner, whose inventor was eventually rewarded with a Nobel prize. The invention was carried out for the British firm Electrical Musical Industries (EMI) Ltd. in the late 1960s. Although EMI produced and sold the CAT scanner successfully at first, the company lost its lead in the U.S. market half a dozen years after introducing it there; its biggest, most successful competitor was General Electric, which quickly developed a somewhat improved scanner and provided hospitals with superior training and servicing. A couple of years later, EMI dropped out of the CAT scanner business.[132]

Promoting Economic Growth

The theoretical basis for intellectual property protection is to promote economic growth by encouraging research and development—a factor of special importance to the United States, since U.S. manufacturing competitiveness depends heavily on technological superiority. Without strong protection, the argument goes, many innovations that would benefit society as a whole might never be made because the innovator could not make enough profit to recover the costs of research and development and compensate for the risks of failure.[133] It should be borne in mind that not all R&D pans out. Profits on the successes must be great enough to cover the costs of the inevitable failures as well. In addition, the world today is so full of competent manufacturers that imitation is occurring faster than ever, making it increasingly harder for innovators to recover enough profits. If they are to get sufficient reward for their inventions, they need strong protection of the law.

This argument for intellectual property protection has some force. However, there is evidence that many inventions would still be made even if legal protection were unavailable.[134] In an opinion survey, 100 firms in the United States were asked what percentage of their patentable inventions commercially introduced in 1981-83 would have been introduced even if patent protection were not available. The answers, by industry, were: 35 percent in pharmaceuticals, 70 percent in chemicals, 80 to 90 percent in petroleum, machinery, and fabricated metal products, and over 90 percent in primary metals, electrical equipment, instruments, office equipment, motor vehicles, rubber, and textiles.[135] In another opinion survey, 130 firms rated patents as fairly ineffective in many industries, including electronics; secrecy and lead time were generally considered more important.[136] Another study also found that patents provide relatively little protection

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131 Inventing around patents is relatively easy in electronics, and relatively difficult in pharmaceuticals. Richard Levin, Alvin Klevorick, Richard Nelson, and Sidney Winter, "Appropriating the Returns From Industrial Research and Development," *Brookings Papers on Economic* Activity, No. 3, 1987, p. 811; Edwin Mansfield, Mark Schwartz, and Samuel Wagner, "Imitation Costs and Patents: An Empirical Study," *Economic Journal,* vol. 91, 1981, p. 913. In general, broader interpretation of what a patent covers can make the patent harder to invent around.

132 David J. Teece, "Capturing Value From Technological Innovation: Integration, Strategic Partnering, and Licensing Decisions, ' Technology *and Global Industry: Companies and Nations in the World Economy*, Bruce R. Guile & Harvey Brooks, (eds.) (Washington, DC: National Academy Press, 1987), pp. 65-66,85-86.

133 Most often the major expense is not in making an *invention* or *discovering* a new result, but rather in subsequent development work culminating in commercial production.

134 The literature on this point is reviewed in Wesley Cohen and Richard Levin, "Empirical Studies of Innovation and Market Structure, ' *Handbook of Industrial* Organization, Richard Schmalensee and Robert Willig, (cd.) (New York, NY: North Holland, 1989), vol. 2, pp. 1091-1093.

135 Edwin Mansfield, "Patents and Innovation: An Empirical Study," *Management Science*, vol. 32, 1986, pp. 174-175. The firms were also asked what percentage of their patentable inventions made during 1981-83 would have been made even if patent protection were unavailable; the responses were similar, The firms were chosen at random from 12 U.S. industries (excluding very small firms). Of the 100 fins, 96 responded,

136 Richard Levin, Alvin Klevorick, Richard Nelson, and Sidney Winter, op. cit., pp. 790, 792, 794, 796-797,811. The firms also rated process patents less effective than product patents. The data suggests several reasons: processes are easier to keep secret and firms prefer to keep processes secret rather than disclose them in a published patent; processes are patentable less often than products; competitors can find alternative processes more easily than alternative products; competitors' uses of patented processes are harder to detect and prove than competitors' manufacture and sale of patented products. Ibid., pp. 794 (table 1), 797 (table 2), 803 (table 5).

in electronics, compared to drugs and chemicals.[137] Yet the electronics industry spends about 8 to 9 percent of sales on R&D, compared to an average of about 3 percent for all R&D-performing manufacturing industries.[138]

In addition, the social benefit of encouraging R&D must be balanced against certain social costs. One cost is reduced diffusion of new technology—including technology that would have been developed even without legal protection. By exercising intellectual property rights, an innovator can prevent others from using the new technology. Thus, people wanting to buy products dependent on the new technology might find the products expensive or unavailable because competition has been stifled. Perhaps even more important, other researchers will be reluctant to build on a protected invention (e.g., by improving it or by applying it in a new way), since the original inventor may try to stop other firms from using any derivative technology. (And if the inventor is willing to license the invention, the royalties might be more than most firms would pay.) For example, the semiconductor industry would have been slower to take off if AT&T had been able to keep others from using the key technology covered by its early transistor patents.[139]

While all patents to some extent risk inhibiting technology diffusion, some recent patents with a broad sweep have aroused particular concern. These include patents on software to display multiple windows on a computer screen and to compare the texts of different versions of a document,[140] and a patent on a new mathematical technique to solve problems such as routing of telephones and scheduling of airlines.[141] The courts might interpret such patents narrowly or find them invalid altogether—but first some firm must have sufficient stake in the issue to mount a court challenge. In some fields, the danger of inhibiting technology diffusion might be relatively low. For example, patents on existing pharmaceuticals generally do not stop rival firms from developing and marketing new pharmaceuticals based on different active ingredients (although patents would stop rival firms from developing, for example, new dosage forms of existing pharmaceuticals).

Patents can also help diffusion of technology, because they are published and must explain how to practice the patented technology. Upon reading a patent, an expert in the field might think of follow-up work or might think of a way to achieve the same result in a different way, outside the patent's purview. Many Japanese firms routinely track patent applications (which in Japan are published 18 months after filing) to learn about new technology. In the United States, applications are published when a patent is granted—typically about 2 years after the application is filed. However, this published information often could be learned instead by examining the products.

There are also costs of running the legal system. Patent applications can be expensive for inventors to file and for the government to evaluate. Lawsuits between patent owners and alleged imitators are expensive for the parties and take up valuable court time. Moreover, in many lawsuits the court finds that no patent rights have been violated, so the time and expense was for naught---a, worse, the suit might even have been brought deliberately to harass legitimate competitors and scare their customers. Another cost is that, to the extent the law is unclear or its enforcement unpredictable, business planning is hindered for both inventors and possible competitors.

Since intellectual property protection entails social costs as well as benefits, providing ever stronger intellectual property protection does not necessarily promote economic growth. The best results come from protection strong enough to encourage innovation but not so strong as to greatly inhibit technology diffusion—with some attention to making enforcement predictable and inexpensive. Unfortunately, determining what level of protection would work

137Edwin Mansfield, Mark Schwartz, and Samuel Wagner, op. Cit., p. 913.

138National Science Foundation, *National Patterns of R&D Resources: 1989*, Final Report NSF 89-308 (Washington, DC: U.S. Government Printing Office 1989), p. 65. This source gives ''Company R&D funds as a percent of net sales in R&D-performing manufacturing companies by industry' for 1986. The percentage for electronic components (SIC 367) is 8.5; for drugs and medicines (SIC 283), 8.8; for other chemicals (SIC 284-285, 287-291), 2.6; and for all industries combined, ***3.2.***

139U.S. Congress, Office of Technology Assessment, *International Competition in Services,* OTA-ITE-328 (Springfield, VA: National Technical Information Service, July 1987), p. 216. As part of a 1956 consent decree settling an antitrust suit against it, AT&T agreed to license its transistor patents to other firms.

140Lawrence Fisher, ''Software Industry in Uproar Over Recent Rush of Patents,' *The New York Times,* May 12, 1989, p. D1.

141Gina Kiolata, ''Mathematicians Are Troubled by Claims on Their Recipes, " *The New York Times,* Mar. 12, 1989, p. E26.

best is largely a matter of guesswork. Empirical studies of how the level of protection affects the total amount of innovative activity (both invention and diffusion) are few and inconclusive.[142] Other effects might also be weighed in the balance. For example, strong patent and trade secret protection can make it harder for employees in an established firm to leave to found their own firm in the same field of technology.[143] Whether this effect is desirable depends on the characteristics of particular industries.

Another effect is that strong protection at home can be a bargaining chip abroad. In the 1960s, both IBM and Texas Instruments gained permission to produce and sell in Japan only by agreeing to grant Japanese firms licenses under their key U.S. patents for computers and semiconductors respectively. In effect, IBM and Texas Instruments gained access to the Japanese market in exchange forgiving Japanese firms access to the U.S. market.[144]

Finally, in considering the optimum level of intellectual property protection, it should be borne in mind that intellectual property protection is not the only way to encourage innovation. For example, the government can fund research and development, give tax breaks or preferential financing to industry investing in R&D and in modern equipment, and collaborate in industrial R&D projects. On the whole, compared with some other countries, the United States has chosen to rely less on these other means of encouraging innovation and more on protection of intellectual property. This choice probably arises from the fundamental, widely held view in this country that government and civilian industry should be separate. Intellectual property protection is seen as proper: it simply lets firms make profits in the marketplace based on their inventions. The alternative that the United States has most strongly embraced—support for basic research and for defense R&D-involves little interaction between government and civilian industry.

If the United States were to put more emphasis on various other means of encouraging innovation, intellectual property protection might become less important.

Convincing Other Countries

Assuming that stronger worldwide protection of intellectual property could improve U.S. competitiveness, is there a realistic prospect that other countries can be persuaded to change their laws? Generally, the less economically developed a country is, the less it desires intellectual property protection.

Less developed countries are not much moved by the argument that imitation is a form of stealing because it takes the benefits of R&D without sharing the costs. These countries are apt to reply that they are already much poorer than we are, and that strong intellectual property protection would just aggravate the difference. Stronger protection would benefit innovators in rich countries while driving prices higher for consumers and stopping capable local imitators in poorer countries.

The argument that protection is good for economic development in the long run, because it encourages local innovators, also falls on stony ground. Imitation of existing technologies is at least as well proven as a springboard for economic development as local innovation. Korea and Taiwan are modern examples. The United States, as colonies and as a nation, based much of its own earlier economic growth largely on imitation of European technology.

Finally, developing countries are urged to consider that they may not always be able to imitate. Sometimes they will need to buy technology from foreign firms, and these firms might refuse to license or sell technologies in countries that lack adequate intellectual property protection. This possibility does not seem to scare developing countries much. For example, many complaints have been lodged about unlicensed imitation or "piracy" of inventions in Korea, yet Korean firms have found willing sellers of technology among U.S. innovators, especially in the semiconductor industry.

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[142] Wesley Cohen and Richard Levin, "Empirical Studies of Innovation and Market Structure," *Handbook of Industrial Organization*, Richard Schmalensee and Robert Willig, (cd.) (New York, NY: North-Holland, 1989), vol. 2, pp. 1089-90, 1094-95.

[143] When a parent firm sues a spinoff for alleged patent or trade secret violations, the cost of fighting the suit can intimidate the spinoff, regardless of the merits of the case. The parent's motivation is often more to prevent hiring away of employees than to protect intellectual property--as shown by the terms of settlements. Professor John Barton, Stanford Law School, personal communication, June 12, 1989 and Feb. 1, 1990,

[144] U.S. Congress, Office of Technology Assessment, *International Competitiveness in Electronics*, OTA-ISC-200 (Springfield, VA: National Technical Information Service, November 1983), pp. 193-194.

If the United States cannot persuade other countries that strong intellectual property protection is in their own interest, it can resort to carrots and sticks. The carrot is often exemption from tariffs for certain imports from that country under the Generalized System of Preferences.[145] The stick can be denial or withdrawal of such benefits, or flexible retaliation (often in the form of punitive tariffs on certain goods) under the recently strengthened Section 301 of the Trade Act of 1974. This approach has achieved some success. For example, partly because of sustained U.S. pressure, Singapore strengthened its copyright protection generally and also applied it to software.[146]

If other countries under our urging do pass tough-sounding laws, that does not guarantee their enforcement. Enforcement requires sophisticated governmental apparatus. A country that has trouble feeding its population cannot be expected to spend large amounts of money to ensure speed and fairness in processing patent applications and trying patent suits. Moreover, a country that has been pressured into granting intellectual property rights might be particularly inclined to give enforcement efforts a low priority.

Specific Problems

Efforts to strengthen intellectual property protection are likely to be most effective when aimed at protection in the United States and in other developed countries. Both have large markets for the products of U.S. technology; and developed countries have more interest in granting strong protection. The weak spots in these countries largely concern procedures for administering and enforcing the law, rather than the law's substance.

U.S. Patent System

Courts in the United States have ruled more favorably toward patent holders in the 1980s than in the 1960s. This applies to rulings on patent validity (in particular, whether an invention was sufficiently non-obvious to merit a patent); scope of coverage (how broad a range of possible imitation is prohibited by the patent grant); permissible conduct by the patent holder (e.g., whether the patent holder may impose various marketing restrictions on its licensees); and compensation to be awarded for infringement. The changed legal climate in part reflects a shift in viewpoint. Traditionally, judges enforced patents narrowly on the ground that patents created undesirable monopoly rights. Increasingly, however, judges have viewed patent rights as simply a legitimate incentive and reward for innovation. In addition, in 1982 patent-related appeals were consolidated in one court, the U.S. Court of Appeals for the Federal circuit. That court's rulings have strengthened and clarified patent law. In fact, some believe that this court has tilted the law too far in patent owners' favor.

The effectiveness of U.S. patent law is limited by delay in enforcement. It takes over 2 1/2 years, on average, to bring a patent case through trial for a ruling.[147] Only then (with fairly rare exceptions) can the patent owner get a court order to stop the imitation.[148] A firm whose patent is being infringed might not make it to the end of the trial, and even if it does the court might not fully compensate for the harm.

Delay is particularly troublesome in suits against imported goods. Often it is hard to trace these imports back to their source, to find out whom to sue. Moreover, the U.S. courts have no way of enforcing a ruling against a foreign manufacturer who has neither assets nor employees in the United States. If the manufacturer is beyond the court's power, the patent owner must sue domestic distributors instead. (The same is true for other intellectual property rights, including copyright, mask work, and trade secret.) The patent owner might hesitate to sue, for the foreign manufacturer's distributor might also be his own, for the same product or others. Even if the court rules for the patent owner and orders the distributor to stop selling the infringing goods, the

145 While granting such preferences might be consonant with our overall foreign policy objectives, these preferences do make foreign competition stronger in the U.S. market, thus to some extent offsetting the gain in our total competitive position due to stronger intellectual property protection abroad.

146 R. Michael Gadbaw and Timothy Richards, *Intellectual Property Rights: Global Consensus, Global Conflict?* (Boulder, CO: Westview Press, 1988), pp. 313,329.

147 *Annual Report of the Director of the Administrative Office of the United States Courts 1988*, p. 221. This report shows a median time Of 31 months from filing to disposition of patent cases after trial; the arithmetic mean, or average, would probably be somewhat greater, since 90 percent of the cases take at least 11 months and 10 percent of the cases take at least 62 months.

148 It is in principle possible to get such an order before trial, called a preliminary injunction. However, in practice it is very hard for a patent owner to get such an order unless he has already won a prior lawsuit based on that patent.

foreign manufacturer need only switch to another domestic distributor. The patent owner will then have to start all over again, first identifying and then suing the new distributor.

The owner of a patent or other intellectual property right can avoid these multiple lawsuits by filing a complaint with the U.S. International Trade Commission (an independent Federal agency) under Section 337 of the Tariff Act of 1930, as amended.[149] If the Commission finds that imports are violating the complaining party's intellectual property rights, it can issue an exclusion order, enforced by the Customs Service, barring importation of those goods. Moreover, the Commission is required to render a decision within a year (18 months in a minority of cases deemed "more complicated"), a considerably shorter time than the average a court suit takes.

The GATT has ruled that Section 337 violates GATT treaty provisions by providing special, harsher enforcement of the patent laws where foreign goods are concerned.[150] Section 337 is still in effect. However, other GAIT members could now retaliate against future use of Section 337 against their fins. The GATT decision found many aspects of Section 337 inconsistent with the GATT treaty, and it will be difficult to amend Section 337 to bring it into line with the GATT decision while still keeping the core advantages of: 1) a quick decision, and 2) an exclusion order.

Japan's Patent System

U.S. firms have often been frustrated by the ineffectiveness of Japan's patent system in protecting their inventions.[151] Part of the problem has stemmed from U.S. fins' lack of familiarity with how the system works. Difficulties have also occurred due to the language barrier. But part of the problem stems from the nature of the system, especially from delays and a public policy that favors granting of licenses to those who improve on a basic patent.

While precise figures are not available, it seems that an application for a Japanese patent, if opposed vigorously by another firm, will generally be tied up for at least 6 years before an inventor can proceed with a lawsuit. (Patent applications in the United States take an average of less than 2 years.) After a patent is issued in Japan, a firm accused in court of patent infringement could probably cause the lawsuit to take at least 3 to 4 years.[152] (U.S. patent trials are not much quicker. They average somewhat over 2 1/2 years, and a determined defendant often can add delay.) This puts an inventor in a poor bargaining position: grant a license, or wait at least 9 to 10 years to get anything from a lawsuit.[153]

In addition, other firms might seek patents for various improvements. This practice is very common in Japan. After an application is first published (generally 18 months after the application), firms frequently file many applications for improvements. Under Japanese law, a firm that receives a patent for an improvement can apply to the Patent Office for a compulsory license under the basic patent, if the owner of the basic patent refuses to agree on license terms. The Patent Office has discretion to grant or deny the request.[154] While this law has never actually been used, its presence can weaken the bargaining position of a patent owner.[155]

The Japanese system, which encourages licensing, might work well for Japan's economy by promoting diffusion of technology. However, it often does not serve U.S. firms well. To succeed at all in Japan, a U.S. firm might have to be the sole supplier of the item in question. As discussed elsewhere in this report, Japanese firms have a strong tradition and bias in favor of buying from

149 19 U.S.C. 1337. This remedy was strengthened by the Omnibus Trade and Competitiveness Act of 1988, Public Law 1OO-418, Sec. 1342.

150 A GATT dispute resolution panel ruled in November 1988, upon the complaint of the EC, that Section 337 violates the ' 'national treatment'' clause of the GATT treaty, which requires that a member country treat imports from another member country in a reamer 'no less favorable than that accorded to like products of national origin in respect of all laws, regulations and requirements affecting their internal sale, offering for sale, purchase, transportation, distribution, or use. ' GATT Article H. The United States subsequently accepted the panel's ruling, making it an official GATT decision.

151 The Senate Committee on Commerce, Science, and Transportation, Subcommittee on Foreign Commerce and Tourism, has held hearings on the Japanese patent system on June 24, 1988 (Serial No. 100-59) and Feb. 28, 1989 (Serial No. 101-19).

152 Yoichiro Yamaguchi, patent attorney registered in Japan, Beveridge, DeGrandi & Weilacher, personal communication, Jan. 30, 1990.

153 Other delays are possible in both the Japanese and U.S. systems. The systems are hard to compare directly. In general, both systems involve similar types of delays (though sometimes in a different order), but the delays are longer in Japan. Ibid.

154 Japanese Patent Law, Law No. 121 of Apr. 13, 1959, as amended, Secs. 7292.

155 Yoichiro Yamaguchi, op. cit.

other Japanese firms. Japan's complex distribution system reinforces the preference for buying Japanese. An exclusive patented technology might be the only way for an American firm to get into the Japanese market if it is forced to license Japanese firms, they might capture the whole market.

The United States has been negotiating with Japan to fix these and other problems. Already, Japan has increased the Patent Office staff to reduce delay, although not nearly as much as the United States believes is necessary. Japan has also lengthened various deadlines for non-Japanese parties, to allow sufficient time for communication and translation. Because Japan is now producing many inventions, it might be receptive to granting stronger power to patentees to exclude competition. The *keidanren*, an influential Japanese association of businesses, has already urged that patent systems worldwide should provide "effective patent enforcement," including "preliminary and final injunctions [i.e., court orders against infringement] as well as monetary awards adequate to compensate patentees fully and serve as an effective deterrent."[156]

Critics of Japan's patent system might keep in mind that the U.S. system has its own drawbacks. Resolution of patent cases that go to trial is slow (on average over 2 1/2 years). In addition, patent litigation can be expensive, and our patent law is quite complex. Thus, foreigners may feel that our system puts them at a disadvantage. While patents are issued relatively quickly in the United States, they are fairly often ruled invalid by the courts. Moreover, 20 years ago the courts enforced patent rights more narrowly than they do now. It should therefore not be too surprising that Japan and other countries, following in our economic footsteps, do not grant as strong protection as we might wish.

Patent Office Procedures Worldwide

Procedures for issuing patents differ from one country to the next. This raises the cost of filing applications in more than one country. The United States has been negotiating in WIPO and with Japan and the countries of the EC on terms of possible harmonization. The negotiations have already borne fruit. At U.S. urging, Japan in 1988 started allowing inventors to put multiple claims (in effect, multiple variants of the same invention) in one consolidated application, as has long been the practice in the United States and Europe.

Most of the changes, however, will probably come only as part of a comprehensive settlement. As part of any package deal, it is likely the United States will have to change from a first-to-invent system (in which the first person to make an invention is entitled to a patent) to a first-to-file system (in which the first inventor to file an application is entitled to a patent). Only the United States and the Philippines follow the first-to-invent system.

A fret-to-file system has some advantages. Since patents disclose the invention, early patenting could increase technology diffusion. A fret-to-file system also avoids extensive legal fights over who was the first inventor. However, switching to a first-to-file system in this country could disadvantage small inventors (either individuals or startup or small firms), who are probably more important in the United States than elsewhere. Having no patent department, small inventors usually have a harder time filing applications and therefore prefer to delay filing, to see if the invention warrants filing and to have more time to prepare the application. Under a first-to-invent system, these inventors can delay filing applications without fear of being preempted. Under a first-to-file system, a small inventor might lose out to a later inventor in a large firm that gets its application filed first. This hardship on small inventors could be lessened by making initial applications easier and cheaper to file, as they are in many fret-to-file countries.

ANTITRUST LAW

Federal antitrust law prohibits a wide range of business conduct that restrains trade or monopolizes a market. Its core provisions, Sections 1 and 2 of the Sherman Act of 1890, as amended, prohibit both business "combinations . . . in restraint of trade" and the "monopoliz[ation], or attempt to monopolize," trade.157 The Sherman Act and other antitrust statutes are worded in general terms, and could by their literal language prohibit a great deal of innocent business activity. The courts therefore have taken the statutes as an invitation to fashion a body

[156] The Intellectual Property Committee (USA), Keidanren (Japan), and UNICE (Europe), *Basic Framework of GATT Provisions on Intellectual Property: Statement of Views of the European, Japanese and United States Business Communities*, June 1988, p. 33.

[157] 15 U.S.C. 1-2.

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of precedent to explain more clearly what conduct is prohibited.

U.S. antitrust law has long been an effective shield against the power of monopoly and has kept many fields open to enterprising, innovative newcomers. Today, as foreign competition looms large in the U.S. economy, some have questioned whether traditional interpretation and enforcement of antitrust law may need some changes. Antitrust law could potentially prohibit firms from merging, forming joint ventures, and cooperating in various other ways—such as setting industry standards and conducting joint R&D projects. This section assesses the extent to which antitrust law might prohibit or discourage such behavior even when it would enhance the competitiveness of U.S. manufacturers.

While direct evidence is scanty, it appears that antitrust law does discourage some competitiveness-enhancing conduct, and would somewhat impede government and private efforts to increase such conduct. In most cases, the law does not actually prohibit the behavior in question; but because the law is unclear and involves stiff penalties, businessmen are often afraid to do anything that even looks like it might be an antitrust violation.

The Changing Interpretation of the Law

The types of conduct prohibited by antitrust law, and the philosophical justification for the prohibitions, have changed somewhat through the years. In the late 1800s and early 1900s, antitrust law was aimed in part at keeping businesses small. Small businesses were seen as more humane and more responsive to local needs. The Supreme Court, for example, criticized the transformation of "an independent businessman, the head of his establishment, small though it might be, into a mere servant or agent of a corporation, ''158 and noted the "widespread impression that corporate power had been and would be used to oppress individuals and injure the public generally.' '[159]

In recent years, antitrust law has been aimed not so much at preventing bigness as such but rather at ensuring fairly free competition. Under neoclassical economic theory, a free market-in which many firms compete and no one firm is large enough to affect the market for its product—is most efficient for society. When one or a small number of firms comes to dominate the market; those firms tend to reduce output and raise prices compared with free market levels. This market power is called oligopoly (if only a few firms are competing) or monopoly (if only one company sells the product).

Since the 1960s, the primary purpose of antitrust law has been to promote competition by minimizing the creation and exercise of market power.[160] Today both the courts and the Federal enforcement agencies acknowledge that some kinds of cooperation can often be justified by compensating benefits to society.[161] For example, suppose several competing firms with large combined market share in metal alloys create a joint venture to develop and sell a particular new alloy. Despite the joint venture's market power, society might be better off with the joint venture than without it because on their own the firms might have taken much longer to develop the product.

In evaluating a firm's conduct, enforcement agencies and the courts most often use a balancing test, or "rule of reason. " Conduct that threatens substantially increased exercise of market power is permitted if the societal benefits outweigh the societal costs (or, as sometimes phrased, if the pro-competitive effects outweigh the anti-competitive effects). The rule of reason is not always used. For example, certain egregious conduct, such as agreements among sellers to fix prices or divide markets, is deemed to be a *per se* (Latin for "by itself' violation. In such cases no balancing test is performed, on the ground that the conduct rarely if ever can have any social benefit.

The wide adoption of the rule of reason by the courts and the enforcement agencies has made antitrust law more accommodating than it once was.

[158] Frederick Rowe, "The Decline of Antitrust and the Delusions of Models: The Faustian Pact of Law and Economics," *Georgetown Law Journal*, vol. 72, June 1984, p. 1517, quoting *United States v. Trans-Missouri Freight Association,* 166 U.S. *290, 319, 323 (1987).*

[159] Ibid., p. 1517 footnote 32, quoting ***United States v. Standard Oil Co., 221*** U.S. 1, 50 (1911).

[160] Phillip Areeda and Louis Kaplow, *Antitrust Analysis: Problems, Text, Cases,* 4th ed. (Boston, MA: Little Brown & Co., 1988), pars. 111, 130, pp. 13-14, 44-45; Frederick Rowe, op. cit., pp. 1524-1535.

[161] *Report of the American Bar Association Section of Antitrust Law Task Force on the Antitrust Division of the U.S. Department of Justice,* July *1989, pp. 8-16.*

Congress also modified the antitrust statutes in the 1980s because of concern for U.S. manufacturing competitiveness. The Export Trading Company Act of 1982[162] provided for advance antitrust approval for firms working together through export trading companies. In the National Cooperative Research Act of 1984,[163] Congress mandated a rule of reason approach, and in some cases lessened penalties, for joint R&D. But whether these recent changes are enough, or whether further modification of antitrust law is called for to enhance U.S. competitiveness, is still an issue.

The Terms of the Debate

There are arguments for maintaining the status quo. In the past decade very few antitrust lawsuits have been brought, let alone won, that challenge activity which arguably should be encouraged on competitiveness grounds (e.g., joint R&D).[164] Moreover, it is hard to find examples of firms' giving up any such activity because of antitrust concerns.

In addition, antitrust enforcement has substantially lessened over the last two decades, especially in the early years of the Reagan administration. For example, civil cases filed by the Justice Department, around 30 per year in the late 1970s, dropped to the low teens by 1983. Cases against conduct other than price-fixing and bid-rigging[165] have become rare, and the Justice Department's guidelines, testimony and other public pronouncements often express a strong concern to ensure that antitrust law not prohibit desirable business activity. Private suits alleging antitrust conduct have also decreased in recent years—from about 1,110 cases filed in the 12 months ending June 30, 1984 to about 660 in the 12 months ending June 30, 1988. Further weakening of antitrust enforcement could send the wrong signal to business, and invite anti-competitive behavior.[166]

There are also arguments for further modification. One argument challenges the neoclassical premise that free markets always benefit society. Although the premise might be true generally, it does not apply in all cases. Specifically, perfect competition may not be conducive to innovation in today's business and technological conditions.

Firms will perform less innovation than would be best for society if they cannot capture substantial benefits of their innovations. In a perfectly free market, other firms imitate the innovator, take away some of the business, and drive the price down to a level that typically does not let the innovating firm recoup its investment. If the innovator can get market power, at least for a while, he can recover more of the value to society of his innovation. In the long run, a society in which innovators can expect to gain some market power, at least temporarily, is probably better off than one in which perfect competition always prevails.[167]

The patent system provides one way of gaining such market power. In fact, patent systems are usually justified on the ground that they encourage invention. A patent owner has the legal right to stop others from using the patented technology for a term of years (in the United States, generally 17 years), and this right often yields some market power, at least until others find a way around the patent.

Sometimes patents are not a very effective way of getting enough market power to repay an innovator (see the section Intellectual *Property* in this chapter). Corning out first with a new or improved product is an alternative way of achieving market power, at least for a time. But it is often the case today that neither patents nor the advantages of being first to market are enough to encourage adequate innovation by single companies. Increasingly, the kind of innovation nations need to enhance

[162]Public Law 97-290, 15 U.S.C. 4001 *et seq.*

[163]Public Law 98-4.62, 15U.S.C. 4301-4305.

[164]OTA is aware of no such cases, except that some cases have been filed (but not won) against groups of firms setting industry standards.

[165]Bid rigging involves the exercise of market power by buyers, which has undesirable effects similar to the exercise of market power by sellers.

[166]*Report of the American Bar Association Section of Antitrust Law Task Force on the Antitrust Division of the U.S. Department of Justice*, op.cit., pp. *4-5, 16-18, A7 (source* for chart on page A7 is U.S. Department of Justice, Antitrust Division Workload Statistics FY 1978 to FY 1987); *Annual Report of the Director of the Administrative Office of the United States Courts: 1988 (Washington, DC: U.S. Government* Printing Office, n.d.), pp. 181, 185; see also Patrick Marshall, "Do Antitrust Laws Limit U.S. Competitiveness?" Congressional Quarterly's ***Editorial Research Reports,*** vol. *2, No.* 1, July 7, 1989, pp. 368-70, The Reagan Administration did file a high number of criminal cases, but largely against small local businesses such as construction. *Report of the American Bar Association Section of Antitrust Law Task Force on the Antitrust Division of the U.S. Department of Justice,* op. cit., p. 17; Patrick Marshall, op. cit., p. 368.

[167]Thomas Jorde and David Teece, "Innovation, Cooperation and Antitrust: Balancing Competition and Cooperation,' *'High Technology Law Journal,* vol. *4, No.* 1, spring 1989, pp. 8-13,

competitiveness requires resources far beyond the means of small companies.[168] Even for very large firms, the expense and risks of R&D may be too great for the firms to go it alone. For example, both high definition television and optoelectronics require expensive technology development in several areas at once.

Capital costs for manufacturing can also be very high. It costs at least $250 million to build a plant to produce the present generation of DRAM semiconductors, and for the next generation capital costs will be much higher, perhaps $500 million per plant. Such costs may be too great for most U.S. firms to bear on their own. The manufacture of semiconductors and other high technology products also requires technical expertise in many fields-often beyond the capability of a single firm.

There are other reasons as well for cooperation among fins. Small manufacturing firms sometimes benefit from pooling their resources and bidding together on large jobs. Voluntary establishment of industry standards requires cooperation between firms. Sometimes mergers are necessary to match foreign fins' economies of scale.

All of these cooperative activities might run afoul of our antitrust laws. The law does not invariably prohibit activities like these. In fact, if firms can advance technology or otherwise improve their competitiveness only by teaming up, then courts may well judge that the benefits to competition outweigh the harm. Under the rule of reason, there would then be no antitrust violation. The trouble is that firms cannot be sure of this ruling in advance. Because elements of the law are vague, and the penalties for antitrust violation can be severe, firms often shy away from cooperative deals out of a combination of fear and ignorance.

Several factors can make it hard to predict the outcome of antitrust cases involving cooperation. Under the rule of reason, the beneficial and harmful effects of the deal must be compared. The harmful effects are determined largely by how much market power the deal creates, but in practice, market power is often very difficult to determine. For example, a proposed joint venture might be expected to sell 80 percent of laptop personal computers, but only 10 percent of all personal computers, in the U.S. market. The venture's vulnerability to antitrust will depend heavily on the extent to which laptops and other personal computers are substitutable. Even if the products do not readily substitute, some manufacturers of non-laptop personal computers might be waiting in the wings, ready to produce laptops if the joint venture tried to raise prices. In that case the joint venture would have little market power. In general, the substitutability of products and the ability and willingness of firms in neighboring fields to enter a market could be points of contention in court. Also in contention could be the deal's claimed beneficial effects. Will the firms substantially advance technology to develop a new product, or is the deal really just a front for pooling market shares? And is it really true that the individual firms could not profitably develop the product in question on their own?

How these points are resolved at trial again depends on several factors. The judge or jury may understand the need for firms to pool their resources but they may not. Facts about the market are hard to determine and are often the subject of conflicting expert testimony. Even after the facts are resolved, the weighing of positive and negative effects is not a precise calculation. It inherently involves the exercise of judgment.

In addition, while the rule of reason is widely used, alternative legal tests might in some cases cut short the full consideration of the activity's benefits. Antitrust doctrine contains the per se test (an activity is condemned without any consideration of its benefits), the "quick look" test (an activity's benefits are considered only if on a quick look it appears reasonably likely that such benefits exist); and the "least restrictive alternative" test (an activity is condemned if the court believes its benefits could have been achieved by another arrangement with less restrictive effect on competition). These doctrines might, for example, be applied to some joint production cases-especially if the

[168] According to the National Science Foundation, 200 companies accounted for 90 percent of all industrial R&D spending in the United States in 1986. The *average* R&D spending among this group was $273 million. If the average R&D intensity of the firms was 10 percent (a very high figure) the 1986 average net sales for companies in this group were $2.7 billion. William L. Stewart, "Effects of Corporate Restructurings on R&D Support," testimony before the House Committee on Science, Space, and Technology, Subcommittee on Science, Research, and Technology, July 13, 1989.

[169] Jorde and Teece, op. cit., pp. 40-42, 47-48.

court is skeptical that joint production can yield benefits for society.[169]

These are some of the complex issues of fact and law that make the outcome of a particular case difficult to predict. They can also make a trial quite expensive. On the average, antitrust cases take longer than other cases filed in Federal district court. For example, of the cases that go to trial, antitrust cases take a median time of 35 months, compared with a median time of 19 months for all cases.[170] Firms therefore have reason to be cautious about activities that might be considered antitrust violations. The severe enforcement regime in antitrust law, which includes multiple enforcers and stiff penalties, reinforces caution.

Both the Justice Department and the Federal Trade Commission enforce Federal antitrust laws. These agencies can file civil suits to stop the offending conduct. Also, if the Justice Department establishes that an antitrust violation has caused economic harm to the government, the defendant must pay the government actual damages.[171] From 1984 to 1987 the Justice Department filed a total of 46 civil suits. Of the 50 civil suits terminated in that period, the government won 39, lost 2, and negotiated an agreement in the remaining 9.[172] For mergers and some joint ventures above certain dollar thresholds, firms must give the government advance notice.[173] If the government announces its intention to challenge the deal in court, the firms involved will usually either modify the deal to satisfy the government's concerns or abandon the deal altogether.

The Justice Department can also file criminal suits with potentially large fines for the corporation and culpable officers and employees, and imprisonment for culpable officers and employees,[174] although criminal suits have been reserved for egregious attempts to fix prices, divide markets, or rig bids. From 1984 to 1987 the Justice Department filed a total of 219 criminal cases. Of the 237 cases terminated in that period, 210 resulted in convictions.[175]

While the U.S. Government's civil enforcement in recent years has not been aggressive, firms are often reluctant to gamble that government policy will remain the same. Firms can seek approval in advance for a particular course of action from the Justice Department or the FTC,[176] but these approvals often take several months and can involve considerable legal expense. Firms usually save this process for substantial projects (justifying high legal fees) that can wait several months. Also, government approval does not insulate firms against private suits, though in practice it lessens the likelihood that private suits will be filed or will succeed.

Private parties can file antitrust suits if they claim to be threatened or to have suffered some economic harm caused by an alleged violation. Private suits are far more numerous than government suits. In the 12 months ending June 30, 1988, private parties filed about 660 private antitrust suits in Federal court, compared with 20 civil and 70 criminal cases filed by the government.[177] Private suits are on average

[170] *Annual Report of the Director of the Administrative Office of the United States Courts: 1988*, op. cit., pp. 220, 221.

[171] See 15 U.S.C. 4, 15a, 25. The Federal Trade Commission proceeds under 15 U.S.C. 21 (mergers) or under the Federal Trade Commission Act, 15 U.S.C. 45.

[172] U.S. Department of Justice, Antitrust Division Workload Statistics 1978 to FY 1987, reprinted in *Report of the American Bar Association Section of Antitrust Law Task Force on the Antitrust Division of the U.S. Department of Justice*, op. cit., p. A7 (total civil cases: filed, won, lost, dismissed).

[173] 15 U.S.C. 18a.

[174] 15 U.S.C. 1.

[175] U.S. Department of Justice, Antitrust Division Workload Statistics FY 1978 to FY 1987, reprinted in *Report of the American Bar Association Section of Antitrust Law Task Force on the Antitrust Division of the U.S. Department of Justice*, op. cit., p. A8 (total criminal cases: filed, terminated, won). In 1987,42 individuals were fined a total of $1,636,000; 15 individuals were sentenced to serve time in jail and 33 more were given probation; 1,994 jail days were served; and 66 corporations were freed a total of $16,265,000. Ibid., reprinted in *Report of the American Bar Association Section of Antitrust Law Task Force on the Antitrust Division of the U.S. Department of Justice*, op. cit., pp. A11-A13.

[176] Neither Justice Department approvals nor FTC staff level approvals are binding on the government, but no firm has ever been sued for conduct within the scope of such an approval. Janice Rubin, Library of Congress, Congressional Research Service, American Law Division, "The Impact of U.S. Antitrust Law on Joint Activity by Corporations: Some Background," May 1, 1989, p. 7 (Department of Justice); Carl Hevener, Justice Department Liaison, Federal Trade Commission, personal communication, Dec. 1 and 5, 1989 (Federal Trade Commission). During 1984-87, the Justice Department received about 25 requests for approval per year and granted roughly 90 percent of them. U.S. Department of Justice, Antitrust Division Workload Statistics FY 1978-1987, reprinted in *Report of the American Bar Association Section of Antitrust Law T&k Force on the Antitrust Division of the U.S. Department of Justice*, op. cit., p. A5 (business reviews),

[177] *Annual Report of the Director of the Administrative Office of the United States Courts:* 1988, op. cit., pp. 181, 260.

less successful than government suits, although the statistics are somewhat unclear.[178]

Private parties that bring suit are usually either customers or competitors. If the suit is successful, the offending conduct must stop and the offender must pay to the complaining party: 1) treble damages, i.e., three times the amount of economic harm the complaining party can show he suffered,[179] and 2) the reasonable cost of the complaining party's attorneys for the successful claims. These are severe penalties. In most other areas of U.S. law, a complaining party, if successful, is entitled only to single damages, i.e., the actual amount of harm he shows he has suffered, and is usually not entitled to reimbursement of the expense of hiring attorneys.

The prospect of treble damage and attorney fee awards can encourage lawsuits by competitors and customers. Even if the defendant believes he could probably win in court, the prospect of paying these large awards—as well as the time and money needed to fight the case-might scare him into paying something to settle the case, and someone contemplating filing a suit knows this.[180]

Antitrust laws may be enforced by State governments as well. Under Federal antitrust law, State governments may file civil suits on behalf of their citizens--e.g., on behalf of a large class of consumers who allegedly paid excessive prices because of an antitrust violation. The penalties are the same as if the citizens themselves had filed suit.[181] State governments also can enforce the State's own antitrust laws, if the State has any.

In sum, even if antitrust law does not usually condemn activities outright that could improve manufacturing competitiveness, it can often discourage such activities. For large firms, able to get expert legal advice, antitrust risk is often considered as one factor among many. Cooperative projects have ordinary business risks as well. Will the technology work? Will the market be there? Antitrust adds another risk, and makes the project that much less desirable. Similarly, the need to pay for a legal analysis of the antitrust risk and for ongoing legal supervision adds to a project's cost at various stages. For small fins, often unable or unwilling to pay for legal advice, antitrust fear is more likely to act as an absolute bar. If a small firm suspects that a project involves antitrust risk, it might drop the idea immediately-even if there is no real risk. The ambiguity and complexity of antitrust law are therefore particularly troublesome to small firms.

While the chilling effect of antitrust is plausible, it is hard to tell how important it is compared with other factors that discourage cooperation. It is difficult to find examples in which antitrust actually killed a cooperative project, and the examples given here are not overwhelming. More telling examples may exist. Firms might hesitate to offer them because word of their actual or contemplated activities could provoke suits or give away strategic information to competitors. More important, business decisions typically depend on many factors, and it is hard even for those involved to say whether fear of antitrust changed a decision. A businessman sensitized to antitrust concerns might even avoid or quickly abandon ideas for cooperative projects. Those ideas will never be counted or noticed as activity discouraged by antitrust.

Some activities-e. g., R&D consortia, joint manufacturing, and resource pooling by small firms—have only recently received serious attention in government and industry as ways to enhance competitiveness. Even if antitrust in the past has not visibly discouraged very much activity, it might do so more in the future as more of these projects are proposed.

178 Of the 891 private antitrust suits terminated in the 12 months ending June *30, 1988, 145 are* listed as "settled," 434 ss "other dismissed,"64 ss ''other non-judgment, ' and 248 as going to judgment by the court. Of those 248,67 are listed as "for plaintiff, " 143 ''for defendant, " and 38 "other." David Gentry, Statistical Analysis and Reports Division, Administrative Office of the U.S. Courts, personal communication, Dec. 7, 1989. It appears that at least 577 cases ("otherdismissed" plus ''judgment for defendant' went entirely for defendant, and that in 212 cases (' 'settled' plus 'judgment for plaintiff'') plaintiff recovered something.

179 Only single damages are paid in suits concerning R&D projects registered under, and within the scope of, the National Cooperative Research Act of 1984, discussed below.

180 Statistics for the 12 months ending June 30, 1988 show 145 private antitrust suits ''settled'' out of 891 terminated, or 16 percent. David Gentry, Statistical Analysis and Reports Division, Administrative Office of the U.S. Courts, personal communication, Dec. 7, 1989. However, some cases where some settlement was paid might be reported under a different heading.

181 15 U.S.C. 15c.

Effect on Business Activity

Joint Research and Development

Traditionally, joint R&D has posed relatively little antitrust risk. Such projects offer obvious potential benefits in spreading risks and improving firms' efficiency and competitiveness. Moreover, member firms are generally free to manufacture and market products on their own (although there might be agreements restricting use of the resulting technology). Experts in the field know of no antitrust case brought against genuine joint R&D, and the Justice Department acknowledges that "[a]s a general matter, joint R&D activities can have substantial procompetitive effects.' '[182]

The National Cooperative Research Act of 1984 lessened the legal risks of joint R&D.[183] First, the Act provides that such activity will always be judged by the rule of reason, balancing its beneficial and harmful effects.[184] While joint R&D would in general have been judged by the rule of reason anyway, this provision did remove some uncertainty and sent a signal from Congress that cooperative R&D can yield important benefits. This probably increased judges' sensitivity to the benefits in balancing the pro- and anti-competitive effects of joint R&D.

The Act also provides that, for joint R&D projects registered promptly for publication in the Federal Register, only actual damages (rather than treble damages) may be awarded in a private lawsuit. (Attorney fees can still be awarded.) [185] As of January 1990, 160 separate projects had filed 323 registration statements including amendments.[186] Some of these projects probably would not have gone forward without the 1984 Act.[187] Registration greatly reduces the financial exposure in undertaking joint R&D and by the same token greatly reduces the incentive for parties to file private suits. The Act further discouraged indiscriminate private suits by providing that one who files a private suit breed on a claim that is "frivolous, unreasonable, without foundation, or in bad faith" must pay attorney fees of the accused party.

One consortium registered under the Act is the National Center for Manufacturing Sciences (NCMS), which started operations in 1987 and by 1990 included over 100 manufacturing firms.[188] The membership encompassed large firms such as General Motors and AT&T; smaller firms such as Kinefac Corp., a 70-employee metalworking firm in Worcester, Massachusetts; and even some firms with fewer than ten employees. (Many of the smaller firms joined at the urging of their larger customers.)

It is not clear whether NCMS would have been formed without the 1984 Act. Even with the Act, antitrust has been a major concern for present and prospective members. In its startup period, through early 1989, NCMS spent about $200,000 for antitrust advice from a law firm. In the organizations' first months, the director of NCMS spent most of his time on antitrust issues. NCMS's early meetings were devoted largely to antitrust concerns, and into early 1989 NCMS was still receiving about two queries a week from members. Antitrust concerns have gradually lessened as 1)NCMS became familiar with the issues and could more easily address members' concerns, 2) members noted that no firm had been sued for R&D registered under the 1984 Act, and 3) competition became more intense and the benefits of joint R&D became more apparent, so that members were willing to accept some antitrust risk.

Before joining NCMS, most members were not in the habit of sharing technical discussions or R&D-partly from unfamiliarity, partly from antitrust fear. NCMS has discovered that its members' pressing R&D concerns overlap considerably, so that coopera-

[182] U.S. Department of Justice, Antitrust *Enforcement Guidelines for International operations,* Nov. 10, 1988, p. 56.

[183] Public Law 98-462, 15 U.S.C. *4301-$305.* There are some limitations, discussed below, on what constitutes joint R&D under the Act.

[184] The Act requires that the rule of reason also be used in judging joint R&D under State antitrust law.

[185] The Act similarly limits damage awards in cases based on State antitrust law.

[186] U.S. Department of Justice representative, personal communication Feb. 1,1990, The first 125 or so projects are described in "National Cooperative Research Act of 1984 Consortia," New *Technology Week, Special* Supplement, June 12,1989.

[187] *The Government Role in Joint Ventures,* hearing before the House Committee on Science, Space, and Technology, Sept. 19,1989, Serial No. 101-58, testimony of Mauro DiDomenico, director, technical liaison office, Bellcore, p. 101; and testimony of Peter Mills, chief administrative officer, Sematech, p. 122.

[188] The material on NCMS comes from Ed Miller, Director, NCMS, personal communication, Apr. 10 and 27, May 3, Aug. 5, Sept. 6, 1989, and Jan. 29, 1990; and Patrick Ziarnik, counsel, NCMS, personal communication, Jan. 26, 1990.

tive R&D can yield substantial savings. One example is R&Don laser beam splitting-i. e., how to use one laser beam for several processes at once. NCMS also facilitates informal technical exchanges among members—for example, while discussing whether to fund proposed projects.

NCMS has sometimes made matches between companies with complementary abilities. It did so, for example, in the development of ductile iron as an inexpensive substitute for structural steel in the non-moving parts of machine tools. A consulting professor had recommended the alternative of ductile iron, but NCMS could not find any U.S. company that could both design the specialized molds needed for pouring the iron and do the pouring. NCMS then brought together firms with the CAD ability to design the molds and a company that could pour the ductile iron once it had the molds. The effort cost NCMS about $50,000. It has saved one NCMS member about $250,000.

Although the 1984 Act lessened fears of antitrust suits arising from joint R&D, these fears have not completely vanished—as shown, for example, by the continuing concern of NCMS' members. Also, the Commerce Department has from time to time provided a "safe house" in which competitors afraid of prosecution for merely discussing a possible R&D collaboration could frost come together to hold discussions under government supervision.[189] The concerns are understandable. Even firms that register their projects may still be sued by the government or by private parties for single damages and attorney fees. Firms that prefer to maintain secrecy and do not register are subject to private treble damages. Even under the rule of reason the firms are not necessarily home free. For example, the Justice Department's 1980 guidelines for joint research ventures state that "[a] joint venture between directly competing companies in a highly concentrated industry . . . will be subject to very close antitrust scrutiny."[190]

In cases where cooperating firms need to exchange cost and marketing information in order to guide the project in a commercially useful direction, the 1984 Act covers such exchanges only when "reasonably required to conduct the research and development." If, despite the firms' belief that certain communications were necessary, a court should hold otherwise, then those communications would not be protected by the Act's provisions.

Also, the Act covers manufacturing only for "experimental and demonstration purposes."[191] Sometimes sizable runs are needed to demonstrate a process, and the firms involved would take a significant loss if they could not sell the items produced. Yet a court might rule that such sale is not covered by the Act.

More fundamentally, the Act does not cover commercial manufacturing. Yet there may be cases in which the scale of the enterprise needed to capitalize on R&D is beyond the means of single fins.

Joint Manufacturing

Joint manufacturing can sometimes make firms more competitive, for example, by allowing economies of scale in production. This could be especially important in fields such as semiconductors where a production facility costs hundreds of millions of dollars. Firms might sometimes need to share technical as well as financial resources. Manufacturing, like R&D, often requires expertise in many fields. Again, semiconductor fabrication offers an example. Future examples might be devices based on optoelectronics or high temperature superconductivity. Sharing both financial and technical resources can mean the difference between being first to market or being an also ran.

Joint manufacturing can have another sort of benefit when it follows joint R&D performed in a central organization. Technology transfer from that central organization back to the member companies can be difficult. It might be easier for the central organization to proceed with manufacturing. For example, some say that it is unfortunate that Sematech will not perform commercial manufacture (see the section in this chapter on R&D consortia). Innovation ideally consists of repeated feedback

[189] Lansing Felker, Director, Industrial Technology Partnership Program, U.S. Department of Commerce, personal communication, Mar. 3, 1989.

[190] U.S. Department of Justice, *Guide for Research Joint ventures* (1980), Illustrative Examples, Case *B—red* Research and Development Joint Venture in Concentrated Industry, reprinted in *Trade Regulation Reports* par. 13,120 (Commerce Clearing House 1988), While these guidelines might be somewhat outdated in view of the more liberal tone of the U.S. Department of Justice, *Am"trust Enforcement Guidelines for International Operations (1988)*, p. *56*, the 1980 guidelines were relied on by NCMS' antitrust counsel in 1989 in giving cautious advice regarding a proposed project.

[191] 15 U.S.C. 4301 (a)(6)(C).

between R&D, design, manufacturing, and marketing. Many rounds of feedback between a joint R&D venture and its members might be much more difficult than many rounds of feedback would be within a venture that did both R&D and manufacturing.

In general, joint manufacturing carries more antitrust risk than joint R&D, because it can directly reduce competition. When firms manufacture jointly, purchasers may have fewer choices of products and suppliers. However, in some risky high technology ventures, joint manufacturing might be the only way to encourage new entrants. High-definition television (HDTV) offers an example of antitrust concerns in manufacturing joint ventures. Starting in early 1989, the American Electronics Association (AEA) sought to promote R&D and manufacturing consortia for HDTV. During the first several months, AEA had trouble even getting firms to talk with each other, largely because of antitrust fears. Antitrust then became less of a concern—partly because the firms with AEA's help were able to think through the antitrust issues, and partly because the many congressional hearings on possible changes in antitrust law made it seem likely that Congress would amend the law, or at least that enforcement agencies and the courts would interpret the law with more appreciation of the benefits of joint production.[192]

Some analysts question whether U.S. firms really need large joint manufacturing ventures, arguing that Japanese firms have done very well without them. Even if Japanese firms do not do much joint manufacturing (and this point is subject to dispute), the two countries are not the same. Japanese firms are much better able to finance large manufacturing projects on their own (see ch. 3). They also sometimes have a wider range of in-house technological expertise.[193] In addition, Japanese high technology firms are sometimes protected against foreign competition-either by the government or by customers who buy Japanese products preferentially.

Antitrust concerns can also discourage small manufacturing firms from cooperating in marketing and in performing jobs that are too big or require too many specialized capabilities for the firms to handle on their own. Japanese manufacturing firms cooperate a great deal in this manner, with the blessing and active encouragement of their government; some European firms have done so as well (see ch.6). Some U.S. industry groups, encouraged by the Commerce Department, are seeking to increase such cooperation in this country.[194] Antitrust concerns seem to have impeded these efforts somewhat.[195]

An example comes from the Flint River Project, Inc., a subsidiary of Efficient Enterprises, Inc., in Troy, Michigan. In 1988, Flint River began trying to form a network of small manufacturers of spare parts for automobiles, heavy equipment, and defense. Flint River proposed to market the fins' products domestically and abroad by finding jobs to be done, selecting a suitable team of firms for each job, and performing any needed technical coordination, including design and project management. The network still had not formed as this report was written. While antitrust was not the only problem, it was a significant one. The firms were afraid that participating in such a network could be deemed an antitrust violation--e.g., a conspiracy to fix prices.[196]

Another example: in the early 1980s, a few members of the Milwaukee chapter of the National Tooling and Machining Association discussed a bid solicitation from the U.S. Department of Defense for about 40 million dollars' worth of special-purpose carts to transport bombs. The members believed that by combining their production capacities and their various specialized abilities (such as welding, precision manufacturing, design, and possession of a large crane) they could do the job as well as and much more cheaply than traditional large defense contractors. However, early in the discussions some-

[192] Pat Hill Hubbard, Vice president, EIA, personal communication, Sept. 8, 1989.

[193] GmgoVTm.y,6'SncW~ Change and Competitiveness: The U.S. Semiconductor Industry, '' *Technological Forecasting and Social Change*, vol. *38*, 1990 (forthcoming); Richard Elkus, chairman, Prometrix Corp., personal communication. Dec. 1 and 7, 1989 (electronics industry).

[194] Theodore Lettes, Office of Technology Policy, U.S. Department of Commerce, personal communication, May 3, Sept. 7, 1989.

[195] Robert Friedman, "Flexible Networks and Antitrust," *The Entrepreneurial Economy Review*, vol. 7, No. 9, May 1989 (published by the Corporation for Enterprise Development, Washington, D.C.).

[196] Michael Hasler, president and chief executive officer, Efficient Enterprises, Inc., Troy, MI, personal communication, Apr. 26, May 3, and Sept. 14, 1989, and testimony at hearings before the House Committee on Small Business, Subcommittee on Regulation and Business Opportunities, Sept. 13, 1988, Serial No. 100-74, pp. 125-28.

one mentioned antitrust, and as a result the idea was quickly dropped.[197]

In neither of these two examples was the fear based on a legal analysis of the particular circumstances. Rather, the firms' managers said in effect at the outset, 'This might have antitrust problems, and I can't afford a lawyer to find out. Unless I somehow get assurances that there will be no problem, I won't proceed."

Standards-Setting

Voluntary industry standards are necessary for industrial efficiency. Without them, for example, light bulbs would not fit into sockets and regional telephone networks could not exchange information. However, it is possible for a standards-setting association to be dominated by a clique of firms that use the process of establishing standards to shut other firms out. For example, a clique might develop standards in secret, so that their competitors would not be able to conform their products to the standard promptly. In addition, a clique might pick one standard not because it is the best, but because it is difficult for competitors to meet. Such practices would probably be deemed antitrust violations, as well they should be.[198]

However, even if firms perform standards-setting with no anti-competitive intent, other firms may nevertheless file an antitrust suit claiming that the standard somehow unfairly discriminated against them. A court might take these claims seriously. The Supreme Court recently stressed that standards-setting can easily be abused to harm competition:

> [T]he members of [standards-setting] associations often have economic incentives to restrain competition and . . . the product standards set by such associations have a serious potential for anticompetitive harm. . . . Agreement on a product standard is, after all, implicitly an agreement not to manufacture, distribute, or purchase certain types of products.[199]

To forestall accusations, many U.S. associations have adopted elaborate procedural rules for setting standards, including open meetings at which all firms are free to express their opinion. According to Bell Communications Research (Bellcore), these open meetings are cumbersome and can slow down adoption and implementation of standards. In fast-moving fields such as telecommunications, delay might mean missed opportunities and reduced competitiveness. Firms could speed up progress by also meeting informally in smaller groups to iron out difficult technical problems; however, they are reluctant to do so for fear of an antitrust lawsuit.[200]

This problem arose in connection with communication standards for ways in which telephone networks in different regions or countries can exchange various information--e. g., route calls around congested lines, determine whether a called party's line is busy, and verify credit card numbers. These standards are handled by the T1.S1.3 Working Group (formerly the T1.X1.l Working Group) of the T1 Standards Committee, which is accredited by the American National Standards Association. According to Gary Schlanger, that working group's chairman for 1984 to 1987, U.S. and foreign approaches to exchanging such information started to diverge in 1986. The working group's efforts to resolve those differences and harmonize the U.S. and international practice were deadlocked for 2 years. Mr. Schlanger believes that with smaller, informal meetings harmonization could have been achieved. Instead, in 1988, the T1 Standards Committee adopted a U.S. standard inconsistent with the international standard used by the rest of the world. Now U.S. equipment manufacturers and phone companies must cope with translating between the U.S. standard and the world standard.[201]

Joining *Forces* Against Foreign Firms

In some cases, a fragmented U.S. industry faces competition from a much more powerful foreign industry. By combining forces, the U.S. firms might achieve similar advantages and hold their own. But some mergers or joint ventures between U.S. firms, each of which hold substantial shares of the same

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197 Carl Edquist, President, Carlson Tool & Manufacturing Co., Cedarburg WI, personal communication, Apr. 28, 1989.

198 See for example *Radiant Burners, Inc., v. People's Gas, Light and Coke CO.*, 364 *U.S. 656* (1961).

199 *Allied Tube & Conduit Corp. v. Indian Head, Inc., 108 S.* Ct. 1931, 1937 *(1988).*

200 Joe Klein, General Attorney, Bellcore, personal communication, Ma,3 and Sept. 13, 1989; Mauro DiDomenico, director, technical liaison office, Bellcore, testimony at hearings before the House Committee on Science, Space, and Technology, Subcommittee on Science, Research and Technology, Sept. 19, 1989, Serial No. 101-58, pp. 106-109.

201 Gary Schlanger, Division Manager, Carrier Interconnections, Standards, and Numbering Plan Management Department, Bellcore, personal communication, Sept. 15, 1989.

market, are either blocked or never attempted because of antitrust law. Under the Justice Department's Merger Guidelines, the firms involved must provide a high level of proof of any claimed benefits. Also, the Department will consider whether similar benefits could be achieved by other means.[202] One merger blocked by the Department was the attempt of BTU International, a manufacturer of furnaces used to produce semiconductor chips, to purchase Thermco, a subsidiary of the Allegheny Corp. (box 7-E). While the Justice Department in this case may have simply followed judicial precedent and the Merger Guidelines, these rules may be out of tune with the realities of failing U.S. competitiveness.

Overall, the uncertain cost of keeping antitrust law as it is today must be measured against the uncertain cost of proposed changes. Several possible modifications would leave intact the basic doctrine of antitrust law and the basic enforcement machinery, but would adjust around the edges. For example, points of law could be clarified; safe harbors and advance approvals could be provided; and treble damages could be reduced in some cases to single.[203] It is not clear that changes such as these would spark significant anticompetitive activity, particularly in light of today's economic conditions. On the whole, it is harder to maintain market power today than it was earlier in the nation's history. In some fields, products and processes have shorter life cycles so today's monopolist might find his position eroded tomorrow by competitors' new technology. Most significantly. foreign firms are more likely than ever before to compete against U.S. firms that try to raise prices above competitive levels.

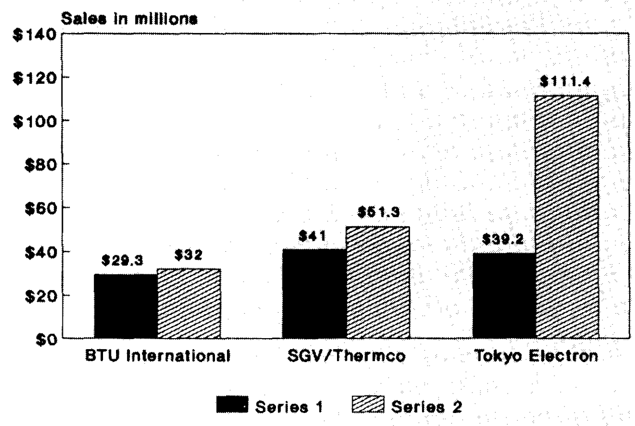
[202] U.S. Department of Justice, "Merger Guidelines," June 14, 1984, sec. 3.5, pp. 35-36.

[203] These and other proposals are discussed in ch 2.

Box 7-E—BTU Feels the Heat[1]

In 1987, BTU International began negotiations with Allegheny Corp. to buy its subsidiary Thermco Inc. At that time, BTU and Thermco together accounted for as much as 93 percent of all U.S. sales of hot-wall oxidation/diffusion furnaces, equipment essential to the manufacture of semiconductor chips.[2] In February 1988, BTU and Thermco filed their intent to merge with the Justice Department. BTU hoped that the acquisition would give it sufficient economies of scale, marketing power, and R&D capability to fend off expected competition from the principal Japanese manufacturer of this equipment, Tokyo Electron (TEL). In May 1988, the Justice Department determined that such a merger would give BTU a monopoly position in the U.S. market and denied approval of the merger. Instead, Thermco was bought by the Silicon Valley Group (SVG). Less than 2 years later, interviews with diffusion furnace manufacturers indicate TEL is on the verge of capturing nearly a quarter of the U.S. market;[3] and within a few more years it might have fully half. The U.S. firms are finding it difficult to compete with the much larger TEL. Executives at BTU and its rival U.S. firm SVG agree that overall the U.S. manufacturers would be in a stronger position to compete with TEL if BTU had been permitted to buy out Thermco, gaining advantages that neither alone can achieve.[4]

World Diffusion Furnace Sales



SOURCE: VLSI Research Inc., 1989.

SVG's Chief Financial Officer, Bob Muller, and BTU's CEO, Paul van der Wansem, explain that when the merger application was pending before the Justice Department, two factors presaged the rise of TEL in the U.S. market. First, TEL's products were already the industry standard for Japanese chipmakers. As Japanese manufacturers established fabrication plants in the U.S., they brought with them their commitment to TEL products. Included on this list are Toshiba's plant in Sunnyvale, California; Hitachi's in Texas; Mitsubishi's in North Carolina; and Fujitsu's in Oregon. Second, and more significant in terms of U.S. market share, U.S. chipmakers had begun to import their process technology from Japan. To maximize the chances that the imported process will give the same high yield in the U.S. facility as it did in the Japanese plant, a U.S. licensee would normally buy the same furnaces. In particular, Motorola, which licensed 1 and 4 megabit DRAM process technology from Toshiba, was expected to use TEL equipment in its new $400 million plant in Austin, Texas.

The Justice Department was aware of these considerations but came to a different conclusion. The Justice Department believed that TEL was unlikely to gain enough market share to prevent monopoly pricing by a merged BTU and Thermco within the 2-year time limit usually used to evaluate future competition. Interviews with diffusion furnace purchasers indicated to the Justice Department that brand loyalty in this type of product was so great that market penetration for a new firm would be extremely difficult. After talking to Motorola, the Justice Department decided that Motorola's expected purchase of TEL equipment was an exceptional case based on "special business conditions" (i.e., Motorola's use of Toshiba's process technology). The Justice Department also decided that the Japanese chip manufacturers who were building plants in the United States and importing their

[1]This section is based on information from the following personal communications: Paul van der Wansem, CEO, BTU International, November 2, 1989; Paul O'Donnell (the lawyer representing BTU to the Department of Justice), Ropes and Gray, January 18, 1990; Bob Cole, President, Varian-TELLtd., December, 1989; Anthony Muller, CFO, Sillicon Valley Group, December 5, 1989; Ken Phillips, Public Relations, Motorola, December, 1989; Bob England, Vice-President, Semiconductor Group, Texas Instruments, January 26, 1990; Representatives of the Department of Justice, December 13, 1989, and January 31, 1990.

[2]According to market share data gathered by Dataquest and filed by Thermco with the Justice Department, BTU had 46 percent and Thermco 47 percent. BTU, defining product categories differently, filed data showing much lower market shares.

[3]While no hard figures are available, the estimates by TEL's U.S.distributor and TEL's U.S. competitor, BTU, agree.

[4]Muller points out that Thermco has increased its market share since its purchase by SVG, so SVG is not really unhappy with the Department of Justice's ruling. Nevertheless, he concedes that the overall strength of U.S. manufacturers in this field, and their ability to resist Japanese entry into the American market, would have been greater if BTU and Thermco had combined forces.

old loyalty to TEL equipment did not represent a sufficiently large share of the market to prevent BTU from gaining a monopoly position.

Immediately after BTU's takeover effort failed, the Silicon Valley Group approached Thermco and was allowed to buy the firm without ado. SVG makes other types of semiconductor production equipment and had previously attempted and failed to enter the diffusion furnace business. Although BTU's market share in the United States is currently larger than TEL's, SVG sees TEL and not BTU as its principal competitor. TEL's 1988 world sides of diffusion furnaces were bigger than the combined world sales of BTU and SVG, making it the world giant.

Though it is impossible to know for certain what the results of a BTU/Thermco buyout would have been, the following seem likely: BTU and Thermco could have combined their current technological strengths, improving production of the most advanced systems; BTU and Thermco combined could have significantly increased their R&D by eliminating duplication; and the increased size of a united BTU/Thermco would have allowed the companies to realize savings in production, marketing, and administration. Whether such advantages could have slowed or stopped TEL's penetration of the U.S. market cannot be known for sure. Further, the beneficial effects of the merger might not have been as great as originally hoped.[5] But both BTU's van der Wansem and SVG's Muller think that combination would have been stronger than the current U.S. configuration of BTU on its own and SVG with Thermco, In this case, the Department of Justice's refusal to permit the merger seems to have hampered the competitiveness of the U.S. manufacturers.

[5] Thermco did not want to be acquired—both because BTU had been an arch rival and because layoffs were bound to result as the tWO operations were meshed. SVG's Muller suggests that enough key personnel might have quit that BTU would have acquired only the hollow shell of Thermco.