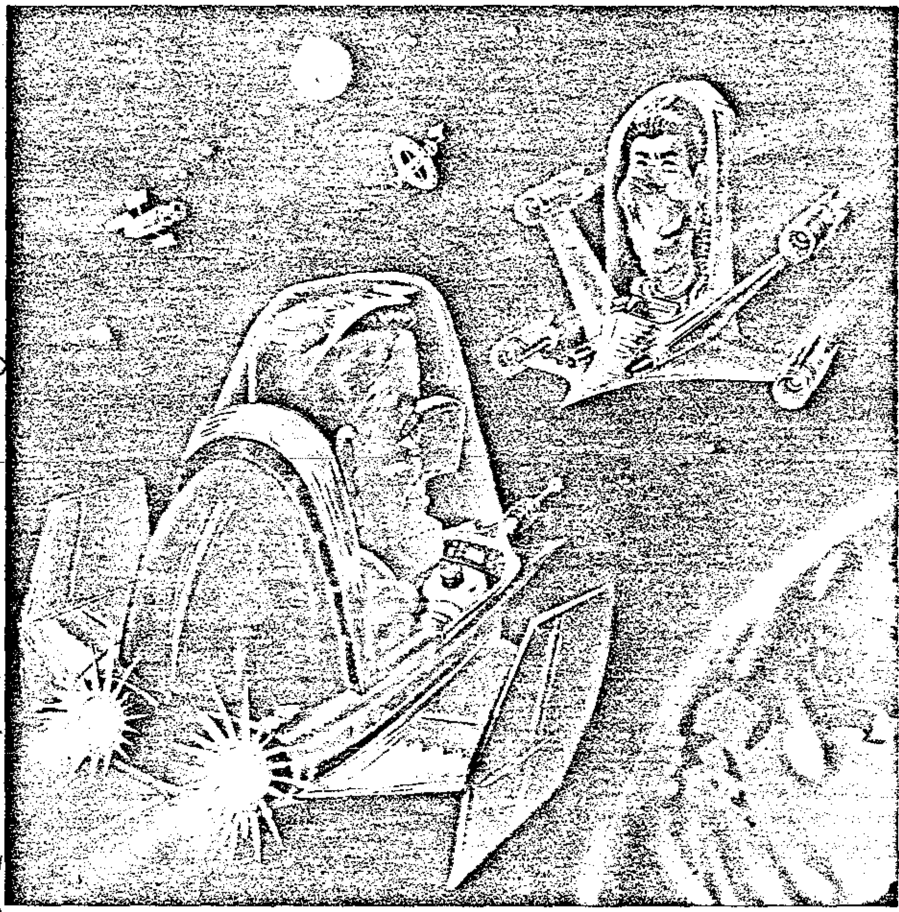
SPECIAL REPORT

THE GREAT DEBATES: TECHNOLOGY AND NATIONAL POLICY



A nation's ability to create jobs and wealth, as well as its standing in the world community, now depends heavily on its prowess in technology. To focus public attention on the promises and challenges of technology, this magazine last year proposed a National High Technology Week. It was passed by Congress in July; appropriately, it will take place on the eve of the presidential election, September 30 to October 6.

The Special Report that follows is our contribution to National High Technology Week. It presents a "state of the union" review of efforts, in the U.S. and abroad, to develop and maintain the high technology competitive edge.

It begins with an analysis of the political outlook: the candidates' views, and pending legislation. It then looks at the scope of high tech within the economy and at efforts to boost its impact. These include new industrial alliances, government incentives for R&D, and modernization of traditional industries. This is followed by a report on similar efforts elsewhere, especially in Europe, and an analysis of global trade. Finally, the critical area of education is examined: how industry is helping schools, and how technology itself promises to play a much larger role in education and training in the future.

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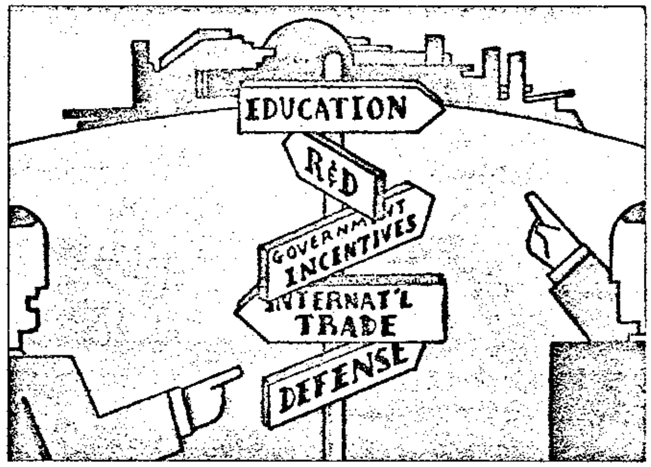
TECHNOLOGY AND THE CANDIDATES

By Edwin Diamond and Norman Sandler



There's one course both Democrats and Republicans unite on in this campaign year. Liberal or conservative, challenger or incumbent, Mondale/Ferraro or Reagan/Bush, both sides have hitched their campaigns to The Future, high technology style.

"We are the future," Mondale declared as he chose his running mate, Geraldine Ferraro, back in July. At the same time, Ronald Reagan was summoning up visions of the U.S. as a "rocket society" leaving the rest of the low tech world behind.

On the rhetorical shape of this future, it's clear, both Reagan and Mondale are in broad agreement. They both see the need to encourage innovation, upgrade schools, and ease the transition from an industrial-based economy to an information society. But beyond the thematic language of these politicians lie sharp differences in how they aim to get from today to The Future. There's also a certain lack of specifics, as far as technology is concerned, in both the Democratic and Republican blueprints. Still, it's possible to discern two different paths in technology policy—the Mondale way and the Reagan way. Here are seven signposts that help distinguish the rivals and their programs.

The candidates themselves

Neither Mondale nor Reagan has any significant technical background, and neither man has, in truth, shown an abiding interest in technology during his political career, recent speeches notwithstanding. Much the same can be said of their running mates. (The one true technology person in 1984 was John Glenn.)

Mondale has a special political problem involving technology. He has had to orchestrate a major program for the future without alienating one of his core constituencies—organized labor, which may still be wedded to the past in certain respects. And he discovered during the primary campaigns that it is a fine line to walk. In attacking Gary Hart's "new ideas" in Pennsylvania, one of Mondale's state coordinators suggested to blue-collar workers that Hart's ideas meant robots taking their jobs. But in California, Mondale was booed by union workers as he wooed antinuclear activists with a call to shut down the Diablo Canyon nuclear plant.

In the same vein, Mondale's support for "domestic content" legislation helped win him the endorsement of the United Auto Workers, but provoked warnings that his policies could trigger a trade war in which high tech and other industries would suffer from closed or restricted overseas markets. Elements of labor, particularly its industrial policy proponents, view high technology with suspicion, mindful that a future choice between economic options ("winners" versus "losers") could threaten the smokestack industries that comprise labor's power base. Mondale has therefore been cautious in broaching his own ideas.

The Democratic platform calls for an Economic Cooperation Council to engage in broad national industrial planning, but does not go so far as to grant this entity any power to order changes in the economy. The idea is a cheaper and less contentious version of the multibillion-dollar Reconstruction Finance Corp. earlier proposed by Mondale and backed by the AFL-CIO not so much to plot a course for a high tech future as to help rescue older, ailing industries caught in the grip of change and competition.

While Mondale has kept his distance from initiatives that might anger labor, he has shown no reluctance to outline an ambitious—and costly—"strategy for excellence in science, research, and technology" couched in the cautious language of an election year. The plan proposes a central role for government as financier, adviser, and occasional partner with industry.

If Mondale has behaved gingerly in approaching technology, Ronald Reagan has resembled a student taking a belated cram course. Beginning last year, his speeches started veering into new territory with references to microelectronics, bioengineering, and structural changes in the economy. His travels also reflect this new emphasis. Reagan has made visits to computer classes, worker retraining centers, a Massachusetts biotechnology firm, and a high tech Detroit auto assembly plant. He has made an election-year commitment to "the vast frontier of space" and an orbiting space station within a decade.

The R&D budget

Reagan approaches high technology as a supply-sider. His view is that Washington can help create a climate conducive to research and development that would improve competitiveness and productivity. This could be done largely by removing legal and regulatory impediments or, where necessary, offering tax incentives. But the country must forgo the "government as subsidizer" role.

In his fiscal 1985 budget, Reagan proposed $53.1 billion for R&D, a 14% increase over 1984. Even with this sizable rise at a time of forced fiscal restraint, his proposals do not measure up

COVER: BOB GROSSMAN   OTHER ILLUSTRATION: MARK FISHER to the spending goal set by the Democrats. Mondale points out that while West Germany, for example, spends 2.5% of its GNP on civilian R&D, the U.S. lags far behind at 1.7%. Mondale proposes almost doubling this Reagan Administration figure.

Still, White House science adviser George Keyworth says the administration has pumped up the federal R&D budget over the last few years out of a sense of urgency attached to the loss of America's technological edge. In fact, much of the money has gone to aid Reagan's $1.8 trillion military buildup for a five-year period spread over the mid-1980s. Of the 15 nondefense budget functions that receive federal money for R&D, only one—general science, which includes much basic research—has shown an increase in constant dollars between 1980 and 1984, according to the National Science Foundation. Mondale has proposed a minimum 3% increase per year in federal support for civilian research. In contrast, the Reagan figures for the last four years show a 65% increase in spending on defense-related R&D and a 30% decrease in other areas.

But no matter who wins in November, the confluence of forces in Washington will put pressure on private industry to pick up the pace of its own R&D efforts. Both Reagan and Mondale stress the importance of industry joining in, if not leading, the drive for excellence they advocate.

Both supported a permanent extension of the 25% tax credit for incremental R&D expenditures. With this kind of bipartisan backing, it came as a surprise to many when the proposal was rejected by Dan Rostenkowski (D-Ill.), chairman of the House Ways and Means Committee, in the final hours of the recent tax conference on Capitol Hill. One of Rostenkowski's objections was that this measure would further trim tax revenues at a time when government was looking for more revenues. But again, no matter what the outcome, this initiative will be back after November.

Both Reagan and Mondale supported legislation that will ease antitrust rules to permit joint R&D ventures. Likewise, both endorse patent-law reforms to reward contractors for innovations developed with federal funds. Mondale favors expanding the investment tax credit to include investments in worker training and education, eliminating the capital gains tax for new long-term investment in smaller businesses or on gains rolled over into such firms, and the creation of technology extension centers to help channel federal R&D money to small businesses.

The administration, meanwhile, has examined how tax write-offs might be used to encourage limited partnerships that could form links between federal, university, and industry laboratories. Reagan has ordered that steps be taken to make better use of the federal laboratories in meeting national goals through greater interaction with the private sector. For example, the Reagan Administration is planning a Center for Advanced Materials at the Lawrence Berkeley Laboratory in California.

The Pentagon's path

Under Reagan, the Pentagon has enjoyed a steady increase in real spending on R&D and procurement. For fiscal 1985 he proposed $939 million for Pentagon-supported basic research, a 15% increase. Total spending on defense-related R&D was slated to rise 22% to $34.2 billion. Moreover, Reagan has fought for and won congressional approval for the MX missile, the B-1 bomber, the Trident II missile, the radar-elusive Stealth aircraft technology, antisubmarine warfare, and a stepped-up nuclear warhead production program. Congress has rejected his requests for money to produce a new stockpile of chemical weapons, though research in this area continues. Congress has also signaled its dissatisfaction with Reagan's antisatellite plans that figured so prominently in the recent diplomatic minuet over talks in Vienna.

While Reagan sets his minimum growth rate in defense spending at 7% for FY 1985, Mondale advocates 4% and would shelve the MX, B-1, and space and chemical weapons. Like Reagan, he supports the Stealth program, the Trident II, and the development of a new-generation single-warhead ballistic missile as a stabilizing replacement to the current land-based Minuteman force and the 10-warhead MX.

Mondale supports the concept of a negotiated nuclear weapons freeze, as well as a proposal for a "build-down" arrangement that would require the superpowers to scrap at least one existing nuclear weapon for each new one produced. Mondale also favors more spending on defense-related basic research than Reagan—and with fewer strings attached. He contends that the administration has been overzealous in its restrictions on industry and its imposition of secrecy on the academic community purportedly to stem the flow of technology to the Eastern bloc. Finally, Mondale has urged the expenditure of $4.5 billion over five years for modernizing university research labs to accommodate the expanded research effort he proposes.

Technology and trade

At a time when the dollar is strong and trade deficits are immense, both sides agree on the need to sell more U.S.

Neither Mondale nor Reagan has a technical background, and neither has shown an abiding interest in technology during his political career.

(LEFT) MARIO RUIZ/PICTURE GROUP, (RIGHT) DENNIS BRACK/BLACK STAR
COVER, ROB GROSSMAN OTHER ILLUSTRATION, MARK FISHER

goods abroad. The question, as is so often the case in politics, remains: How and where?

Despite his aversion to big government, Reagan came out for creation of an International Trade and Industry Department. Its mission would be to consolidate the trade functions now being carried out separately by the Department of Commerce and U.S. trade representative William Brock—and to prevent Commerce and Brock from working at cross-purposes. The idea was unveiled with fanfare at the White House in 1982, but was later allowed to die a quiet death on Capitol Hill.

Mondale champions the cause of "free and fair" trade, hinting that the United States should be prepared to fight back when its partners overseas resort to subsidies or other instruments of protectionism. Not surprisingly, this position, especially when viewed together with his support for the domestic content bill, has left Mondale himself vulnerable to charges of protectionism. Reagan opposes the domestic content bill, fearing a backlash of countermeasures that would be felt from the grain-exporting Midwest to Silicon Valley.

The two sides also disagree on export policy and information flow. Alarmed by the inadequate protection of U.S. manufacturers from rip-offs, and determined to keep potentially sensitive technology out of Soviet hands, the administration has tried to fashion a trade policy that simultaneously satisfies the desires of American industry and U.S. foreign policy objectives. It has been largely an exercise in futility, frustrated by bureaucratic infighting—among the State Department, Commerce Department, the Pentagon, and the White House—that Reagan has been loath to step in and resolve. He has imposed tight export controls on a range of products with potential military applications (to the chagrin of allies who want the technology for themselves), while trying to reestablish the United States as a principal vendor of nuclear materials and a major supplier of arms. Reagan asked Congress for expanded authority under the Trade Act of 1974 to negotiate reductions in nontariff barriers to increased foreign commerce in such areas as services, investment, and high technology, on grounds that the current law does not adequately provide for agreements in these key areas of future growth. At the same time, the administration has shown a willingness to forgo its anti-big-government zeal in order to pursue other Reagan goals. For example, Reagan proposes government regulation of some exported services as part of a broad antiterrorism plan. He also won passage of the Export Trading Company Act, a measure supported by both parties and designed to enable smaller firms to improve their overseas sales potential through formation of export trading companies previously discouraged by antitrust rules and other laws.

On the Democratic side, there is distaste for Reagan's promotion of nuclear exports, even though Mondale has urged the relaxation of "foolish export control policies." The Democrats' criticism of Reagan's export restrictions was bolstered earlier this year by a National Academy of Sciences report which concluded that the administration has gone further in limiting technology transfer and information flow abroad than an NAS panel recommended two years ago—or than the situation warrants.

Science and technical education

The rhetoric on both sides portrays the nation's schools as the first line of defense against the threat of technological inferiority, but nowhere do the two parties differ more in their approaches to a shared objective.

Reagan calls for a renewed commitment to quality education rivaling that of the post-Sputnik period—a period marked by a return to basics. Mondale argues that technological excellence cannot be achieved without an across-the-board program, fueled by money from Washington, to improve schools, colleges, universities, and technical training centers.

Reagan, again, champions the notion that the federal government has a limited role to play. Early in his presidency, he sought to cut funding for science and math instruction and do away with the Department of Education, maintaining that the need for improvement did not imply a need for greater financial assistance from Washington.

Congress restored some, but not all, of Reagan's education budget cuts. Over the last year, in a notable change of tune, the administration has taken credit for increases in the amount being spent to encourage teaching in technical fields, improve math and science instruction, and reward outstanding students. In June, Reagan announced a $3-5 million NASA program dubbed Operation Liftoff that will use space themes to stimulate interest in math and science in elementary and secondary schools.

Mondale would take a quantum leap beyond the modest course charted by Reagan with a $10 billion-plus education agenda that places heavy emphasis on science and technology. His proposals include a $4.5 billion Fund for Excellence that would make additional resources available to local school districts: $1 billion a year to enhance the attractiveness of teaching as a career, increased aid to college students in science and mathematics, and a broad program of Advanced Study Awards, loans, and research grants to bolster postgraduate education. This is a more ambitious version of the Presidential Young Investigator Awards initiated by the National Science Foundation this past year and warmly embraced by the Reagan Administration. Mondale also backs the bipartisan "Apple bill"—legislation that would increase the already generous write-offs that computer manufacturers and vendors may take for equipment donated to schools.

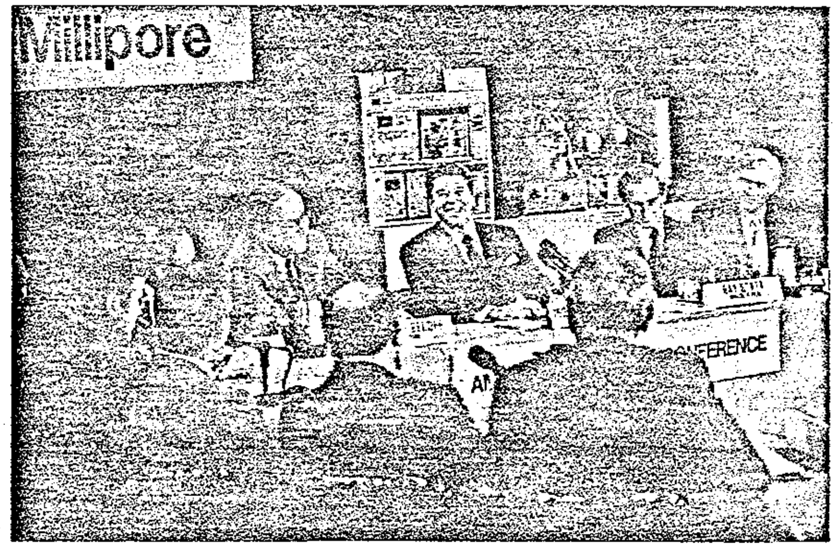
In the related area of technical training, the candidates' approaches also diverge along partisan lines. Reagan upholds as a major achievement the Job Training Partnership Act—a successor to CETA that provides block grants for state-directed public/private programs that retrain workers displaced by technological change. The Democrats propose larger-scale retraining programs supported by federal funds, by employee contributions, or even by a tax on wages (likened by its proponents to a premium on an insurance policy against being cut out of future shifts in the economy).

Into space: racing or walking?

Most of NASA's fears that the space program would feel the cutting edge of the Reagan budget policies have proved unfounded. Reagan heeded his political advisers (and rejected the advice of budget director David Stockman and the Pentagon) in buying NASA's proposal for a permanent manned space station that could cost anywhere from $8 billion to $20 billion. He has continued support for the shuttle, while placing increased emphasis on its military applications.

The shuttle, in fact, is now seen as a symbol of Reagan's aspirations. Last year he suggested that Mondale had been among the "short-sighted" members of the Senate who "led the fight against the Space Shuttle system a decade ago." The charge, which came at a time of renewed interest in the space program, caught Mondale off guard. His aides insisted that Mondale was a supporter of space exploration but that he had feared huge cost overruns on the shuttle program. The record shows that at the time the shuttle program was before Congress, Mondale said a space program of $2 billion to $3 billion a year, "largely in unmanned instrument flight, but also in some manned flight, could give us a fully sophisticated program."

The Democrats still approach space with caution. The 1984 Mondale has dropped his earlier reservations about the shuttle and would give NASA a major role, along with the National Science Foundation, the National Institutes of Health, the Department of Energy, and the National Oceanic and Atmospheric Administration, in boosting real federal investment in civilian space research through an expanded competitive grant system.



President Reagan met with the Massachusetts High Technology Council during a brief visit in January 1983 to Boston's Route 128.

TOM CALLAN/PICTURE GROUP

This contrasts with the National Space Policy outlined by Reagan, designed to promote the privatization of space through commercial applications of the shuttle and by clearing the way for the private operation of expendable launch vehicles. Reagan also has taken steps to spin off parts of the government's satellite program.

The area of space policy that provokes sharpest disagreement between Republicans and Democrats is weaponry. In his "Star Wars" speech of March 1983, Reagan took the first step toward what could become a $25 billion-plus program to develop a defense against ballistic missiles. He also pushed ahead with development and testing of an antisatellite weapon. Mondale opposes both programs.

Energy and environment

Since 1981, federal outlays for fossil, geothermal, and solar energy have dropped some 80%. This is because the Reagan Administration concluded that the tens of billions of dollars spent since the 1970s on energy research and development had done little to improve the nation's energy picture. Energy R&D projects had incurred the wrath of David Stockman and other members of the Reagan budget team, their instincts fueled by a belief that much of the money spent during the Carter Administration (and before) had provided unwarranted bonanzas for industry or, worse yet, had been squandered on worthless projects. In this spirit, Reagan has slashed funding for demonstration projects and has taken steps to tighten the reins on or cancel programs financed by the Synthetic Fuels Corp.

In the nuclear realm, by contrast, Reagan has increased funding for fission and fusion projects and came to the rescue of the domestic nuclear power industry with an agreement intended to open the door to a $20 billion market in China. The pact now appears to be in abeyance because of a lingering rift over proliferation safeguards.

A change of occupancy of the White House would be seen as a victory for the alternative energy people. But although Democrats in Congress have fought Reagan's budget cuts in fossil fuels and renewable resources, and although Gary Hart sponsored legislation to create jobs through the development of renewable energy technology, the extent of such a victory would be uncertain.

The Democrats also accuse Reagan of dragging his feet on the question of acid rain. While Mondale has called for a federally mandated cut of 12 million tons in sulfur dioxide emissions, accompanied by a joint public/private effort to develop technological approaches to cleanup and prevention, Reagan has deferred any major policy decisions until after the election. For the time being, he says, the issue deserves study, not action. In this area, it's Reagan who has chosen to wrap himself in the mantle of caution.

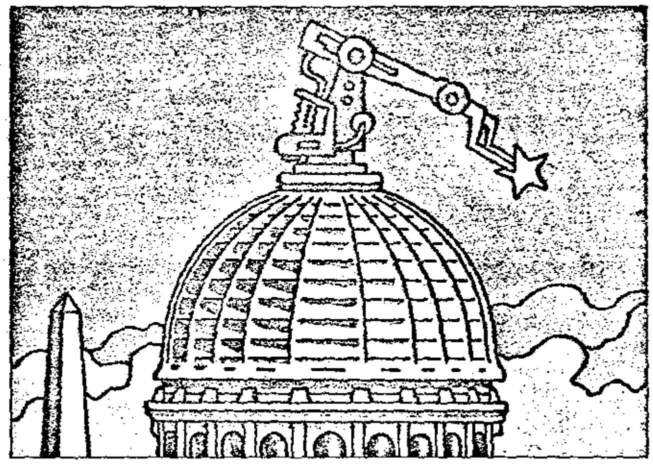
As for the wider issue of the environment, there is a basic difference in the approaches of the candidates. Mondale favors vigorous government action, arguing that if regulations are slapped on industry, it will respond by developing the new technologies needed to comply. The Reagan way is a hands-off approach to regulation. He would forgo rulemaking until the technology is available, thus giving industry time to prepare for mandated changes.

Although the buzzwords will fly on both sides, the fact remains that technology per se is not of central interest to either candidate. Nor is it even clear that technology issues will play a major role in the current campaign. But technology is deeply embedded in the broader issues—the role of the federal government, private initiative, the size of the deficit and the level of federal expenditures, the balance between civilian and military needs—that are the decisive battlegrounds of the election. The rhetoric about technology may soar, but the campaign struggle is anchored in pragmatic politics.

Edwin Diamond is head of the News Study Group at MIT. Norman Sandler is a White House correspondent for United Press International.

HIGH TECH ON CAPITOL HILL

By Daniel Gottlieb



Democrats and Republicans agree that the American high technology star is in danger of being outshone by foreign competitors. But congressional activists on high tech issues—led by Rep. John J. LaFalce (N.Y.) for the Democrats and Rep. Ed Zschau (Cal.) for the Republicans—are poles apart on the proper role for government in helping U.S. industry compete in world markets.

The Democrats propose a central planning agency, paired with a new industrial bank. This scheme would rationalize what they see as conflicting U.S. policies toward industry, as well as strengthen declining industries and promote innovative technologies.

In debunking the Reagan Administration's talk of a "free market" approach to these issues, the Democrats claim that Republican rhetoric simply masks what the administration is actually doing. "It is avidly pursuing protectionist policies for a wide range of industries and continues to hand out tens of billions of dollars each year in badly targeted, insufficiently conditional, and largely ineffective aid to industry," says the Democratic majority in a House Banking Committee report.

The Republicans, however, argue that government should "target the process of innovation" by "creating an environment... in which innovation, new ideas, and new companies are likely to flourish and in which mature industries can modernize," according to the High Technology Initiatives report from House Republicans. The party therefore leans toward increased funding for basic research, as well as science and engineering education. It also supports tax incentives for R&D and removal of government barriers to innovation, such as restrictions created by antitrust and patent law.

The Republicans' report states that the Democrats' approach of targeting industries is "doomed to failure," will be rejected by industry, and will give money "to the industries and regions best represented in Washington" rather than those that most deserve it.

The Democratic agenda

The key Democratic proposal is the Industrial Competitiveness Act (HR 4360, sponsored by LaFalce), which would establish three new bodies:

• Council on Industrial Competitiveness. This group of sixteen business, labor, government, university, and public interest representatives would create industrial promotion policies to make U.S. businesses better able to compete with foreign firms.

• Bank for Industrial Competitiveness. Funded at $8.5 billion, the bank would sign on as a minority partner with private-sector banks in making loans to industries facing "serious international competitive challenges." Instead of continuing the "free of charge" credit policies of the Reagan Administration, the bank would grant credits based on pledges from labor and management to cut costs and increase productivity, and on promises of cooperation from local government in affected areas. LaFalce based this program on the successful Chrysler loan guarantee program.

• Federal Industrial Mortgage Association. Modeled on Fannie Mae (Federal National Mortgage Association), "Finny Mae" would provide a secondary market for long-term loans to small and medium-sized businesses. Commercial banks have had difficulty providing long-term "patient" capital to such firms because bank deposits have become very short-term and sensitive to interest rates in recent years, says the House Banking Committee report.

If the Industrial Competitiveness Act reaches the floor, LaFalce expects a tough fight. Neither side of the aisle is unified on high technology policy, so there is crossover on some issues and bipartisanship on others (like the House's 388–0 vote to protect chip masks from piracy). Even some high tech Democrats, like Rep. Timothy Wirth of California, want the bank dropped from the bill to avoid having the party tagged for supporting a big spending measure in the face of a $200 billion budget deficit. In any case, neither the Senate nor President Reagan is likely to approve the bill, but LaFalce plans to press it anyway, hoping to build future public support.

A companion piece to the Industrial Competitiveness Act is LaFalce's Advanced Technology Foundation Act (HR 4361), which would create centers for applied research at universities and help finance industrywide joint R&D ventures.

Republican priorities

In response to the so-called Atari Democrats and in hopes of galvanizing support for administration policy, the Republicans have set up their own High Technology Task Force. The group has backed several bills:

• R&D tax credit. The 25% credit for incremental R&D expenditures (above a firm's average outlays for the preceding three years), which was passed in 1981, would be made permanent before it expires on December 31, 1985. Bills passed by both houses during the last session would have narrowed the definition of R&D to benefit high tech industries, made the tax credit available to start-up companies (by allowing them to write off R&D expenses against later-year profits), and liberalized tax treatment of donations of computers and other equipment to schools and universities. Despite widespread support that included backing from the administration, the effort looks dead this year because of a deal between the House and Senate conferees to pass a deficit reduction package. "The high tech community was very disappointed," says Marc Rosenberg, executive director of the National Coalition for Science and Technology. Prospects for next year appear to hinge on how much pressure will be brought to bear to reduce the budget deficit.

• Joint Research and Development Act (HR 5041). As passed by the House, the bill sponsored by Rep. Peter W. Rodino (D.-N.J.) provides partial relief from antitrust laws to companies banding together to do research they might not be able to afford to do alone. Joint R&D ventures would be protected from civil antitrust suits in three ways: If the complainant proved that a joint venture had anticompetitive effects, courts would have to consider the potential benefits of a joint venture rather than simply declaring it a per se violation; joint venture firms could avoid potential future liability for treble damages in successful suits by notifying the government of the nature of their operation when they start it; and the likelihood of frivolous suits would be lessened by making unsuccessful litigants pay attorney's fees to the winning party.

Although the bill passed the House, similar legislation has been held up in the Senate (S 1841). Sen. Howard Metzenbaum (D.-Ohio) is threatening to block it because of the provisions regarding treble damages and attorney's fees. Nevertheless, Ken Hagerty, the American Electronics Association's VP of government operations, claims the bill could pass this year if it reaches the Senate floor.

• Semiconductor Chip Protection Act. Both houses have passed bills to protect the mask designs for semiconductor chips from unauthorized copying or piracy. The Senate version (S 1201, sponsored by Charles Mathias, R.-Md.) would apply to chip designs retroactive to January 1, 1980; the House bill (HR 5525, sponsored by Don Edwards, D.-Cal.) would cover only those made after January 1, 1984. The Senate puts chips under the protection of the copyright law; the House creates a unique 10-year proprietary protection. The Semiconductor Industry Association supports both House and Senate bills, but publishers and data-processing groups oppose bringing chips under the copyright law for fear of diluting its protection. A chip protection bill is almost certain to pass, if not this year then in 1985, industry sources say.

Despite election-year politics and concern with the budget deficit, industry lobbyists are satisfied with legislative activity in the 98th Congress. New lobbies like the Industry Coalition on Technology Transfer (formed to fight for easing of export controls) and the National Coalition for Science and Technology (founded to lobby for science and technology education and research) are helping to get attention and support for high tech issues. "The high tech lobby is kind of an adolescent," says Zschau's aide for high technology, Jim LeMunyon. "They certainly don't rank with the AFL-CIO or the realtors." But the efforts of new lobbyists have been bolstered by congressional activists. Both the Republican task force and Zschau's leadership have had "a significant and substantive impact" on the Hill, says AEA's Hagerty. And with the President's Commission on Industrial Competitiveness scheduled to report at the end of this year, Republicans and Democrats expect the 99th Congress to deal with more legislation on high tech issues, regardless of who occupies the White House.

Daniel Gottlieb of Washington, D.C., is a freelance reporter who frequently covers technology policy.

HIGH TECH: HOW BIG? WHAT NEXT?

By Dan Dimancescu

Just what and how big is the high technology industry? And what is its present and future impact on the U.S. economy? Definitions and estimates are bedeviled not only by the vagueness of the term but by the blurry line that often separates makers and users of high technology products and processes.

Nevertheless, official counts undertaken by federal and state agencies have established the most commonly quoted measures of the industry's size. Out of approximately a hundred million working Americans, it is estimated that between 3 and 6 million are employed by high technology firms in jobs as varied as senior researchers, marketers, production-line technicians, service people, or custodians. Gross annual sales of these firms total $200–400 billion, or about 6–12% of the GNP.

Who is high tech?

Efforts to define high technology firms rely on two principal characteristics: a large proportion of professional and technical employees and a significant percentage of sales revenues devoted to research and development. Both properties reflect a vaguer commodity—"knowledge intensity"—that is an essential ingredient of high tech products and a necessary attribute for continued innovation. Typically 40–65% of the high tech firm's employees have engineering and scientific degrees or are skilled technicians with two or more years of post-high-school education. And in general these firms reinvest between 5% and 15% of their revenues in R&D. These percentages are two to five times higher than for non-high-tech companies.

Two widely used definitions of the high technology industry, both based on three-digit Standard Industrial Classification (SIC) data, come from the federal government and Massachusetts. Both are official attempts to pin down specific numbers of workers employed by U.S. high technology firms. The Federal Department of Labor's Bureau of Labor Statistics recognizes three broad categories: manufacturers of high technology products, such as computers; technology-intensive companies, such as chemical or turbine makers; and high technology services such as data-processing and software companies. In total, the bureau estimates, these firms employed 6 million people in 1982.

The Massachusetts Department of Employment Security (DES) takes a narrower approach. It defines high technology as a single grouping of 20 manufacturing industries and excludes service-sector categories altogether. By this measure, about 3.6 million people in the U.S. worked for high tech firms in 1982.

New industries, old labels

While such definitions and the employment counts that go with them are useful and widely quoted, they are far from all-inclusive and are somewhat contradictory. For example, the computer and data-processing service industry (SIC 737) is left off the Massachusetts DES list while the watches and clocks industry (SIC 387) is on it. The federal groupings omit the latter and include the former. While this suggests a certain arbitrariness in characterizing high technology, there is another reason why the search for a precise definition remains elusive.

The difficulty starts with the SIC codes themselves. The most frequent problem is that old labels, which do not necessarily apply to new industries, are accepted anyway in order to maintain statistical continuity. The classic example is nonelectrical machinery (SIC 35). It is the parent two-digit SIC industry for all computer manufacturing (SIC 357), a classification dating back to the days of hand-cranked calculators and to the once meaningful split between manufacturers of machinery for the electric power industry and the producers of machinery for, say, textiles and shoes. Thus every modern computer—from Cray mainframes to Apple micros—is in this category. The same is true for robots, which are treated as nonelectrical construction equipment under SIC 353.

High tech pockets

Another problem in defining the industry is the often fuzzy distinction between the maker and user of high technology tools. The producer of a 256K chip and the manufacturer of a microcomputer dependent on this chip are clearly high technology companies. But what about the end user in a bank or manufacturing plant who must write sophisticated software for this tool? Within numerous large firms, appropriately labeled with non-high-tech SIC codes, sizable pockets of employment exist with all the required high tech characteristics. But actually measuring them and integrating them into high technology job statistics is not possible using methods based on SIC codes, and the result is that the full magnitude of high tech employment—both present and forecast—goes understated.

For example, the automotive industry falls under SIC 371, a low tech category. Yet CAD/CAM is used extensively in design, cars will soon be built in modules that are then clipped together, and plastic engine blocks are in the works. Auto industry leaders like to say they are entering an "autotech" era, with the average car of the near future having the equivalent of an Apple computer to monitor the vehicle's performance and tell the driver about it in a choice of dialects. In 1983 alone, GM's R&D budget was $2.87 billion, much of which paid the salaries of high tech professionals in fields such as solid-state sensor design. At Ford Motor Company, more than half of the 600 staff members of the central engineering department are electrical engineers. Yet such jobs usually elude the high technology census.

> *A blurry line often separates makers and users.*

Lynn Browne, senior economist at the Federal Reserve Bank in Boston, agrees that the prevailing definition of high technology is too narrow. Writing in the *New England Economic Review*, she notes that "growth in some of the most rapidly expanding business services is, to some extent, a reflection of the growth in high tech manufacturing." Her analysis of employment data shows, for example, that jobs in the computer hardware sector create almost an equal number of high tech service jobs. Similarly, one might well add such SICs as Business Management & Consulting Services (7392), Engineering and Architecture Services (891), or Non-Profit, Educational, Scientific and Research Organizations (892) to the high technology categories.

Bullish predictions

Because defining and measuring the high technology industry is so fraught with uncertainty, estimates of its future cannot be made with confidence. Nevertheless, the Bureau of Labor Statistics, which is forecasting overall growth in new jobs between 1982 and 1995 of 23.4 to 28.6 million, estimates that between 2 and 4 million of these new jobs will fall under high tech SIC codes.

Much of this growth will be fueled by increased demand for high technology products. The world computer market, according to *Electronics* magazine, is expected to jump from $100–150 billion in 1983 to $500–700 billion (in current dollars) by 1993. The demand for chips alone will grow almost sixfold—from $16 billion to $90 billion—with half this increase due to U.S. markets. By 1993 the production of just the coming generation of supercomputers will yield an expected $6.5 billion a year in sales, as well as create 80–100,000 manufacturing jobs and another 100–250,000 jobs in the operation of the new systems. In another high tech area, biotechnology, the University of Texas predicts that current research will spawn 1 million new jobs.

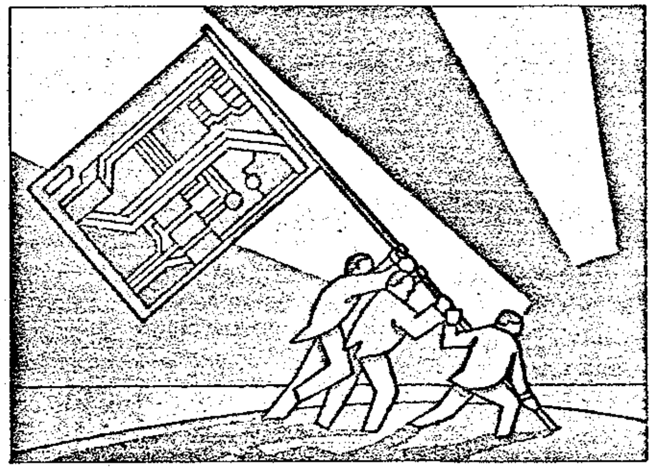
While forecasts can never be guaranteed, of course, bullish predictions of high tech growth over the next decade are realistic because private sector demand will be the principal driving force. And the demand for new products and processes will be further stimulated as mature industries invest in new generations of production technology. Barring a sudden and severe global recession, worldwide commercial demand is relatively insensitive to short-term policy shifts. By contrast, defense contracts were the primary reason for the growth of high technology businesses in the '60s and early '70s, and the industry soon began to suffer when federal policy changed and defense R&D expenditures were cut back.

Yet the continued growth of the industry depends not only on demand; a variety of actions must be taken to assure the supply. These include substantial federal and industrial investments in R&D, expansion of engineering and science programs in the nation's universities, improvements in the quality of education in primary and secondary schools, and the development of better ways to accelerate the transfer of technology from the lab to the marketplace. This agenda will increase our national productivity and revitalize the international competitiveness of our industries.

Dan Dimancescu is a consultant and writer on high technology policy issues.

R&D CONSORTIA: CAN U.S. INDUSTRY BEAT THE JAPANESE AT THEIR OWN GAME?

By Jonathan B. Tucker



U.S. industry's position of global leadership in high technology has eroded since the early 1970s because of declining federal and corporate investment in R&D at a time when other nations were stepping up their research efforts. But a consensus is emerging in both the public and private sectors that strong remedies are necessary to restore and maintain America's technological edge.

The major challenge comes from Japan, where the Ministry of International Trade and Industry (MITI) has organized and subsidized large multicompany R&D consortia in certain target industries, including steel, automobiles, microelectronics, TV, machine tools, satellites, biotechnology, and artificial intelligence. These consortia pick a specific research objective (say, a 4-megabit memory chip) and assemble teams of top industrial scientists to develop the generic technology; the member companies then convert the basic prototype into their own commercial products. As a result of this innovative approach to technology transfer, Japan has managed to carve out large shares of several U.S. markets.

Japan's successes have put American industry on notice that it can no longer take the industrial innovation system for granted, and that it must transfer laboratory advances into effective commercial technology more rapidly than in the past.

Because of the escalating costs of manpower and equipment, however, development of certain types of generic technology has become too expensive and complex even for corporate giants to attempt single-handedly. As a result, large U.S. manufacturing companies in electronics and other internationally competitive fields have begun to band together in joint research ventures that eliminate wasteful duplication of effort and speed up the pace of technology transfer. As in Japan, participating companies share the generic technology derived from their joint efforts and then compete with one another to develop commercial products and market them.

"Companies are increasingly willing to collaborate for the good of their industry," says Tom Noble, program manager in the Technology Utilization Office at Battelle Columbus Laboratories, "especially where they're threatened by foreign competition in an area that requires major funding or where the market is not yet well developed."

The move toward research consortia has been fueled by a positive climate in Washington. The Reagan Administration favors joint research ventures because they are organized and financed by the private sector, providing a way to increase U.S. productivity and competitiveness without direct government intervention. Research consortia are also popular in Congress, which is removing many of the real and perceived legal obstacles to joint research.

Lowering antitrust barriers

U.S. industry has long been wary of joint research ventures because of their ambiguous legal status under the antitrust laws. Since the antitrust guidelines say that no more than 25% of any market is allowed to collaborate in a given consortium, it can be risky for several major firms in the same industry to work together on generic research.

This obstacle will soon be removed by legislation passed recently by both houses of Congress. The bills provide that in actions under the antitrust laws, government agencies and the courts should not consider joint research ventures unlawful per se if companies with large market shares are participating, but should apply a "rule of reason" analysis to judge them by their effects on competition.

The two bills also specify that if joint research ventures are reported in advance to the Justice Department and the Federal Trade Commission, the potential liability of participating companies is limited to actual damages, instead of the treble damages awarded under present law. Moreover, losing parties are required to pay the winner's attorney fees, a measure designed to discourage frivolous antitrust suits.

The House bill, known as the Joint Research and Development Act of 1984 (HR 5041), sailed through the House in early May with a vote of 417–0, and the Senate version (S 1841) also passed by a unanimous vote of 97–0 in early August. The legislation is now in conference committee and may be signed into law this fall.

Joint funding of basic research

Joint research ventures have been pioneered by the electronics and computer industries, which must compete head-to-head with powerful Japanese consortia. The first industrywide effort was the Semiconductor Research Cooperative (SRC—Research Triangle Park, N.C.), established in 1982 as a nonprofit subsidiary of the Semiconductor Industry Association. SRC pools funds from member companies and sponsors basic research on microelectronics at key universities around the country. The consortium numbers about 35 companies, including IBM, Motorola, Hewlett-Packard, Control Data, Digital Equipment, National Semiconductor, Intel, RCA, and Rockwell International.

To meet SRC's $13.5 million budget in 1984, the corporate sponsors contributed a minimum of $60,000 and a maximum of 10% of the annual budget through fees based on semiconductor-related sales. The cooperative is funding 54 research projects at some 40 universities, including Berkeley, Carnegie-Mellon, Cornell, MIT, Rensselaer, and Stanford. All such projects are generic, in the sense that they provide information that will be useful to a broad spectrum of the member companies over a 5–10 year period. But "we are gradually biasing our research agenda to carry out more long-range research," says Robert M. Burger, SRC's chief scientist and senior technical officer.

Member companies are represented on a Technical Advisory Board that defines research strategy, advises the SRC staff on research priorities, and helps evaluate the quality of the research being done. In addition, all corporate sponsors have equal access to information generated by the cooperative's research activities, which is disseminated to member companies through published reports and topical conferences. Although the results of SRC-funded research eventually appear in the open technical literature, sponsors get an early look at the results and thus gain valuable lead time. Participating companies also have a royalty-free, nonexclusive right to any patents or copyrights ensuing from the research.

SRC's greatest contribution, Burger contends, is in education. Before the consortium was founded, there was relatively little university research on silicon devices, even though they constitute by far the largest part of the semiconductor market. Now nearly 300 graduate students are working in SRC-funded research programs. As these students complete their education and move on to research positions in industry and academia, many will continue their work on silicon devices, contributing to an expanding research effort in the field. Moreover, SRC's impact will be national rather than regional. "By directing its research through various universities and centers of excellence," says Regis McKenna, president of Regis McKenna, Inc. (Palo Alto, Cal.), a high technology marketing firm, "SRC's effect is to disperse technology throughout the country, so that a few areas don't become dominant in everything."

In addition to its work in research, SRC is thinking about extending the cooperative concept to development, including a plan—dubbed Project Leapfrog—to design the next generation of microchip fabrication equipment. Interest in the proposal is strong among many SRC member companies, Burger says, and preliminary discussions are underway.

Chemical, TV industries follow suit

The chemical industry's equivalent of SRC, the Council for Chemical Research (CCR—Allentown, Pa.), was founded in 1982. CCR is a consortium of 43 major chemical companies, including Allied, Du Pont, Dow, Monsanto, and Exxon, and 142 U.S. universities that offer PhDs in chemistry or chemical engineering. "CCR tries to serve as a catalyst to encourage the interaction between universities and industry," says executive director Jim McEvoy. The council also runs a Chemical Science and Engineering Fund, supported by member companies, that finances basic university research. This year the fund has distributed a total of $630,000, with the size of the grants determined solely by the number of PhDs each school confers annually.

Another joint research venture emerged in October 1983, when ten communications companies banded together to establish the Center for Advanced Television Studies (CATS). The cooperative, which includes all four national networks (ABC, NBC, CBS, PBS) and Home Box Office, as well as leading TV manufacturers (Ampex, Harris, 3M, RCA, and Tektronix), is funding basic research at MIT on concepts and techniques that could be used in new TV systems. Each member company has agreed to contribute $100,000 a year to fund MIT's Advanced Television Research Project at an annual level of $1 million over a three-year period. CATS's board of directors is chaired by Jules Barnathan, president of operations and engineering at ABC, and the cooperative is administered by the Public Broadcasting Service in Washington, D.C.

"There's a lot of interest worldwide in obtaining better TV pictures and getting rid of some of the defects in all of the existing broadcast standards," says John E. Ward, a member of the MIT research staff. "For example, the broadcast standard here in the U.S. dates back to 1952. Japan, England, and Germany are working hard in this area, and the U.S. companies decided that it was better to do it jointly than each try to go it alone."

Because all of the major networks are involved, the consortium was subjected to eight months of scrutiny by the Justice Department for possible anticompetitive effects. Approval was granted because the purpose of the center is not to develop commercial products or prototypes but to understand the implications of new technology and lay the groundwork for future TV developments.

The MIT group is concentrating on basic research into TV transmission and display, including higher-resolution line standards, faster frame rates, and improved audio. It will report its results to the member companies, which will then be able to apply them as they see fit. Although all of the project's findings must be published in the open literature, the sponsoring companies will be given royalty-free licenses to any patented technologies that result from the research. "We're trying to start with a clean sheet of paper and come up with the best possible system given today's technological environment and what we think will happen over the next few years," says HBO's Ed Horowitz, the cooperative's publicity chairman.

Generic technology development

While industrywide cooperatives such as SRC, CCR, and CATS fund basic university research, the Microelectronics & Computer Technology Corp. (MCC), a private R&D consortium based in Austin, Tex., focuses on generic technology—the middle portion of the R&D spectrum between basic research and product development. "The bulk of the basic research is still done in universities and will continue to be," says Bobby R. Inman, MCC's chairman and president. "We're taking existing theories, proving them, and turning them into prototype systems."

The primary rationale behind the consortium is the scarcity of highly trained scientists and engineers. "Precisely at the time that new opportunities are opening for expansion, particularly in explosive areas like information handling and biotechnology, the pool of trained talent is decreasing," Inman says. Industry therefore has a strong incentive to bring together a critical mass of talent in joint R&D efforts. Another rationale is the fact that Bell Laboratories and the Defense Department, which sponsored much of the generic technology on which the semiconductor industry was based, have since refocused their efforts on applying the fruits of this research. Thus companies must work together to ensure the continued development of generic technology that will spawn the products of the future.

MCC started formal operation in January 1983, despite concerns on the part of several participating companies about its legal status under the antitrust laws. Since then, the ambiguities about the consortium's legality seem to have been resolved. Today MCC has 18 corporate sponsors and a budget of more than $70 million. Most of the participating companies are large corporations in the microelectronics and computer fields; the smallest members have annual sales in the range of $125–500 million. "A few giants like IBM have not expressed interest in joining," Inman says, "but from an antitrust point of view, their being outside is probably our major security blanket."

MCC is unique among cooperative R&D efforts in the computer field in that it is a for-profit corporation that does the bulk of its research in-house. By mid-1984 MCC had hired 162 people, 138 of them professional-technical. Eighty percent of the research staff comes from industrial labs, the rest from academia and government. Of the industrial scientists, 45% are on loan from their companies and 55% are direct-hire. Says Inman, "We're about five months ahead of our most optimistic projections of where we would be in assembling talent, and research is underway in all the facilities."

Each corporate member of MCC must purchase a share of stock (at $500,000 per share), in addition to supporting one or more of four research programs:

• A six-year program to develop new methods of packaging integrated circuits.

• A seven-year program in computer software technology, with an emphasis on the use of expert systems to assist in writing software.

• An eight-year program in the computer-aided design of very large-scale integrated (VLSI) circuits.

• A program called Advanced Computer Architecture, comprising four independent projects in parallel processing, artificial intelligence, database management, and human interface with computers. According to Inman, this effort is "comparable to the Japanese Fifth-Generation Project, except that it's broader-based."

Fees for membership in the research programs vary with the number of corporate sponsors, since costs are divided equally among the participants. Actual figures are confidential, but Inman estimates that it costs a company about $1 million a year to support one research program and $6–7 million to support all four programs. Although shareholders are given general descriptions of the goals, approaches, and timetables of all the research programs, only those companies funding a particular program have access to proprietary data on new processes, techniques, and prototypes. Licensing of patented technologies arising from the research programs is also limited to sponsor companies for up to three years, whereupon licenses will be made available to the general public.

A rationale behind consortia is the shortage of highly trained scientists and engineers.

In April, MCC announced an Associates Program for smaller firms that cannot afford the cost of full membership. These companies will be provided descriptions of current research programs and will be informed about new technologies available for licensing before public release. An important category of associate members is companies that supply materials, instrumentation, and support services to the computer industry; they need to keep abreast of emerging technologies so that they will be in a position to provide products and services to the shareholders when the new technologies reach the marketplace. The fee for membership in the Associates Program is on a sliding scale based on annual purchases or sales of computer-related hardware and software. Companies that have sales or purchases under $250 million, for example, pay $25,000.

Although it is too early to tell how successful MCC will be, a similar consortium is already in the planning stages. In May, Battelle Columbus Laboratories, a nonprofit research organization, proposed a fiber optics industry R&D cooperative. Its aim would be to ensure future U.S. leadership in fiber optics in the face of mounting foreign competition—particularly from Japan, which recently embarked on a $100 million, seven-year national development program in this area. The economic stakes are high: Battelle estimates that by the year 2000, fiber optics could become a $30 billion market in the United States alone.

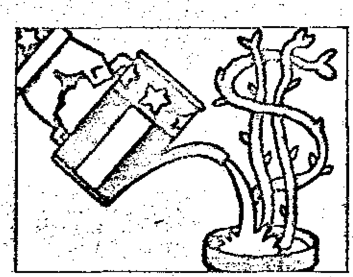
At present, commercialization of fiber optic systems is blocked by the lack of practical high-performance components for connecting sets of fibers with digital information systems. Such optoelectronic components are required for switching, splitting, amplifying, and modulating light signals, and for processing optical data. "What's needed is a toolbox of manufacturing technology that companies can use to develop and fabricate these components," says program director Robert L. Holman. "The industry needs generic materials, as well as fabrication, microassembly, and packaging techniques for mass-producing these components in a cost-competitive manner."

Battelle's proposed program, costing roughly $60 million over seven years, will comprise three major projects: automated microassembly and packaging technologies, manufacturing processes for fabricating optical circuits, and processes for producing optical-quality crystals for guided-wave optics. Battelle is now organizing the initial phase of the first project, requiring a total of $12 million in support over three years. At least 20 companies will have to participate at a fee of $200,000 per year to fund the project at the desired level.

Battelle is already hiring a multidisciplinary research team, including experts in guided-wave optics, physical chemistry, materials science, and manufacturing, and all work will take place in its own laboratories. Corporate sponsors will participate in administration and oversight of the project through advisory boards and will receive a continuous flow of research results from the projects they support, as well as royalty-free licenses.

U.S. biotechnology companies have

FEDERAL PROGRAM BOOSTS SMALL BUSINESS R&D



By Frank J. Catalano

Japan's advances over the past two decades into markets once dominated by the U.S. have convinced the federal government that the nation's climate for technological innovation needs to be improved. Although Democrats and Republicans generally have different approaches to the problem, they are in rare agreement on a plan for stimulating innovation among the companies that historically have been one of its major sources—small businesses. In 1982, President Reagan signed into law the Small Business Innovation Research (SBIR) Act, designed to increase the flow of federal R&D money to companies with fewer than 500 employees.

Since the turn of the century, small businesses have received more than 60% of the patents issued in the U.S., according to Roland Tibbetts, codirector of the Office of Science and Technology Innovation at the National Science Foundation (NSF). A study by Gellman Associates (Jenkintown, Pa.), reports that, on the average, small firms produce 2.5 times more innovations per employee than larger firms and commercialize these innovations one year faster and at 25% the cost.

Yet despite small businesses' technological contributions through the years and their efficiency in translating R&D into products, such firms have been receiving less than 6% of all federal R&D contracts. In fact, the Gellman study found that when competing for the same contract, a large company is 2.8 times as likely to receive an award as a small firm.

"There's been a feeling in the government that if the big corporations can't solve a problem, no one can," notes Richard Shane, acting assistant administrator of the Office of Research, Innovation and Technology at the Small Business Administration (SBA). "We seem to have forgotten that many of our most creative minds—Thomas Edison, Alexander Graham Bell, and the Wright brothers, for example—started out with small firms."

The government's apparent preference for large organizations threatened to hurt not only small business but the economy as a whole, notes Shane. Small companies employ 60% of the nation's workforce, he says, and are major contributors to both the tax base and the Gross National Product. But without government contracts, many firms, especially those just starting out, might not be able to survive. An SBA study reports that 74% of the small high tech companies in existence in 1981 performed federal R&D during their early years; 48% of the chief executive officers of those firms contend that without such work their companies would have gone under.

"Almost half of all R&D in this country is funded by the federal agencies," says Shane. "In adopting the SBIR program, the government finally realized that a fair share of that money had to be channeled to small business as a means of fostering innovation and stimulating growth."

Now in its second year, SBIR was modeled after an NSF pilot program begun in 1977. Contracts are issued in three phases. Phase I awards, amounting to as much as $50,000 for a six-month project, call for awardees to determine the technical and commercial feasibility of their ideas. Winners are selected on the basis of 25-page proposals they submit in response to solicitations issued annually by 11 participating government agencies. Each solicitation contains a listing of basic and applied research areas.

Companies whose Phase I results demonstrate the greatest potential are then awarded Phase II contracts. These projects are worth as much as $500,000, last no longer than two years, and could lead to prototype hardware development. Before applying for awards, candidates are urged to seek assurances from a venture capital firm, a large corporation, or another small business that funding would be provided for commercialization of the innovation following the project's successful completion. While this assurance is not required, it could be the deciding factor between two proposals of equal merit.

A project moves into commercial development during Phase III, which is funded by a private concern rather than the government. Although a federal agency, such as the Department of Defense, may decide to issue a procurement contract for the innovation during this phase, that contract would not be part of the SBIR program.

In 1983, the first year of the program, 700 Phase I projects were funded at a cost to the government of $45 million. By '88, more than 2000 Phase I and 1000 Phase II projects, with a combined value of over $500 million, are expected to be in progress.

"What we're doing," says NSF's Tibbetts, "is giving some of the most creative companies in the U.S. a chance to prove ideas that may be too far out, too risky, for the venture capital community. But as awardees carry out research for the government, they'll strengthen their credibility among private investors."

Both the House and the Senate passed the SBIR Act by an overwhelming majority, despite objections from some critics. While the bill was still pending, many government officials testified that small businesses are not as adept at performing research as large corporations and that the measure would create unnecessary red tape. Furthermore, groups lobbying for universities argued that SBIR funding would cut into their share of federal R&D, thereby hurting the academic community financially.

But while it's still too early to judge SBIR's success, the results of NSF's pilot program have been favorable. So far the agency has issued five rounds of Phase I and four rounds of Phase II solicitations. Winners of the first Phase II awards completed their projects last year. While NSF's funding for those firms totaled $5.3 million, private investors committed more than eight times that amount in commercial development financing. Furthermore, participating companies increased their employment an average of 125% over a five-year period. Success stories abound:

(Continued on next page)

• Spectron Development (Costa Mesa, Cal.) received 18 SBIR contracts for research involving test and measurement applications of high-energy lasers. That record is impressive, considering that only one in 10 SBIR proposals now receives funding. So far, two commercial products have come out of Spectron's work—a particle-sizing system and a device to measure aerodynamic flows. "There's no question that SBIR has helped us accelerate our growth," notes Chris Busch, president of the 60-person operation. "We have venture people coming to us now as well as government agencies."

• As a result of a $25,000 Phase I contract funded by NSF in 1977 and a $239,000 Phase II award, Collaborative Research (Waltham, Mass.) developed a process to enhance the production of animal proteins using genetic engineering techniques. Following completion of the project, the company received a $6 million contract from Dow Chemical (Midland, Mich.) and a $1 million contract from Japan's Green Cross to tailor the process for those firms' own needs. Dow subsequently invested $5 million for a 5% equity in Collaborative Research, which went public in 1982 with a $14 million stock offering.

• Crystal Systems (Salem, Mass.), which specializes in growing crystals for laser applications and currently has 10 SBIR projects in the works, has thus far attracted investments of $1.5 million from Cabot Corp. (Boston) and $100,000 from Sanders Associates (Nashua, N.H.).

While early SBIR opponents are still closely monitoring the program, Milton Stewart, president of the Small Business High Technology Institute (Phoenix)—a private nonprofit group that is helping to promote and coordinate the SBIR program—says that many of their initial fears have been allayed. "Agency officials have stated that they've been remarkably surprised by the quality of work coming out of SBIR participants," says Stewart. "The only difficulty they're having is in deciding which proposals to fund." Last year, the Defense Department's solution was to award more SBIR contracts than it was required to by law.

"This program is as American as mom and apple pie," notes SBA's Shane. "It's fostering the innovation process that our country is known for, it's helping the little guy, and it's improving our quality of life through new jobs, products, and processes."

Frank J. Catalano is business editor of HIGH TECHNOLOGY.

not banded together into an R&D consortium, despite the recent formation of a Japanese consortium in this area. The reason is that most firms have yet to bring products to market and thus are focusing on "raising enough funds to support their own research, rather than trying to find a common ground to develop generic technology," says Zsolt Harsanyi, vice-president for biotechnology at E. F. Hutton (Washington, D.C.). Still, the industry is supporting basic research at a number of university centers, and all biotechnology firms will soon face the common problem of producing and purifying large quantities of biomaterials. Development of the necessary scale-up technology will be particularly amenable to industrywide collaboration, Harsanyi says.

The recent passage of the Senate version of the joint R&D bill to shield collaborative research ventures from antitrust actions should spur the formation of R&D consortia in other industries as well, such as energy and chemicals, according to MCC's Inman. Ever since the House version passed unanimously, he says, the number of queries MCC has received from firms outside the computer field "has gone up exponentially."

Will it work?

The Commerce Dept. is a strong advocate of collaborative R&D, contending that it could revitalize new and old industrial sectors alike. "Industries that are clearly on the upswing, like microelectronics, are most likely to start joint research ventures," says Lance Felker, director of the department's Industrial Technology Partnership Division. "But the ones that need it most are steel and other smokestack industries. It has tremendous applicability to everyone."

Armand Tanguay, associate professor of electrical engineering at the University of Southern California (Los Angeles), maintains that consortia are the only viable approach in fields where the technology is being driven rapidly by other countries. "There are a number of areas of modern technology—including very large-scale integrated and very high-speed integrated circuits, fiber optics, large-area networks, and integrated optics—in which the ability to manufacture certain items requires R&D breakthroughs that are much more amenable to solution by the consortium approach," he says. "These technologies are just too big for any one company to attempt, at least on the time scale that's being allowed."

But Tanguay cautions that consortia are not as valuable in areas where there is less international competition. "In cases where we have the luxury of exploring a particular field over a reasonably long period of time without the threat of external competition, I think domestic competition among companies makes more sense," he says. "It has been an extremely productive avenue of research for American corporations, and I don't think it's one to be lightly turned aside."

Dennis G. Hall, a professor of optics at the University of Rochester, believes that R&D consortia are good for American industry as a whole, but questions the willingness of many individual companies to engage in them. The major obstacle to collaborative R&D in the United States may be more cultural than legal, he suggests. While Japan's corporate culture encourages the notion of working together on problems of mutual interest, American business stresses independence and self-reliance—a cultural norm enshrined in the antitrust laws.

Says Hall: "You're asking U.S. industry to do two things that it's suspicious of—collaborate in developing new manufacturing processes and undertake long-range planning." Since American companies normally view manufacturing processes as trade secrets that can provide a competitive edge, they may be reluctant to work with competitors on developing new technologies.

Thus the jury is still out on whether joint research ventures will work as well for American industry as they have in Japan. The verdict will likely depend on the quality of the results that the pioneering U.S. consortia are able to produce over the next few years.

Jonathan B. Tucker is a senior editor of HIGH TECHNOLOGY.

THE TRANSFORMATION OF BASIC INDUSTRY

By Ernest Raia

One hears the same lament over and over. U.S. industry, world leader in technological development, is falling behind other nations—most notably Japan—in the application of new technology. And there is compelling evidence to support this contention, such as the permanent closing of hundreds of factories across the nation in industries like steel, automobiles, and machine tools, in which the U.S. was once the indisputable leader.

According to the National Academy of Engineering (NAE), which has recently completed studies of the competitive status of several U.S. industries, the success of the Japanese is rooted in their commitment to manufacturing excellence and a strategy that uses manufacturing as a competitive weapon. By contrast, American firms consider the basis of competition to be in "marketing, styling, and dealerships." By the late '50s, the NAE study concluded, manufacturing had become "a competitively neutral factor" in the U.S.

Marshall Plan for manufacturing

It is now generally agreed that if basic American industries are to extricate themselves from their problems, manufacturing will once again have to be top priority. "The competitive battle in the auto industry will be fought and won on the factory floor," says Donald Peterson, president of Ford.

And it appears that American industry is starting to bankroll the new technologies that will be deployed in this effort. The automakers alone are planning to invest more than $100 billion dollars to develop new products. This is more than was spent in the Marshall Aid Program to rebuild Europe after World War II, notes Eric Mittelstadt of GMF Robotics (Troy, Mich.).

Manufacturing—particularly automated manufacturing—will be central to future strategies in industry. Some examples:

• Pratt & Whitney's plant in Columbus, Ga., represents the company's most ambitious effort thus far to apply advanced manufacturing concepts on a wide scale. The production of aircraft engine disks and compressor blades will be under computer control from the time raw material enters the production process through final inspection.

• Chrysler, which paid $194 million for Volkswagen's Sterling Heights, Mich., plant in '83, is investing an additional $456 million to get its new flagship assembly facility ready for production of H-body automobiles that will compete with the Japanese in the middle segment of the automobile market (e.g., against the Honda Accord and Mazda 626). This "world-class" assembly operation, says Stephen Sharf, executive VP of manufacturing at Chrysler, will use over 100 robots.

• Flexible manufacturing systems at General Electric's locomotive plant in Erie, Pa., have trimmed the production time for traction motor frames from 16 days to a mere 16 hours.

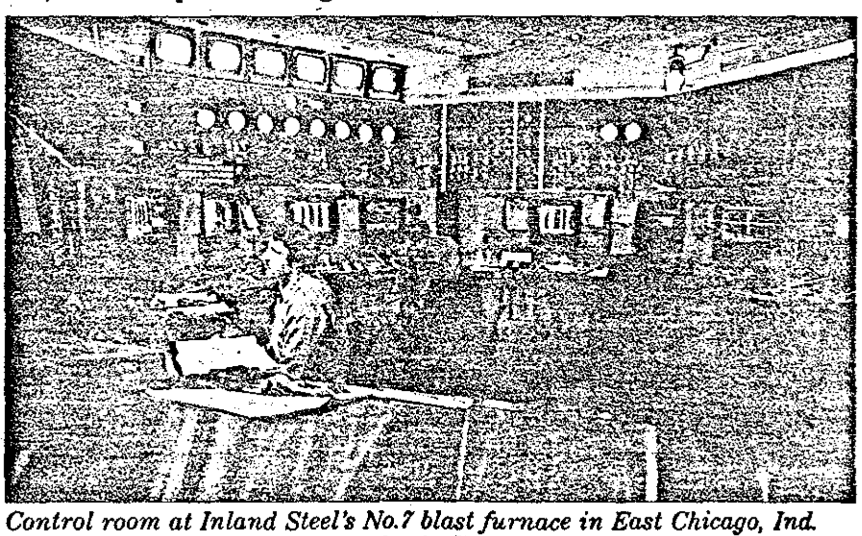
• At John Deere's new $500 million tractor plant in Waterloo, Iowa, computers control all materials-handling functions, matching parts to specific orders and managing inventories on a just-in-time basis. Although it operates at only 50% of capacity, the plant has been in the black ever since its doors opened in '81.

• Last August, Inland Steel (Chicago) started up its No. 3 continuous-anneal line, which will produce new grades of high-strength steels. The line can process a coil of steel strip in 10 minutes instead of the 5-6 days required by batch annealing. Employing over 100 microcomputers to control strip temperatures at every point on the line, it is the most advanced facility of its kind in the world, claims Jay Mayberry, assistant plant superintendent.

Inland is one of the few integrated mills that have consistently reinvested in their steelmaking operations; in fact, having recently bowed out of the container and shelter businesses, Inland is more of a pure steel company today than it was a few years ago, something that can be said for few of Inland's domestic competitors. The company's goal is to lower its break-even point—Inland can now show a profit at an operating rate of as low as 65% of capacity—by investing in the most advanced steelmaking processes.

The new look in steel

In 1980, the Office of Technology Assessment (OTA) noted that the domestic steel industry "has a good record for product innovations, but is less inclined to introduce new steelmaking processes." But the OTA stressed that new processes would be essential if the domestic steelmakers ever hoped to catch up with foreign competition. It appears that the U.S. steelmakers are now heeding this advice. Inland's continuous-anneal line is notable not only because it dramatically reduces processing times but also because it gives sheet steel significant new properties. Steels that were previously just laboratory curiosities can now be manufactured in com-



Control room at Inland Steel's No.7 blast furnace in East Chicago, Ind. The furnace is one of the largest in the Western hemisphere.

T FULLER

mercial quantities. "The continuous-anneal line is a remarkable metallurgical tool," says Carlton Schraeder, assistant to the VP of steel manufacturing, "because of its ability to alter strength without having to go back to changing chemistry at the steelmaking shop."

Last March, Inland's directors also gave the go-ahead for a preliminary engineering study of a continuous cold rolling mill. This $250 million complex, which will be patterned after the only other plant of its type in the world, Nippon Steel's Hirohata Works, will rely heavily on computers to cut processing times from 12 days to less than one day. The proposed mill includes pickling, tandem rolling and annealing, and automatic inspection in a continuous and fully automatic sequence.

The use of continuous casters, which convert molten steel directly into solid shapes ready for rolling, now accounts for about a third of the industry's total steel output. (At the time the OTA report came out, only about a fifth of the output was continuously cast; and a decade ago the figure was a mere 9%). Between the end of '81 and the end of this year, 16 new continuous casters, with an aggregate capacity of 16 million tons, will have gone into operation in the U.S. And the American Iron and Steel Institute (AISI) expects that at least four more large casters will be built within the next several years.

The switch to continuous casting has brought another advanced technology into the spotlight: ladle metallurgy. This is a generic term for a number of different refining processes conducted outside the basic steelmaking furnace in a special ladle prior to continuous casting (HIGH TECHNOLOGY, Sept. '83, p. 26). Ladle refining is resulting in major gains in both productivity and product quality.

The steel industry on the whole is expanding its use of microprocessors and computers in an effort to conserve energy in every phase of the steelmaking process. Moreover, the AISI is coordinating collaborative research between member steel companies and groups outside the steel industry. Several such research projects relate to the development of sensors that will be tied to automatic process controls.

Intelligent tools

In 1949 the Air Force began sponsoring research at MIT that led to the development of a revolutionary advance in machine tool technology: machines that employed encoded numerical data to cut metal at extremely close tolerances. Yet this new technology was slow to catch on in American industry. Even today, numerically controlled (NC) machines account for only a minuscule portion (4–5%) of the installed machine tool base in U.S. industry. Indeed, about 40% of the machine tools in use today in the U.S. are over 20 years old (versus around 20% in Japan), predating the commercial availability of NC machines.

However, the impression that industry has been slow to leave the dark ages is misleading. In terms of the total number of machine tools in use on the factory floor, NC machines are still rare birds. But since 1974, multifunction NC machines and other specialty metal-cutting machines have accounted for over a third of the total value of new orders, according to tallies kept by the National Machine Tool Builders' Association (NMTBA). Tacit confirmation that industry is not resisting the latest technology is provided by one of the largest machine tool builders in the U.S.: "Half of our sales today to U.S. firms are in machine tools that didn't exist five years ago," says Richard Kegg, director of machine tool research at Cincinnati Milacron.

Despite dismal sales and the barrage of imports (or perhaps because of them), a number of machine tool builders are preparing for a rebound by increasing their R&D budgets, reports Laura Conigliaro, industry analyst at Prudential-Bache (New York). Cincinnati Milacron, for example, has recently built a new $8 million research center. John Deam, technical director of NMTBA, cites other firms, such as Ex-Cello, Monarch, and South Bend Lathe, that have also established new research centers.

Much of the current research is converging around machines with built-in intelligence, covering a wide variety of developments from computerized numerical control (CNC) to automatic tool changing and automatic handling of parts. What all of this signals is a steady increase in the transfer of skills from the operator to the machine. At Chrysler's Detroit Trim Plant, for example, a CNC machine cuts bolts of cloth, vinyl, and leather according to directions entered at a computer terminal. In the past, fitting seat patterns on cloth for minimum waste was a long and tedious process. A worker had to climb on top of the bolts of cloth and jigsaw paper patterns together in much the same way as a seamstress does with dress patterns. Now a computer rapidly calculates the optimal cutting patterns and generates instructions for cutting cloth, saving Chrysler over $500,000 annually in material costs alone.

Economies of scope

The newest generation of NC systems, known as direct numerical control (DNC), go a step further, linking the minicomputers that direct the operation of each machine tool to a central mainframe that monitors and directs the operations of a whole flock of machine tools, sometimes 100 or more simultaneously. Clearly, the computer is the linchpin in the automated factory, bringing together computer-aided design (CAD) and computer-aided manufacturing (CAM) into a single integrated process. Computer-integrated manufacturing (CIM) is being heralded as everything from the cure for stagnation to the spark that will ignite a new industrial revolution.

John Deere's Waterloo tractor plant and GE's Erie locomotive plant are two of the brightest examples of the new technologies at work. While Deere's competitors have lost millions during the current "dog years" in the off-road equipment market, the Waterloo plant has been a consistent money-maker. GE's Erie plant was a questionable survivor before it was transformed into a manufacturing showcase; now GE is once again a major force in the locomotive business.

Over the next decade, manufacturing processes are likely to become more decentralized and more oriented toward the production of custom goods. The low-cost flexibility of the computer will revolutionize batch manufacturing. The past bias toward high-volume production of identical items will be supplanted by the production of goods tailored to smaller market segments, predicts Harry Thompson of A. T. Kearney, a Chicago-based consulting firm. The computer, he says, will replace economy of scale with economy of scope. To accomplish this, U.S. firms don't need to copy the Japanese; they just have to diligently apply the technology that they've already created to make the factory of the future a reality.

Ernest Raia is a senior editor of HIGH TECHNOLOGY.

CAN EUROPE CATCH UP IN THE TECHNOLOGY RACE?

By H. Garrett DeYoung

A British government official recalls how, back in the early 1970s, a single Member of Parliament tried to blow the idea of a joint European aerospace industry out of the sky:

"We'd been discussing this with industry, government ministries, and EEC [European Economic Community] representatives for several months, and were almost ready to put the idea to paper. Then one day a Labor Party MP slammed the table, jumped to his feet, and said: 'You know, of course, this means we'll have to trust the French—and I bloody *don't*!'"

Many of the project's basic principles nonetheless survived, shortly to grow into the European Space Agency and the Airbus jetliner. But the tale illustrates the centuries-long suspicions and resentments that still divide Western Europe. It also suggests how far the EEC nations—"the Ten"—must go if they are to represent more than token competition with the U.S. and Japan in the world technology marketplace.

The Ten clearly have their work cut out for them:

• Of all the personal computers sold in Europe, 80% are U.S.-made; nine out of 10 video recorders marketed in Europe are made in Japan.

• The EEC is now running a $5 billion trade deficit in information technology (IT), a market segment that includes software, microelectronics, information processing, office automation, and computer-aided manufacturing. In 1975, by contrast, IT enjoyed a $1.7 billion surplus. The deficit threatens to reach $10 billion by 1986.

• Despite a glorious history of technology innovation, the Ten seem almost arthritic in the leap from laboratory to marketplace. Although the EEC's R&D investment is twice that of Japan, says a Community representative, the Japanese file four times as many patents.

• Many Europeans are beset by a profound technological inferiority complex, says Robert Sheaf, EEC industrial liaison officer in London: "Many firms here don't feel that they can keep up with the U.S. and Japan. Their attitude is 'If we can get some of the pickin's, that's all right with us.'"

• For high-unemployment nations, such as England and Holland, international prestige is only part of the payoff. "If technology in Europe were on a par with that in the U.S., there would be as many as 3 million more Europeans working today," says Jean-Marie Cadiou, the Community's IT director in Brussels.

Many of the Ten are already engaged in costly steps of their own to revitalize national R&D (with a heavy emphasis on the D); as a result, practically every new science, from composite materials to processing in space, is now being studied for commercial potential. By far the biggest investments, however, are being poured into biotechnology and the information technologies.

ESPRIT de corps

It's doubtful that any EEC nation can score a meaningful victory by itself. Despite the Community's emphasis on sharing knowledge, information flows far less freely in Europe than in the U.S. European researchers are often isolated from their colleagues elsewhere in the Community, and even from other investigators in their own country. "No single European nation can hope to achieve a technological balance with the U.S.," says Sheaf. "It's a problem for all of us."

Perhaps the most ambitious technology revival plan of all is thus a collaborative one—EEC's European Strategic Program for Research in Information Technologies, or ESPRIT. The year-old plan is intended to do in a decade what diplomats and warriors have failed to do for centuries: unite the Ten into a powerful commercial alliance, thereby bridging the technological gulf between Western Europe and its competitors. Budgeted at $1.3 billion for the first five years—half from the Community, half from industry—ESPRIT will underwrite basic research in the five IT areas targeted for rapid growth.

To qualify for program support, a proposal must be submitted by different companies from at least two member nations. "These proposals must be very detailed, including specific milestones—submicron chips by 1986, for example—and how they will be achieved," says Richard Nobbs of the EEC's information technologies task force in Brussels. More than $11 million was approved for 38 programs during ESPRIT's recent pilot stage. Two examples are the development of a VLSI description language by Holland's Philips and West Germany's Siemens, and a thermal imager for inspecting composites, proposed by companies in England and Italy.

There are good reasons for IT's starring role. For one, the collection of disciplines now affects about 62% of Community jobs in one way or another, according to EEC figures. For another, there is hardly an IT application—from teleconferencing to molecular graphics software to robotics—that could not enhance European business or academia. Potential users are already keen to tap into ESPRIT technology, such as the application of local-area networks to banking, says Cadiou in Brussels.

IT is perceived as so central to a nation's well-being, in fact, that most of the Ten have set excellence in commercial electronics as a top priority. For example, England's Alvey plan, instituted in 1983, will pump some $480 million into British industry by late 1988. (The plan was named for British Telecom's John Alvey, who led the government committee that assessed Britain's standing in electronics.) Like ESPRIT, Alvey funds are limited to basic research in such areas as software, robotics, VLSI architecture, and CAD/CAM. Any British company, research institute, or university is eligible for assistance, as is any foreign company with facilities in the U.K.

Also like ESPRIT, the cost is shared equally by government and industry, with much of it pegged to personnel. "We've lost a lot of top-notch researchers, in all fields, to higher salaries in other countries," says a spokesman for the British Department of Trade and Industry in London. "We hope that programs like this will lure some of them back."

West Germany has joined the electronics parade, pledging $1.14 billion to the industry over the next four years. And as in ESPRIT and the Alvey plan,

EEC's Cadiou: As many as 3 million new jobs for Europe are riding on the global technology race.

the West German's Ministry for Research and Technology aims at a wide range of the electronics market: CAD/CAM, optics, telecommunications, microelectronics, and robotics. The biggest share, $535 million, is reserved for electronic components. Much of that is pegged to the joint development of submicron chips during the second half of the 1980s.

But many of the most ambitious projects in West Germany are being privately funded. Siemens, for example, the country's largest electronics company, turns out a million 64K random-access memories a month, is gearing up for 256K RAM production, and has committed $200 million to its 1-megabit RAM project.

France now commands only about 5% of the world's electronics market. (The EEC as a whole commands 10%, and the U.S. nearly 50%.) But under the two-year-old plan called *filière électronique*, government, industry, and universities will have invested some $16 billion in electronics research and created 80,000 new jobs by 1986. (The *filière électronique* is the chain of economic, technical, and social activities associated with the electronics sector.)

The socialist Mitterrand government has taken a sweeping approach to overhauling French technology, as evidenced last July by the appointment of Laurent Fabius as prime minister. Formerly the minister for industry and research, Fabius presided over the EEC council that spawned ESPRIT, and has gone on record as wanting to hike the nation's R&D spending from the recent 2% of the gross national product to 3% within the next few years. (The U.S. spends about 2.6% of its GNP on research, while the EEC as a whole spends about 2.2%.)

The French have devised an array of educational, social, and economic carrots to optimize the *filière électronique*'s chances of success. One provision of the plan, for example, is that research projects—in such fields as consumer electronics and high-speed computers—will be delegated to certain nationalized companies for development and commercial follow-up.

Assessing technology policy in the Netherlands is more difficult, since much of it is still being hammered out in public and private studies. In late 1982 the government formed a semiprivate $400 million "corporation for industrial projects" (*Maatschappij voor Industriele Projecten*, or MIP) to identify and finance high-risk ventures by Dutch companies. "Our support goes across all types of industry," explains MIP president and director A. G. de Boer in The Hague. "But obviously there are areas of special attention, such as electronics and biotechnology. Eventually, MIP would hope to sell its share of the venture back to the company, or perhaps encourage the company to go public."

A report released early this year by the Dutch Ministry of Economic Affairs, meanwhile, named several fields for special aid, including electronics, transportation, and new materials. Approximately $182 million in support was set aside in the 1984 budget, with another $68 million to be added next year.

The money isn't an outright gift, however. "We don't propose to have government riding to industry's rescue," says de Boer. The 1984 ministry report calls for several key changes in Dutch technology. One proposal would step up the involvement of small and medium-sized businesses in the national R&D scenario. Those businesses now account for only about 10% of the nation's research, while the five largest Dutch multinational companies conduct about 70%.

Industrial modernization (computerized manufacturing, for example) is also given high priority. But while the Dutch acknowledge the need for rapid growth in this area, the ministry notes a general reluctance to invest in methods that are perceived as new and therefore risky.

The multination ESPRIT plan will put the Community on a par with the U.S. and Japan by the early '90s, says EEC's Nobbs.

Biotechnology

Europe isn't putting all its R&D eggs into the electronics basket, says EEC's Nobbs. The Community has recently proposed a five-year $200 million biotechnology action program. A more modest plan has been in place since 1982 to consolidate research in seven biological fields, including enzymes and industrial microbiology.

National biotech programs abound. Along with electronics and new materials the science is singled out for special treatment in Holland—a clear effort to capitalize on Dutch expertise in biotechnology. The huge Gist-Brocades in Delft, for example, has long been one of the world's commercial leaders in industrial enzymes, antibiotics, and fermentation. And the MIP is now creating a multicompany biotechnology park at the University of Leiden in an investment scheme that could ultimately top $100 million.

Another example is England's Celltech, based near London, which was formed by the government in 1980 as a commercial extension of its Medical Research Council. In just four years, the government's 44% share in the company has dropped to 28%, with the rest held by banks, insurance companies, and venture capital groups. Celltech is now a $25 million company, largely through joint ventures with Japan's Sumitomo, Boots (England's leading pharmaceutical company), the Italian therapeutics giant Serono, and others.

"We knew from the beginning that

we had to behave commercially," says CEO Gerard H. Fairtlough. "In that respect, we're no different from a Cetus or a Genentech."

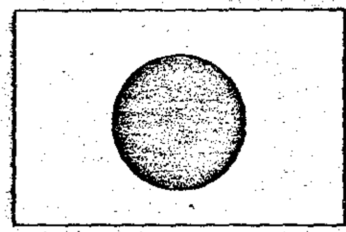
In Belgium, meanwhile, commercial technology is being pursued on three fronts: The national government in Brussels funds much of the country's ground-floor research, while the two regional governments—Flanders in the north and the Walloons in the south—support commercial application. The Belgian government's Science Policy Office distributes some $80 million a year (about 16% of the national science budget) for basic and applied research, especially in energy, materials, aerospace, electronics, and biotechnology.

The Flemish government has promised nearly $2 million to a year-old agricultural genetics company called Plant Genetic Systems (PGS), based at the University of Ghent in Flanders. PGS is a direct spin-off from plant bacteria research conducted by genetics professor Marc van Montagu, who heads the company. With about 50 full-time employees, PGS is now heavily dependent on contract research, says van Montagu, and has formed a joint R&D venture with Advanced Genetic Systems (Berkeley, Cal.). In return for a $1000-a-month fee, the company shares both physical facilities and many of its staff with the university.

The arrangement would probably raise a good many American eyebrows. But "we have no problems with business-university links," says van Montagu. Since Belgium is a largely agricultural nation, he adds, the work is clearly in the long-term national interest, and "it gives the university students a chance to apply their knowledge to a commercially important area."

Flanders also hopes to become a major European technology center through Technology International, its biennial electronics, new materials, and biotechnology trade fair. The first fair, in 1983, consisted of 600 exhibitors from 17 nations and drew 117,000 visitors from all over the world. "We literally had to turn people away," says van Montagu. The 1985 fair (February 23–March 3 in Ghent) aims to double the number of exhibiting nations.

JAPAN ADDS BIOTECH TO ITS TARGETS



Only part of Europe's technological competition comes from across the Atlantic. Both the European Economic Community and the United States are casting nervous glances toward the East, speculating about how and when Japan will score its next commercial coup.

Their concern is well-founded. By and large, Japan has carved out a generous share of the world marketplace, especially in consumer electronics, by capitalizing on existing technology. But the Japanese government's commitment to the fifth-generation "intelligent" computer project—some $450 million over the next nine years—makes it clear that the nation has stepped off in a new direction. The magic words now are "basic research," and Japan has earmarked R&D expenditures of some $25 billion a year to pay the bill.

The fifth-generation program is now under development by a research consortium that includes Nippon Telegraph and Telephone (NTT), Hitachi, Sharp, Matsushita, and others. Slated for completion in the early 1990s, the project will be the cornerstone of NTT's $100 billion Information Network System.

But there's more to Japan today than electronics. While the intelligent computer captures most of the attention, the Japanese boosted their biotechnology R&D expenditures by 55% earlier this year. In fact, biotechnology was one of the "future technologies" (areas to be fully commercialized by the year 2000) identified in 1981 by their Ministry of International Trade and Industry (MITI).

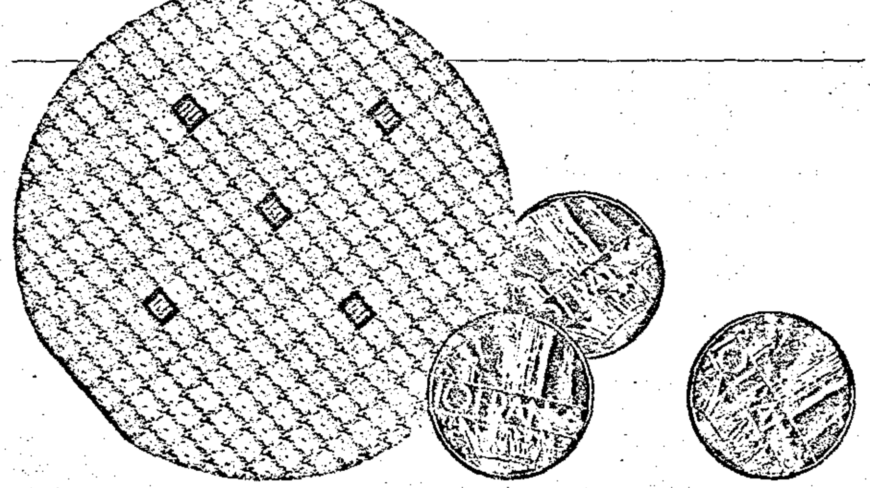
"The Japanese were doing very little work in biotechnology before the late 1970s," says Jon K. T. Choy, an analyst with the Japan Economic Institute in Washington. "No one thought the science would develop before the end of the century. When they saw they'd been caught flat-footed by the Americans, they decided to catch up."

Given their long experience in fermentation, biotechnology is a natural enterprise for the Japanese. But by granting special favor to the science, MITI adds extra weight to the Japanese variable in the international equation—so much weight that the Congressional Office of Technology Assessment calls Japan the United States' "most serious competitor in the commercialization of biotechnology."

One reason for that designation is the growing number of linkages between small Japanese research firms and large trading companies. The latter—consisting mainly of six multinationals, including Mitsui and Mitsubishi—can bridge the resource gap between themselves and the small firms that have traditionally been locked out of the capital markets. "The venture capital concept is very new to Japan," explains Choy. "Unless a small company has made a big discovery on its own, it typically has very few contacts with banks." The trading company solves that problem by providing up-front financing, marketing, shipping, exporting, and other services to the small researcher, usually for a flat fee.

The six trading companies now account for about half of Japan's total foreign trade and investment, says Toshio Itoh, senior researcher at Nomura Research Institute in Japan. Already instrumental in food processing, chemicals, agricultural equipment, and oil refining, they are now gearing up for a similar presence in biotechnology: Mitsui has no fewer than 70 biotechnology specialists, Nissho Iwai has 30, and Marubeni 25.

But Japan's success in commercial biotechnology is not a foregone conclusion. Despite the involvement of aggressive, well-heeled trading companies, the relative novelty of the venture capital concept will effectively bar many small companies from full participation, at least in the near future. The Japanese regulatory climate, which is even more exacting than that of the U.S., is another potential obstacle. In the case of pharmaceuticals, for example, most countries accept clinical data gathered in other countries. Drugs developed outside Japan, however, must be fully tested on Japanese patients before being allowed to enter the domestic market. "Clinical trials in Europe or the U.S. are still suspect," says Choy.



This 200-IC wafer is part of France's ambitious electronics program.

Scotland, which also promotes itself as a world-class biotechnology center, offers a variety of government support schemes (including tax-free "enterprise zones") to lure domestic and foreign business. "Scotland has plenty of venture capital," explains Mina Henley, program coordinator at the British government's Scottish Development Agency (SDA—Glasgow), "but very little is available for high-risk businesses." The nine-year-old SDA thus assumes the venture role for itself, rounding up government and private funds for start-ups in electronics, biotechnology, energy, robotics, and other fields.

Late last year, for example, Edinburgh-based Bioscot was formed as a joint venture between the University of Edinburgh and Heriot-Watt University. Initial funding of about $1.4 million was provided by the SDA, the Bank of Scotland, and the universities. The company is still in a start-up stage, says managing director Bruce Haddock, and it has only a few full-time staff members. Like Celltech in England and Edinburgh's Inveresk Research (a potential major competitor), Bioscot will gradually stake out its own overseas clients, joint venture partners, and areas of special expertise—for example, process engineering and oil recovery biotechnology. "A lot of companies are ahead in commercial products such as human growth hormone," says Haddock. "We don't see any point in doing something just because someone else is doing it."

Roadblocks ahead

That the Ten are out to give the U.S. and Japan a run for their money is obvious. So are the roadblocks to their success—barriers that, ironically, once formed a valued part of European tradition and that will not be easily torn down.

A major impediment can be found in the European educational system, says EEC's Nobbs. In many British schools, for example, electrical engineering has remained basically unchanged for years. "If you want to learn about integrated circuits, you have to take extra courses," he explains. An even more serious problem exists in Belgian academia, says a geneticist at the University of Liège: Government grants, fellowships and research programs are freely available at the lower educational levels, but they drop to near zero as the researcher scales the academic ladder. "The result is that a lot of Belgian PhDs go either to the U.S. or on welfare," he explains.

Other problems include the ultraconservatism of the financial community, a general lack of venture capital in many countries, and a broad-based aversion to risk. For example, while business failure in the U.S. is considered part of the game, it is a stigma in many European countries. Similarly, American lenders accept risk as an inevitable part of investment; most Belgian bankers, says the Liège researcher, work their hardest at merely protecting money rather than looking for growth.

These attitudes often extend to the workplace, where they develop into a deadly complacency. "When people here get jobs, they're essentially protected for life," says Philippe d'Oultremont, biochemical research coordinator at Solvay in Brussels, one of Europe's largest chemical companies. "The result is a kind of 'disinnovation.' It's hard to be technologically daring with such a system."

Nor are the powerful labor unions, many of them spirited defenders of the status quo, likely to welcome the new European industrial fabric. "There's no doubt that there will be a serious mismatch between workers displaced by new technology and those who will be needed to run it," says EEC's Cadiou. "But as the industries expand, there will be a ripple effect that will help in employee retraining."

In view of recent strikes by British coal miners and West German metal workers, however, the thousands of employees who have already drifted outside the ripples won't simply shrug off their misfortunes as the price of progress. The here-and-now attitudes typical of so many unions are illustrated by a veteran policy analyst in London who recalls the coal miner faced with the government closing of his depleted mine last spring. "He said he was striking to protect his job for his kids," the analyst says. "How do you explain to him that coal mining is probably today's buggy whip industry?"

Entrepreneurial spirit

For some European technologists, these and other obstacles are just too much. Many of them say that programs like ESPRIT are great public relations but that the Ten's apparent inability to settle many recent problems—budgetary contributions, for instance, and the de facto impotence of the European Parliament (the EEC's legislative body)—casts serious doubt on a genuine technological collaboration.

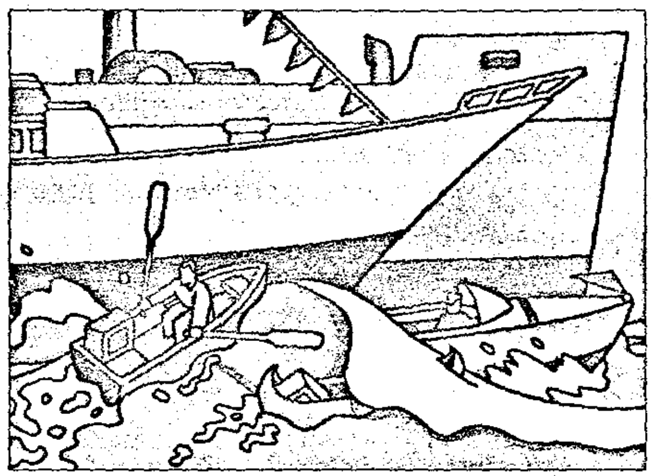
But most analysts are convinced that the stakes are so great that the table-scraps approach described by EEC's Sheaf will slowly give way to a new entrepreneurial spirit within the Community. Celltech's Fairtlough, in fact, argues that his company's success will go on the books as an early illustration of this new spirit.

"Certainly many companies are burdened with a status quo mentality," he says. "But the Community has too many technological and financial resources for us to simply be written off by the rest of the world. What's more, Celltech is proving that innovation is not dead here. We want to be an inspiration to other companies to stop moaning about their limitations and get up and *do* something."

H. Garrett DeYoung is a senior editor of HIGH TECHNOLOGY.

BATTLE LINES BEING DRAWN FOR GLOBAL TECHNOLOGY MARKETS

By Bohdan O. Szuprowicz



Global trade in engineered products has been growing rapidly. Over a 20-year period it grew 15-fold, topping $500 billion in the early '80s (the most recent U.N. data are for 1981). About 25% of this total is for high technology products, including aircraft, computers, nuclear reactors, microchips, machine tools, medical equipment, instruments, telecommunications equipment, office machines, and gas turbines. Another fast-growing high technology sector is hidden in what's called "invisible trade," the $700 billion services sector, including banking, consulting, data processing, engineering, insurance, shipping, and construction.

As the pie has grown, so has the international competition to get a bigger slice. Battle lines are being drawn for future high technology growth markets, and a major trade conflict could develop. Competition is intensifying because the stakes are not just economic gains, which promise to be considerable, but political strength. Since the ability to develop high technology industries is becoming so important, both for industrialized nations and for those whose economies have traditionally depended on mineral resources or agriculture, there is not a nation in the world that is not practicing some form of protectionism, declared business economist Harold B. Malmgren at a recent meeting of the Pacific Basin Economic Council. Trade relations between nations, he added, are at their lowest point since 1947.

Many high technology products are in great demand worldwide, but so far almost all of them come from only a handful of industrial nations that possess the necessary combination of resources—including advanced R&D, engineering skills, venture capital, and marketing know-how—to compete in technology markets. Almost 90% of all high technology exports originate in the United States, Japan, West Germany, the United Kingdom, France, Italy, the Netherlands, Canada, Sweden, and the Soviet Union.

Nearly every country, large or small, is finding it necessary to obtain advanced technologies in order to retain market shares and stay in the international economic race. Most are striving to develop high tech industries internally. Many protectionist measures today are meant to shield budding high tech industries and, in some cases, to force the market leaders to transfer some of their advanced manufacturing know-how to emerging nations.

Unlike earlier forms of international trade, based predominantly on bartering agricultural and mineral products directly linked to natural resources and geographic location, high technology is completely portable. It depends on scientific capabilities, technical skills, and surplus capital, which can be developed anywhere, instead of on large ore deposits or sea ports. If R&D skills are mastered so that products can be readily adjusted to meet changing needs in global markets, they hold long-term promise for production and export of goods in high demand worldwide. This means continued employment, and usually a steadily rising contribution to the economy, in place of dependence on a few agricultural products whose prices are unpredictable or on materials that in time will become depleted.

Wiping out trade deficits

The high technology ambitions of small and developing countries were illustrated recently by Avraham Suhami, chairman of Elscint, an Israeli medical imaging equipment company that generates 97% of its revenues outside Israel. Since high technology industries average over $100,000 in output per employee, Suhami proposes to solve Israel's $5 billion annual balance-of-payments deficit by building up high technology industries. When employment reaches 200,000 workers, translating into $20 billion of output, high tech exports should be earning sufficient revenues to wipe out the trade deficit.

This strategy is viewed with favor in many newly industrializing countries, particularly in Asia's Pacific Rim. The People's Republic of China, for example, is openly proclaiming and implementing a policy of enhancing exports while simultaneously impeding imports of any products that can be manufactured domestically.

International trade statistics reinforce the trade surplus theory. While the top 10 high technology exporting countries account for 90% of all such trade, they absorb only a little over 50% of imports. For some of these countries, high technology exports are several times larger than imports, providing continuous trade surpluses.

Japan, often viewed as the most successful adherent of such policies, exports four times as much in high tech goods as it imports. The U.S., despite negative balances in certain high tech industries, still exports about 2.5 times what it imports and accounts for more than 33% of global high technology exports.

But top prizes go to Bulgaria and East Germany, which export over six times as much in high technology as they import. While the bulk of th trade is with the Soviet Union and Eastern Europe, their performance demonstrates the potential of state-controlled protectionism within a trading bloc, and provides a model that other developing countries may wish to emulate.

Protectionism for limited periods is justified, many developing nations believe, when it supports infant industries that can sell within national markets. But critics argue that such protection also stifles innovation and product improvement and encourages inefficiency in domestic producers, thus keeping them from becoming competitive in world markets.

Fostering high technology industries can be a particularly thorny issue, because high technology products often enhance productivity in other industries. This means rising unemployment unless industrial output grows faster than productivity. At the same time, if jobs are protected in less productive industries, it means a loss of markets to competitors who are faster to introduce high technology improvements. Eventually this could lead to even more drastic setbacks, with plants closing and many more jobs lost. Aggravating the dilemma is the fact that, despite wide publicity and mounting popular interest, high technology industries represent a small percentage of any economy. California, considered the most advanced high technology region in the world, projects that while high technology industries will grow twice as fast as overall employment, high technology employment by the year 1990 will still account for only one out of 14 jobs in the state.

Top high technology exporters

(Totals about 98% of all global exports)

Country	Exports ($ billions)	Imports ($ billions)	Exports/imports ratio
USA	32.0	12.3	2.60
West Germany	12.7	7.6	1.67
Japan	12.4	3.3	3.76
United Kingdom	7.9	6.2	1.27
France	5.9	8.6	.69
Italy	4.1	3.5	1.17
Netherlands	3.2	2.8	1.14
Canada	3.0	3.8	.78
Soviet Union	3.0 (est.)	3.6	.83
Sweden	1.9	1.5	1.27
East Germany	1.8	.3	6.00
Belgium/Luxembourg	1.4	1.8	.77
Singapore	1.3	1.1	1.18
Bulgaria	1.3	.2	6.50
Ireland	.9	.8	1.12
South Korea	.9	1.2	.75
Hong Kong	.8	1.1	.73
Israel	.7	.4	1.75
Austria	.7	1.1	.64
Poland	.6	.3	2.00
Totals	96.5	61.5	1.56

Source: Derived by 21st Century Research from UN International Trade Statistics for Engineering Products, 1981 (latest data available).

Aircraft top trade list

Aircraft exports, civilian and military, are by far the largest high technology category in world trade, and the U.S. is the undisputed leader, with over 50% of global exports. West Germany recently displaced the United Kingdom as the second largest aircraft exporter, and France and Italy rank fourth and fifth. These top five exporters together control almost 90% of a more than $27 billion market in the West. The Soviet Union is also a major aircraft-manufacturing country, exporting primarily to Eastern Europe, China, and a number of third world countries. These nations, including Syria, India, Nigeria, Cuba, Peru, Vietnam, and Mozambique, equip their air forces with Soviet MIGs, perhaps the most popular fighter aircraft in the world. Military markets are an important factor in aircraft trade. International statistics show about $4 billion in aircraft exports unallocated as to destination. This is a larger percentage of clandestine high technology than in any other export category.

Telecommunications equipment is the second largest export segment. It is dominated by Japan, which controls 25% of this $19 billion market. Companies like Nippon Electric Co. (NEC) and Fujitsu started as telecommunications manufacturers and expanded in a Japanese market dominated by Nippon Telegraph & Telephone, which for many years adhered to the buy-Japanese-only policies encouraged by the government. Today such companies have become integrated multinationals that manufacture semiconductors, electronic components, computers, and robots, as well as telecommunications equipment.

Because telecommunications is a state monopoly in most countries, other governments are strongly tempted to try to duplicate the Japanese success. Few of these nations, however, have a big enough domestic market to justify the investment required to develop an independent telecommunications equipment industry. And global export markets are already dominated (over 63%) by Japanese, American, German, British, French, Swedish, and Hungarian manufacturers.

Coming: taxes on data flow?

But a new twist is developing in telecommunications. Individual countries, since they control all telecommunications services within their territories, are now looking at opportunities to tax information flow across their borders. This could prove to be a major continuous revenue source. Only the naive believe that current efforts to set up international data controls are aimed at the professed goal of protecting data privacy.

Brazil and France are seriously considering specific taxes on information transmission and are among the leading proponents of such controls. The French Commission on Transborder Data Flows has already designed a system of quantifying, classifying, and taxing such information. Brazil, Canada, West Germany, and Mexico have already enacted similar legislation, and the General Agreement on Tariffs and Trade (GATT) is under heavy pressure to add trade in services such as information processing to its regular policy agendas.

Any taxation of information flow would have momentous effects on the international activities of banks, credit card firms, insurance companies, and travel services. It may increase costs by as much as five times in some cases, forcing many firms to abandon foreign ventures. To elude such taxes, multinational corporations may find it profitable to launch and operate their own global communications networks, which could boost exports of private satellite communications systems.

Pioneering efforts by the U.S. and Britain to deregulate their telecommunications services, with the hope that the rest of the world will follow suit, appear so far to be unsuccessful. The opening up of American telecommunications markets to foreign competition resulted in imports jumping from 3% in 1978 to almost 11% by 1983. The Inter-

Leaders in major high tech markets

Category	Trade volume ($ billions)	Top 5 exporters and their shares (%)			
Aircraft	27.2	USA	54	France	7
		W. Germany	12	Italy	4
		UK	10	TOTAL	87
Telecommunications	19.2	Japan	25	UK	7
		USA	16	France	5
		W. Germany	10	TOTAL	63
Automatic data processing (ADP)	14.1	USA	35	Japan	6
		W. Germany	10	France	6
		UK	9	TOTAL	66
Machine tools	12.0	W. Germany	24	Italy	8
		Japan	15	Switzerland	7
		USA	13	TOTAL	67
ADP & office machines parts & accessories	9.9	USA	43	France	9
		W. Germany	11	Japan	8
		UK	9	TOTAL	80
Office machines	6.1	Japan	43	Netherlands	7
		W. Germany	11	UK	7
		USA	9	TOTAL	77
Microcircuits	3.9	Japan	23	W. Germany	11
		USA	19	South Korea	9
		Singapore	17	TOTAL	79
Medical equipment	2.9	USA	39	Japan	8
		W. Germany	19	France	5
		Netherlands	10	TOTAL	75
Gas turbines	1.7	USA	65	France	4
		UK	11	Italy	4
		W. Germany	7	TOTAL	91
Nuclear reactors	0.8	Belgium	31	Switzerland	12
		W. Germany	23	Sweden	6
		France	20	TOTAL	92

Source: Derived by 21st Century Research from UN International Trade Statistics, 1981.

national Trade Commission predicts that the U.S. will run a $3 billion trade deficit in telecommunications equipment by 1993 if this trend continues. Bills now being introduced in Congress would give foreign trade partners two years to remove their domestic telecommunications barriers or face reciprocal tariffs.

Automatic data processing (ADP), the international trade category for computer hardware, is dominated by the U.S., which accounts for 35% of such exports worldwide. Taken together, ADP plus parts and accessories for computers and office machines account for about $24 billion, making this the second largest trade segment (see table, p. 61). There is little doubt, moreover, that the rapid growth in this category will soon make it the largest high technology export segment. If office machine trade is also thrown in, it already is.

The U.S. actually controls even more of this trade through shipments from foreign subsidiaries in such leading computer exporting countries as West Germany, the U.K., Japan, and France.

At the same time, Britain, West Germany, France, the Soviet Union, and the U.S. are all billion-dollar markets for imported hardware. They are increasingly being targeted by third world countries trying to get into the computer hardware export game.

The United States has had a trade surplus of about $6 billion in computer hardware in recent years, but this is eroding rapidly with the rise of hardware-exporting countries such as Japan, South Korea, Taiwan, Singapore, and Hong Kong. Intense competition in electronic products such as computers is forcing manufacturers to shift production to countries with lower wage rates, and emerging nations in the Pacific Basin have been happy to oblige.

Brazil and Mexico are two Latin American countries that are also seen as significant future competitors in world computer trade. Brazil regards independence in computer technology as a strategic necessity, and the government has taken strong steps through its Special Informatics Secretariat to restrict domestic minicomputer and microcomputer markets exclusively to Brazilian manufacturers. A coalition of military officers, local entrepreneurs, and critics of multinational corporations control Brazil's computer markets, and as soon as a local manufacturer develops new hardware it is protected from foreign competition. As a result, while sales of Brazilian computers grew to $700 million in 1983, hardware imports have declined dramatically to below $200 million.

At present the biggest threat to American computer trade domination comes from Japan, which exported $1.5 billion worth of computers, peripherals, and parts to the United States in 1983, almost twice as much as in 1982. This turned a previous trade surplus with Japan into a deficit; U.S. exports to Japan edged up a mere 7.3%, to $828 million, during the same period. These developments prompted Lionel H. Olmer, undersecretary of commerce, to tell U.S. high technology executives last March that the Japanese market remains "essentially closed" to foreign high technology products.

Unlike earlier forms of global trade, high technology is completely portable.

In the office machines category, which includes typewriters, copying machines, word processors, and other equipment, Japan is by far the largest exporter, accounting for 43% of nearly $10 billion in global trade during 1981. The U.S. was a poor third, on a par with the Netherlands and Britain. Together with West Germany, these five countries control almost 80% of global exports of office machines.

U.S. slips in machine tools

Machine tools constitute a critical high technology trade sector because of their major role in automating industries. They account for $12 billion in annual exports. West Germany alone controls a quarter of world exports of machine tools. The top five, which also include Japan, the U.S., Italy, and Switzerland, ship almost 70% of the total. The United States, only third in exports, is by far the leading importer of machine tools. What's more, during the last ten years the percentage of imports of all machine tools sold in the United States rose from about 15% to 40% of the total, while U.S. exports make up only 13% of total global trade.

Major targets within the U.S. are rapidly growing segments of electronic equipment industries, which are big consumers of precision machine tools and metalworking machines. Fast changes in these markets mean manufacturers need highly versatile production systems so that product changes can be made easily and quickly. Several countries are trying to develop adaptive intelligent robots and flexible manufacturing systems, in hopes of capturing a big slice of this growing market.

In microcircuits, another pivotal market, Japan has become the leader, with at least 23% of global exports, by targeting specific semiconductor memory categories. So far only about eight other countries are significant microchip exporters, including the U.S., Singapore, West Germany, South Korea, Britain, France, the Netherlands, and Italy. They account for well over 80% of all such trade.

Increasingly, however, political, military, and business leaders throughout the world are concluding that integrated circuit production is a strategic necessity, and they are looking for ways to establish such capabilities within their own borders. Britain, which accounts for 30% of European integrated circuit markets, is determined to become a major player, in part by encouraging U.S. and Japanese semiconductor manufacturers to build advanced production facilities there.

Other countries are considering strategic stockpiling of certain semicustom VLSI microchips. Final masks for such chips, to produce customized microcircuits, could be manufactured quickly using sophisticated computer-aided-engineering workstations. The Belgian government teamed up with an electronics manufacturer to form MIETEC, a new firm designed to manufacture custom VLSI microchips with the specific objective of eliminating foreign imports.

Satellite links being set up by both Japanese and U.S. companies also could eventually allow customers access to sophisticated IC manufacturing facilities from almost anywhere in the world. Complex proprietary circuits that could provide a temporary edge in some electronic systems markets might be designed from any nation via such transborder links.

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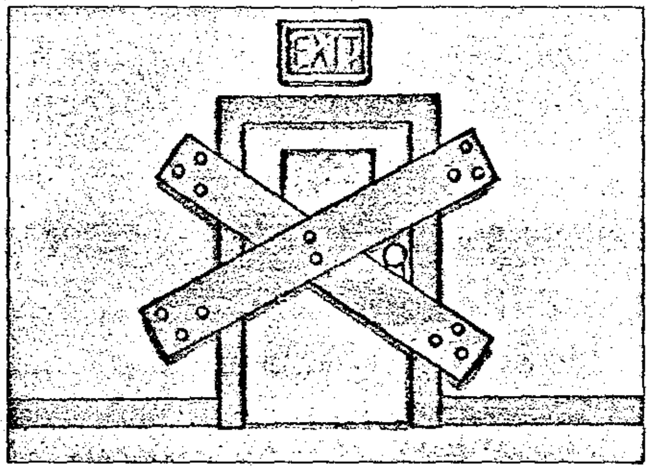
WESTERN ALLIANCE TIGHTENS RESTRICTIONS ON COMPUTER EXPORTS

By Paul Kinnucan



For several years, the Western Alliance has been divided on the question of how to stem the flow of militarily critical technologies to the Soviet Union and other Warsaw Pact nations. The Reagan Administration has advocated a restriction or outright ban on exports of any technology or product that might bolster the Soviet military machine—even indirectly. Many of the United States' allies, on the other hand, have insisted on a more laissez-faire export policy. The result has been a proliferation of often-conflicting unilateral control policies.

Until recently, that is. Now, in a major victory for the U.S., the Western Alliance has agreed on comprehensive controls on the export of computers—the technology that tops the list on the Reagan Administration's high tech export control agenda. The agreement is expected to serve as a model for accords now being negotiated on controls for other militarily sensitive technologies.

The agreement was reached by the Coordinating Committee for Multilateral Export Controls (CoCom), which oversees trade between the Western Alliance and Warsaw Pact nations. Based in Paris, the committee includes the NATO allies (except Spain and Iceland) and Japan. Its purpose is to establish a uniform export policy for its members, and it meets periodically to review policy for proscribing trade in militarily critical technology.

While a 1974 CoCom agreement was aimed primarily at limiting export of high-performance mainframe computers, the new guidelines are much more comprehensive. They slightly relax controls on mainframe computers but place tight restrictions on the export of personal computers and superminicomputers. In addition, the agreement restricts the export of computers for use in certain ostensibly civilian applications, such as telecommunications and microelectronics design and manufacturing, that are considered militarily critical. Another new restriction is a ban on the export of certain types of computer software.

A general accord was reached on July 12 in Paris and was announced in the U.S. by the Department of Defense (DOD) on July 22. A few remaining details of portions of the agreement were to be ironed out by the end of September, but many provisions of the agreement have already been put into effect by CoCom members.

Multilateral controls

The agreement ends nearly a decade of negotiation aimed at updating the 1974 CoCom agreement, which had become a target of bitter criticism by the Western military establishment led by DOD. The Pentagon complained that the policy was not restrictive enough because it allowed the export of low-performance systems, such as personal computers and superminicomputers, whose small size gave them military value. Despite intense pressure from the U.S., however, CoCom was unable to agree on more comprehensive restrictions.

As a result, the U.S. established unilateral controls on personal computers and superminicomputers, and waged a vigorous campaign to convince other CoCom partners to do likewise. While some nations complied, others refused, leading businesses in the U.S. and other countries with strict controls to complain that foreign competitors had an unfair advantage. At the same time, the impasse led to a neglect of CoCom by the U.S. and other member nations, and it created friction in the Western Alliance. Moreover, the prolonged CoCom negotiations created a climate of uncertainty for Western businesses in negotiations with Eastern bloc countries.

"The new accord is healthier for all of us," says Stephen D. Bryen, deputy assistant secretary of defense for international economic, trade, and security policy. The pact, he adds, will eliminate the tensions caused by the varying unilateral controls that it replaces.

Bryen also believes that the agreement, by restoring confidence in the ability of the Western Alliance to establish multilateral controls on key technologies, will help revitalize CoCom. "The indications are that it's already on the path to rejuvenation," he says.

Although the U.S. has been pressing for an updating of the 1974 accord since 1976, it has been unable to get an agreement until now, in part because of the difficulty of obtaining a formula that would be comprehensive enough to cover legitimate security concerns without being so comprehensive as to deny Western businesses trade in noncritical items. The U.S. negotiating team, representing the Departments of Defense, Commerce, and State, has also been hampered by internal discord over negotiating objectives.

As might be expected, the new agreement's control formula is complex, entailing many compromises. For example, it relaxes controls slightly on mainframe computers, allowing export of machines with a performance data rate (PDR) lower than 48. In contrast, the 1974 agreement had banned the export of any machine having a PDR greater than 35, although exceptions could be made with the concurrence of CoCom members. (PDR is a measure of system throughput established by CoCom for regulatory purposes. The PDR of a particular system is determined by running benchmark programs.) According to the Pentagon, the relaxed guideline will prevent export of supercomputers that might be used in designing weapons, such as ballistic missiles, and in weather prediction, while facilitating export of lower-performance systems. Western companies had complained that the earlier PDR limit had prevented them from trading in large systems that would have little impact on military security. This was because the performance cutoff point did not reflect the growing speed of both Western and Eastern computers. Businesses complained that most state-of-the-art mainframes exceeded the 1974 PDR limit. Hence they had to apply for exceptions, which required not only the consent of their own government but the concurrence of the allies, which delayed license approval considerably.

New restrictions

While relaxing controls on mainframes, the CoCom agreement places tight restrictions on the export of personal computers. Those with a PDR of less than 2, such as the Atari 400 and the Radio Shack TRS-80, may be exported; and more powerful personal computers may be sent to Warsaw Pact nations upon issuance of a license by the exporter's government. Personal computers in the 2–5 PDR range may be exported under a bulk license; more powerful systems require individual licenses.

The CoCom agreement prohibits the export of computers that have been designed to withstand abnormally high temperatures, shocks, and vibrations. This would include computers designed specifically for military applications and some portable computers, such as Grid Systems' Compass, that are aimed at civilian applications. The agreement also prohibits the shipment of bubble memories that can store more than 256K bytes. (These solid-state memories can be used to replace electromechanical mass storage devices, such as tape and disk drives, which are the most physically delicate component in most personal computers.)

In addition to restricting the export of personal computers, the CoCom agreement places an outright ban on the transfer of technology used to build computers—even those whose export is permitted. The technology ban includes design specifications such as blueprints and printed circuit board artwork; components such as chips, disk drives, and power supplies; and production equipment such as soldering and component insertion machinery. This provision is intended to prevent Warsaw Pact nations from mass-producing Western-developed computers whose export is forbidden or limited in quantity.

The agreement also prohibits the export of add-on and add-in products, such as memory and processor boards, that may be used to upgrade a computer system. This provision is intended to prevent an exporter from avoiding controls by first shipping a low-performance system and later shipping upgrades.

These new guidelines address the Pentagon's concern about the shipment of personal computers, which was allowed under the previous CoCom agreement because of the machines' limited processing power. Such computers have important military applications because of their small size. For example, U.S. field commanders use them for targeting artillery and missile fire.

Previously, the U.S and a few other CoCom members had instituted unilateral restrictions on the shipment of small computers. For example, the U.S. banned shipment of any computer based on microprocessors with word lengths of 8 bits or more, which effectively stopped U.S. export of personal computers to Warsaw Pact nations. But because other CoCom members were not prevented from exporting personal computers, U.S. businesses complained that they were being discriminated against. Also, the microprocessor rule did not reflect technological advances, since most personal computers are now based on 16-bit processors. U.S. companies were prevented from exporting even the older 8-bit computers, which had little military value and were already being made in the Eastern bloc.

Also banned are computers with more than half a gigabyte of virtual memory. This guideline prevents the export of superminicomputers, which have important military applications because of their small size and low cost. The 1974 agreement allowed export of superminis because they fell within the 1974 performance limit. Although the U.S. had unilaterally banned the shipment of superminicomputers, they were available from foreign sources, causing concern among American manufacturers that their foreign competitors would have the Warsaw Pact market to themselves.

The recent agreement forbids export of any computer intended for use in the design and manufacture of integrated circuits. "We believe that 90% of the microelectronics circuits produced in the Soviet Union go into military systems," says DOD's Bryen, "and we don't want to feed that industry." Likewise proscribed are the export of computer-based telephone switching systems (the national telephone networks of the Warsaw Pact countries serve as the backbone of their military command and control systems) and the export of advanced software, such as that used for computer-aided design and manufacturing.

Software controlled

Under the new agreement, companies will for the first time be required to obtain a license to export software for applications—such as artificial intelligence, cryptoanalysis, signal processing, computer-aided design and manufacturing, and software development—deemed militarily critical. This provision addresses a Pentagon concern that the 1974 agreement, with its focus on hardware performance, did not reflect the unbundling of software. At the time, software generally could be run only on the hardware with which it was sold. Thus the banning of the hardware virtually prevented export of advanced software. Now most software is designed to be machine-independent and is sold separately.

Bryen warns that the new agreement in itself will not prevent militarily critical computers from finding their way to the Eastern bloc. That will require industry's compliance with the agreement, as well as strict enforcement. "If you're asking our companies to play ball, it's only fair to make sure that the bad guys don't steal away their business," he says.

To facilitate enforcement, says Bryen, the U.S. plans to propose this fall that CoCom establish an Interpol-like clearinghouse for information on potential violators.

Paul Kinnucan is a senior editor of HIGH TECHNOLOGY.

REBUILDING MATH AND SCIENCE EDUCATION: BUSINESS LENDS A HAND

By Margie Ploch

The nation's businesses are sending their technologists back to school—not to study, but to teach. Their goal is to breathe life back into precollege math and science education and hence to produce a new generation of talented scientists and engineers as well as a technologically literate public. What is at stake, claim business representatives, is nothing less than the technological leadership and economic health of the United States. "With international competition, the quality and numbers of engineering graduates are vital to us," says William A. Orme, secretary of the General Electric Foundation.

The importance of precollege math and science education came into focus when businesses began pumping money and equipment into college and graduate engineering education in order to ease the shortage of engineers. Companies found that the majority of students were (and still are) reaching college barely literate in science and math; according to the National Science Foundation, 75% of 1980 high school graduates were unqualified to take undergraduate courses in these disciplines.

Hence industry's college programs cannot realize their potential unless the problems that beset precollege math and science education are solved first. Foremost among them is the national shortage of qualified math and science teachers, so desperate in some states that teachers from other fields are filling in. Even if enough qualified teachers were available, however, the requirements for math and science courses would still be insufficient to prepare students for jobs in an increasingly technological society. Outdated and inadequate teaching materials, curricula, and equipment further cripple instruction. And school days in the U.S. are fewer and shorter than in many other countries. As a result, by the end of first grade, American children have already fallen behind their Japanese and Taiwanese counterparts in reading and math, according to a recent University of Michigan study.

Although there are some federal education programs, the Reagan Administration has advocated private sector initiatives as the means to revitalize math and science education. Businesses are responding by lending employees, and donating equipment and money to elementary and secondary schools for math and science education. Companies have sponsored programs to provide employee volunteers to enrich math and science courses, to recruit or retrain teachers, to create instructional materials and curricula that cover recent advances in science and technology, and to attract more students to engineering and technical careers. "A natural symbiotic relationship is emerging between industry and education," says Louis Robinson, IBM's director of industry relations. "Growth in technology depends upon innovation and creativity, and that relates directly to the quality of education in math and science."

Improving teaching

Teacher certification requirements usually prevent scientists and engineers from teaching full time in public schools, but many districts are eager to have volunteers supplement the regular curriculum. More and more companies, such as Kaiser Aluminum and Chemical Corp. (Oakland, Cal.) and Arco (Philadelphia), are giving their employees paid time away from work for these activities. Professional organizations, including the IEEE, are encouraging members to volunteer some of their time. And adopt-a-school programs, in which a business pairs up with a school, commonly involve company volunteers working in the school. Most of the more than 1000 Dallas companies that have adopted local schools send tutors to help individual students, especially in math, says Mary Brouillette, a spokesperson for the Chamber of Commerce. Xerox's Science Consultants Program in Rochester, N.Y., sends employees twice a month to local fourth, fifth, and sixth grade classes. The program stresses hands-on learning through the use of 400 instructional kits created by the consultants and supplied by the company. In the 15 years Xerox has supported the program, consultants have reached an estimated 11,000 children.

Retirees—recruited and organized by their former employers, like Dow Chemical (Midland, Mich.)—are also being tapped for math and science instruction. At one Pittsburgh high school, for example, retired scientists advise students in the laboratories, says Jane Burger, project director for the Allegheny Conference on Community Development (Pittsburgh).

Although few scientists and engineers have been trained as instructors, schools usually praise the quality of their teaching. In some cases companies formally prepare employees before sending them into the classroom. Xerox seeks out technical staff members who appear to have the ability to work well with children and teachers, then equips them with materials and outlines for lessons. And Project SEED, a math enrichment program, puts its instructors through a rigorous course before sending them into a classroom, says

Dallas-area director Hamid Ebrahimi. They learn the Socratic method of teaching by questioning, which Ebrahimi claims is the reason for Project SEED's success in teaching advanced math to elementary school students.

Originally designed by educator William Johntz to boost the academic achievement of minority students through success in math, Project SEED has been run in many communities with help from such corporate sponsors as Bell Labs and IBM. In Dallas, volunteers from Texas Instruments and Southwestern Bell are part-time staff members. An independent research report to the Dallas school board described Project SEED as "an excellent instructional system" that was likely to encourage students to take more advanced math courses.

Other business efforts to improve teaching focus on training and retraining math and science teachers. Many undergraduates who would make excellent teachers are lured into industry by the higher salaries. To attract these people to teaching careers, Digital Equipment Corp. and the Univ. of Massachusetts School of Education have created a 14-month master's degree program.

In addition to paid internships during the course, each graduate is guaranteed three years of summer employment at DEC. "We think that for people to have the wherewithal to become teachers, they need additional money," says Russ Johnson, DEC's manager of U.S. college relations. "And after they go through the internship, they have skills that can help us."

Although teachers are needed for science and math courses, other subjects are often oversubscribed, especially in secondary schools. Therefore, another approach that businesses are funding is to take teachers from other disciplines and retrain them, usually at a local university. For example, Arco, the Council for Basic Education, and the University of Texas at Dallas have supported a summer institute just for this purpose.

But even teachers certified in math and science may not have kept up with technological advances. According to the National Science Board Commission's report, hundreds of thousands of elementary and secondary school teachers need additional training in math and science. Elementary school teachers often lack the math and science background necessary to teach these subjects effectively. Furthermore, many secondary teachers who had adequate skills ten or twenty years ago are now foundering in the wake of technological change. Few teachers are hooked into the networks of industrial technologists who are using the latest techniques; worse yet, there is little contact between high school teachers and their counterparts at colleges. Consequently, many science museums are offering sessions to update teachers in science and math instruction. And the largest school districts in 25 states are now participating in IBM's computer literacy program; teachers attend summer sessions to learn how to use and teach with microcomputers the company has donated to their schools.

Retaining qualified and experienced math and science teachers has proved increasingly difficult. Awards, fellowships, and summer jobs—many of them sponsored by businesses—are ways of recognizing the best teachers and, in some cases, increasing their incomes.

This year the Los Angeles Educational Partnership organized an ambitious summer program with support from Arco. Thirty-five outstanding math and science teachers, selected by their peers, attend a two-week symposium, consisting of seminars conducted by leading technologists and tours of sponsoring companies. Afterwards fellows lead workshops at their own schools to share what they've learned with their colleagues. "We're trying to put these people in contact with resources in industry, then get them to help improve other teachers," says Partnership director Peggy Funkhouser.

Summer jobs in industry help science and math teachers learn about advances in their fields.

THE STANDARD OIL COMPANY (OHIO)

One proposed means of retaining teachers is differential and merit pay for master teachers and teachers of technical subjects. Such a scheme, however, conflicts with traditional tenure systems, through which teachers are promoted and paid according to the amount of time they have worked in the school district. Differential pay schemes now being tried by some states and local districts provoke teachers' fears that prejudice and preference will inevitably play a part in evaluations.

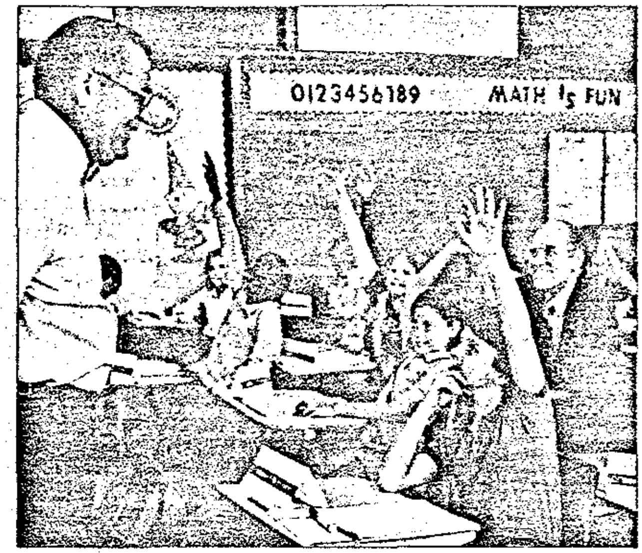
Yet businesses, because they are independent from the public education system, can skirt the burdensome bureaucracy that has sometimes blocked changes. Many compaines sponsor programs to selectively reward and encourage teachers. For example, Ciba-Geigy (Ardsley, N.Y.) offers $1000 annual awards for science teachers at all levels. And Honeywell (Minneapolis) has just begun a program of summer jobs for local math and science teachers that it hopes will benefit both teachers and the industry people they work with. Teachers will gain experience in industrial research and will develop contacts in the technology community, while Honeywell employees will learn more about the methods and difficulties of teaching.

G. Donald Long, chief scientist of the company's Physical Sciences Center, hopes that friendships made during the summer will help bridge the gap between schools and industry. "There is no mechanism for bringing people together," he observes. "We're trying to create that." A similar summer-jobs program, the Cleveland Teacher Internship Program, has worked so well that one sponsor, Standard Oil (Ohio), plans to increase its placements from 25 to 100 per summer by 1985.

Career education

Better teaching and materials alone may not influence enough students to pursue advanced studies in math and science. To fill their own future needs for technologists, businesses are pushing career education—especially for minority students, the group least likely to enter scientific fields. "We have to convince kids in seventh, eighth, and ninth grades not to opt out of scientific and technical careers," says GE's Orme. His company is pumping $1 million a year into programs across the country to encourage minority youth to pursue math, science, and technology careers.

Some companies develop career education materials, and others sponsor field trips to their offices so that students can see "engineers at work." But most programs depend on visits to schools by company volunteers. Scientists and engineers who visit classrooms serve as role models and are important in influencing students to pursue similar careers. "We try to identify interested and talented kids, encourage them, and set up programs to help them succeed," says Orme. A similar program, METCOM (Metropolitan Consortium for Minorities in Engineering) in Washington, D.C., organizes volunteers from industry and government labs to give high school students presentations on engineering jobs. Board member Marilyn Berman, assistant dean of the College of Engineering at the Univ. of Maryland, believes that METCOM has helped increase minority participation in engineering programs at her school.



Hap Vaughan of Texas Instruments is a volunteer teacher in Project SEED, an elementary school math enrichment program in Dallas.

Schools for math and science

The most ambitious collaborations between businesses and education are embodied in high schools devoted to math and science. Such schools are being established in cities and states across the country, and businesses have speeded their growth. The North Carolina High School of Science and Mathematics, for example, is a statewide residential public high school. Students who have shown exceptional talent attend for their last two years of high school. The school has received $7.5 million in funding from private sources, including IBM. Since it graduated its first class in 1982, the school has produced over 160 National Merit semifinalists, the highest percentage of recipients at any school in the country.

Three years ago, Honeywell and the Minneapolis school district set up Summatech, a "magnet school" (one that draws students from an entire metropolitan area). The company put $40,000 into the pot, and provided the services of 62 volunteers (mainly scientists and engineers) in the planning year, says Rita Kaplan, Honeywell's manager of education programs. Employee volunteers continue to teach special classes, give career education presentations, and advise the teachers and administration, according to Honeywell's Long, who oversees the company's involvement in Summatech. To graduate from Summatech, a student must pass four years of math and science, and two of computer science, as well as courses in humanities and social sciences. Honeywell is also funding a program to enrich math and science at a Minneapolis elementary school, says Kaplan.

Xerox and IBM will each lend a staff person full-time to the planned School of Science and Technology (Fairfax, Va.) to assist with preliminary fundraising efforts, says superintendent of schools William J. Burkholder. In addition, the school is looking for lab equipment donations and staffing help from industry. "We expect to depend on business to a great extent for people who have specific abilities in areas we'd have trouble finding among the pool of teachers," he explains.

Because of the school's status as a governor's magnet school for science and technology, Burkholder believes that the state will "let us waive or alter certification requirements, although this would be done on an individual basis." Such special teachers will complement the regular faculty, Burkholder says, and the school will provide whatever in-service training and support they need.

Partnership structures

The framework for collaboration between businesses and schools usually takes either of two forms: one-on-one or systemwide. In either case the partnerships may be established through intermediaries.

One-on-one programs, commonly called adopt-a-school, were especially touted during 1983–84, which President Reagan declared the National Year of Partnerships in Education. Local chambers of commerce often help organize "adoptions" within their area by matching a school (or magnet school-within-a-school) with a business. The most successful relationships, says Honeywell's Kaplan, are those that are carefully tailored to the needs of the school, business, and community.

While businesses may contribute money to sponsor special activities or donate equipment (especially for labs in science classes), most partnerships emphasize the human resources the firm can share with the school. In fact, the value of volunteers' contributions to math and science education may far exceed a company's monetary donations. The Chicago Adopt-a-School program, says director Al Sterling, asks not for money, jobs, or equipment, but only for people. Because volunteers are usually highly motivated, he adds, they will often bring the equipment and money with them if they see a need for it. In turn, the volunteers feel good about giving their skills to the community. "The morale of the staff goes up," Sterling says. "It's the first time that many of these people are asked for anything beyond their job description."

In contrast to such one-on-one partnerships, businesses may work with an entire school district or with districts across the country. MathCounts, sponsored by the National Society of Professional Engineers (NSPE), the National Council of Teachers of Mathematics, the CNA Insurance Companies, and the National Science Foundation, is one such program. During the 1983–84 school year, 400,000 seventh and eighth grade students from 47 states and the District of Columbia learned advanced math skills from materials created and

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provided by the sponsors. The best students in each class competed in school, regional, state, and national contests. Next year, says Leslie Collins, a spokesperson for NSPE, the program will double in size and include students from all 50 states.

Partnerships and systemwide relationships may be brokered by private foundations, as well as state and federal agencies. California alone has over 100 such private foundations, according to a National Alliance of Business report. The intermediaries try to match schools' needs with corporate donors' resources. They also provide the continuity and motivation necessary to start and maintain successful partnerships, says Gladys Thatcher, director of the San Francisco Education Fund. Her organization is a community-based nonprofit group working with about 70 companies in creating programs to benefit the San Francisco public schools.

Financial support

All of business's contributions to schools amount to a tiny fraction of total U.S. educational expenditures. But their dollars and volunteers are usually more mobile than public funds and personnel. "Private dollars can be flexible and quick, and they should be spent where public money can't or won't go," says David Bergholz, president of the Public Education Fund (Pittsburgh), a national organization that helps establish educational partnerships.

While private sector funds usually pay for programs that enhance the standard curriculum or activities, the burden of financing public schools has traditionally fallen to taxpayers. Business partners, however, are beginning to contribute more directly to school budgets.

In North Carolina, for example, the state legislature insisted that the majority of operating and capital expenses for the state's School for Science and Mathematics be drawn from the private sector, says Mark Leuchtenberger, assistant development officer for the school. As a result, the school is continually soliciting money from businesses and foundations. "Our ability to raise money from the private sector is a measure of our quality and the respect we are accorded," Leuchtenberger explains. "If we can't generate income, we're not doing what we're supposed to do."

Businesses' contributions to schools are ultimately self-serving in that they produce more qualified workers. Giving resources to local schools also strengthens the company's image and the community's economic base. "The important issue in business/school relationships is not just dollars but making closer contact so that business knows what's going on in the schools and becomes a supporter of public education," the Public Education Fund's Bergholz explains.

For the partnerships to be effective, they will have to last. "It's going to be a long haul, maybe 10 years," says Peggy Funkhouser, director of the Los Angeles Educational Partnership. Funkhouser's organization stresses funding of at least three years for its projects, and tries to make them self-sustaining. "We are always trying to get successes built into the system or get them to stand on their own," she says, "so we don't have to keep raising funds."

Margie Ploch is managing editor of HIGH TECHNOLOGY.

LEARNING WITH TECHNOLOGICAL TUTORS

By Dwight B. Davis

Educators have a problem. The world is changing so rapidly, propelled in large part by the proliferation of new technologies, that conventional teaching methods that were developed to cope with an earlier, relatively stable environment have become obsolete. Appropriately, educators are turning to technology to improve teaching of both children and adults in this technological age.

Central to this trend are low-priced microcomputers and a blizzard of educational and training software. Almost 98% of the country's 9272 school districts with more than 600 students now have at least one microcomputer for classroom instruction, according to a survey conducted last April by Quality Education Data (Denver), a market research firm. Many of these microcomputers were donated by manufacturers, but schools nevertheless spend 20% or more of their materials budgets on educational software, or courseware.

At the adult level, a major shift is occurring away from instructor-taught seminars toward individualized, computer-based self-study. Accelerating this trend is the use of laser videodiscs; when linked to microcomputers, they can serve as highly interactive tutors that operate at a level and a pace suited to each individual's needs. Other technologies that promise to play growing roles in educational systems include speech synthesis and recognition and various implementations of artificial intelligence, including expert systems.

Some people view technological aids as panaceas that will eventually prove better than human teachers in most situations; others have a strong aversion to any use whatsoever of computers in educational settings. Between these two extremes are the majority of educators, who believe technology can play an important part in teaching, but only as a set of tools for competent, well-trained instructors.

But there are many unanswered questions about how and when computers and related systems can best be used, especially at the primary and secondary school level. Pressured by parents and a widespread computer mania, many schools have rushed to acquire the machines in what critics term a "buy now, plan later" approach. The introduction of computers into a classroom inevitably displaces part of the existing curriculum, and there is little agreement about what subjects should be sacrificed.

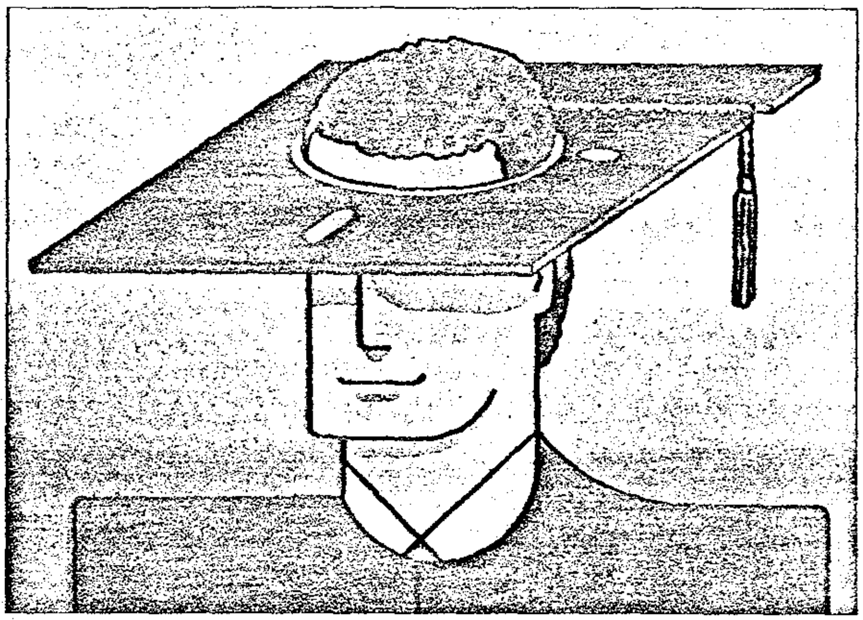
Complicating matters further, some educational software doesn't provide much beyond what is already achievable with noncomputerized teaching techniques. Although courseware is growing in sophistication, becoming more interactive and adding such features as simulations of natural phenomena, the bulk of the programs are of the drill-and-practice type. Given the costs involved, using computers simply as "electronic page turners" or "electronic flash cards" is often difficult to justify. "Much of what initially happened with computer-aided instruction was merely translation of print media onto computers," notes Roger Orensteen, director of industry marketing for high technology at Wilson Learning (Eden Prairie, Minn.). "There was no new dimension of learning at all." But just as the early automobile gradually lost the trappings of the horse-drawn carriage, rote learning by computer is slowly fading as new ways to present material begin to explore the technology's potential.

Learning about learning

Before educational technology can fully be exploited, however, much remains to be discovered about the learning process in both children and adults. Wilson Learning, which develops and runs training programs for corporations, has established an alliance with the University of Minnesota's College of Education "to conduct research into how adults learn and how technology can aid learning." Various programs are also studying learning in children and trying to establish a role for technology in that process. Harvard University's Graduate School of Education, for example, has a $7.7 million contract from the National Institute of Education to explore how computers and other technologies can improve the teaching and learning of science, math, and computers from kindergarten through grade 12.

Both the Wilson Learning and the Harvard programs recognize that a better understanding of the nature of learning is a crucial first step in determining how technology can best fit into the educational picture. "The fundamental thesis that shapes everything we're doing," says Judah L. Schwartz, codirector of Harvard's Educational Technology Center, "is that if you're going to explore the ways in which technology can be useful in science and math learning, you'd better first find out what's hard about science and math learning."

In a perfect world, complete knowledge about the learning process would precede all attempts to improve teaching—a situation that clearly doesn't exist. Rather, technological teaching aids will be used in a variety of ways, some of which work, some of which fail. This process, in turn, should add to our insight about how learning occurs. But even when learning improves in the presence of computers, it's not easy to discern which improvements are directly related to the computers and which to other factors, such as better teacher training. "Education is just too muddy a business to be able to put your finger on *the* element that makes the difference," says Schwartz, who is also a professor of engineering science and education within MIT's School of Engineering.



While hard statistics are difficult to come by, several studies have indicated that computers can aid learning. A 1982 Office of Technology Assessment report states, "There is a substantial amount of agreement that, for many educational applications, information technology can be an effective and economical tool for instruction."

Many believe that a large part of the computer's success in education lies in its novelty and its intrinsic allure. Many educational software vendors, recognizing the power of video games to rivet youngsters' attention, are trying to incorporate gaming features into their packages. Some observers fear, however, that the teaching potential of computers may diminish as the machines become more commonplace and their novelty wears thin. But if courseware is properly designed, says Schwartz, computers should retain their allure much as books continue to attract readers.

Even though the debate about computers in schools has largely shifted from "Should we use them?" to "How do we best use them?" plenty of controversy remains. There is disagreement about how to evaluate the educational software inundating the market, about whether computer use by very young children discourages active play, and about whether to teach programming and computers as subjects unto themselves.

A particularly stormy controversy surrounds the choice of a programming language, if one is to be taught. The Basic language, long a leader in educational settings, has come under fire from proponents of the more sophisticated Pascal language and from others who favor the more flexible Logo. Developed almost 20 years ago by Seymour Papert and others at Bolt Beranek and Newman (Cambridge, Mass.), the graphics-oriented Logo language has attracted much support because it is not only easy to learn and fun to use but also very powerful in establishing student control over the computer and in teaching logical thinking.

Such secondary benefits are as important to some as the actual programming skills acquired. "I believe that learning to program is important because it is the best way to get in touch with how the idiot machine works," wrote Steve Bergen, codirector of The Teaching Company (Brookline, Mass.) in a recent issue of *Independent School*. "Additionally, learning to program in any language involves considerable logical, intellectual, and aesthetic skills—certainly the domain of education."

Adult training

Although the use of computers in classrooms still stirs debate, their presence in adult training situations has become generally accepted. Control Data (Minneapolis) pioneered computer-based training with Plato—a mainframe computer-based educational system developed in the '70s at the University of Illinois. Plato boasts a collection of educational programs that, today, is probably the most extensive in the world. This library of courseware has recently been made more accessible through the introduction of Micro Plato, an implementation of the system on microcomputers. But lately, such text-oriented training systems have been eclipsed by the newest technology on the block—interactive videodisc.

Laser videodisc players and their associated media are best known as a movie-presentation technology for home TVs. When the players are linked through controllers to microcomputers, however, they can become powerful teaching tools that combine video images and audio instruction with text and computer data. Because the players can quickly access any location on the videodisc platter, designers can produce systems that let students jump between subjects and levels of difficulty according to their individual needs. The resulting improvements in learning can be astonishing, claim the technology's proponents.

Bringing the interactive video component to computer-based training "is as dramatic as the addition of sound to movies was," says David A. Lubin, cofounder of Interactive Training Systems (Cambridge, Mass.). ITS, which has produced over 100 training videodiscs for corporate clients, recently formed a joint venture with Advanced Systems (Arlington Heights, Ill.) to develop a highly interactive videodisc/computer system. "We believe the marriage of laser videodiscs with personal computers will be ubiquitous by the end of the decade," Lubin says.

One of the prime benefits of videodiscs in training situations, according to Lubin, is that interactive video, run by each student at a personalized pace and level, helps keep the student's attention. "In a conventional learning environment," he says, "students spend 25 to 50% of their energy just trying to stay focused on the presentation."

Lubin claims that by using videodisc systems, ITS has been able to compress the time needed to learn any given curriculum—by factors of as much as six to seven—while improving the retention of the learned material by up to 40%. In addition, the computer can closely monitor each student's capabilities, and can slow course progress and postpone completion if the student isn't learning adequately. Finally, interactive videodisc training costs considerably less than conventional training methods—a crucial point for cost-conscious companies. "The cost of live instruction runs approximately $250 per student per day," says Lubin, "whereas our videodisc systems cost only about $50 per student per day."

As more young children use classroom computers, questions arise about the machines' impact on developing minds, social abilities, and physical activities.

These benefits will bring major changes in the business of training adults, says Gary Quinlan, executive VP at Wilson Learning. Today only about 10% of Wilson Learning's programs are of the self-study variety. But a survey performed by the firm's parent company, John Wiley & Sons (New York), indicates that the Fortune 500 companies expect as much as 50% of their training efforts to use some sort of individualized interactive technology within five years.

Smarter systems

A still-embryonic area of educational technology is artificial intelligence. Broadly, AI involves the programming of computers with traits normally associated with human intelligence; thus its possible applications in the teaching world are many and varied. ITS is exploring AI in hope of enabling the computer to take into account the background and the skills of each student. "We expect that AI will make the system smarter about who you are and how you want to see things," says Lubin. ITS also hopes to use AI techniques to shorten the time required to produce new training programs. "At some point," predicts Lubin, "the developer will just give the course content to the system, and the system will devise how to teach the material."

One of the most active areas of AI today is that of expert systems, which catalogue the knowledge of human experts along with the rules and procedures they use to exploit that knowledge. Some foresee the development of expert teaching systems. But even expert systems not specifically designed for teaching are usually well-suited to educational uses, says Thomas P. Kehler, executive VP of technology at IntelliCorp (Menlo Park, Cal.), a producer of expert systems and related developmental tools. "Expert systems usually have an 'articulation' facility that explains why the system did what it did," he says. Students who don't understand a process can therefore query the system.

If used properly, the various educational technologies won't just expedite the learning process, they will alter its very nature. Conventional learning involves the acquisition and long-term retention of specific knowledge. But in a world where most of an engineer's training becomes obsolete within about five years, such "maintenance" learning won't suffice, says Wilson Learning's Quinlan. Rather, the company argues, education should shift its emphasis toward "anticipation" learning, which better prepares students—child or adult—to adapt and modify their knowledge as circumstances require.

While people of all ages might benefit from such an educational shift, Wilson Learning expects children to find changes in the learning process easier to adapt to than adults. "Our task in training adults is much harder," says Orensteen. "People who are established in their careers or views have a significant amount of unlearning to do before they can make new connections." And he believes that technology has a major role to play in rendering such training effective. "It can help create a compelling way," he says, "for learners to challenge their own beliefs in private."

Dwight B. Davis is a senior editor of HIGH TECHNOLOGY.

For further information on the Special Report see RESOURCES *on page 111.*