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Government's Response to the Competitiveness Problem

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The Competitiveness Problem

Sandia Analysis

By the mid 1980s there was growing concern that U.S. companies were experiencing difficulties in international competition. The President's Commission on Industrial Competitiveness, Congress[2], and numerous other groups studied the problem. Most of these studies had difficulty converging on the root cause of industrial competitiveness problems. Instead, everything from K-12 education, to industrial management, to cost of capital, to federal emphasis on defense R&D, to lack of use of total quality manufacturing principles were claimed to be contributing causes. Retrospective analysis of these recommendations suggest that few were well-grounded in data-based analysis.

In 1990 personnel at Sandia's Systems Analysis Department responded to the Secretary of Energy's encouragement of the National labs to apply their expertise to the economic competitiveness of the U.S. The Sandia team allowed that if they were to make any contributions to helping solve the "competitiveness problem", they had to first figure out what the problem really was and identify it's root cause. To do that they conducted a macroeconomics analysis of the U.S. position in national accounts, international trade, productivity, and standards of living to see if the rising sense of doom could be supported by data. They found that it could not.[3] The major observations of this study include:

- The U.S. GDP, adjusted for purchasing power parity, was 2.75 times that of the second largest economic power, Japan.
- The U.S. GDP growth rate for the previous 15 years was midway between that of Japan and Germany and comparable to both.
- The U.S. was the leading world exporter of goods and services.
- The U.S. has the highest manufacturing and overall productivity in the world.

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[1] Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

[2] U.S. House of Representatives Committee on Science, Space, and Technology, Technology and Its Impact on the National Economy, December, 1989.

[3] John Arfman and Bob Paulson, Assessing the Competitive Position of the United States: A Macroeconomics View, an unpublished Sandia National Laboratories systems analysis, December 5, 1990.

DISCLAIMER

- The U.S. per capita buying power, adjusted for purchasing power, was 50% higher than that of Japan and Germany.

- The U.S. standard of living was the highest in the world and it was maintaining that position.

While this study offered an overall optimistic analysis of the U.S. economy, it noted that some U.S. industry sectors had lost market share to foreign competitors. Thus, the "competitiveness problem" was only being experienced in selected industrial sectors and it did not reflect a general industrial trend and did not warrant great concern.

Supporting Perspectives
Krugman argues that concems about U.S. competitiveness are almost completely unfounded and concludes that obsession with competitiveness is not only wrong, but dangerous, because it skews domestic policies and threatens the intemational economic system.[4] Defining U.S. economic problems as a national competitiveness issue is popular largely because of its simplicity and appeal to traditional win-lose reasoning.

Endless comparisons of per capita R&D investment and productivity growth in Japan and the U.S. failed to shed much light on the "competitiveness problem". These comparisons usually failed to account for the following facts: about 25% of Japan's workers are engaged in manufacturing in comparison to about 15% in the U.S., manufacturing is overall much more R&D intensive than services, and the productivity growth in manufacturing is over two times that of services. To be meaningful, comparisons of Japan's R&D investment to those in the U.S. must be made on a sector-by-sector basis and they must distinguish between manufacturing and services.

Another claim often made during the competitiveness scare was that the U.S. has been deindustrializing and that was somehow bad for our society.

> *Deindustrialization is often perceived as evidence of economic decline. On the contrary, it is a natural consequence of economic progress. ... Productivity improvements in farming caused the same thing to happen in agriculture over the past century. Having made up 50% of all American jobs in 1860, farming now employs only 3%.*[5]

Competitiveness Data
Although most of the proposed solutions to the "competitiveness problem" recommended that the federal government make substantial investments in research, the data shown in Table I revealed that U.S. companies competitiveness difficulties had little to do with inadequate research, because in most of the areas where Japan's companies were winning in the marketplace, U.S. institutions had been the early R&D leader and in most instances U.S. institutions had introduced the first product into the marketplace. In a review of the market strength of today's U.S. companies, we could find no instance over the past three years in which we could identify a product or technology where the U.S. had lost market leadership to a foreign firm.

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[4] Paul Krugman, Pop Internationalism, The MIT Press, 1996, p5.

[5] The Economist, "It's Wise to Deindustrialize", April 26, 1997, p. 78.

Table I: A comparison of research leaders, first product introduction leaders, and current market leaders for several products and technologies that are internationally traded.[6]

Technology or Product	R&D Leader	First Product	Current Leader
Advanced Composite Materials	U.S.	U.S.	Japan/U.S.
Anti-Skid Brakes for Autos	Europe	Europe	Japan/Europe
Automatic Focus Cameras	U.S.	U.S.	Japan
Automobiles	Europe	Europe	Japan
Biotechnology	U.S.	U.S.	U.S.
Commercial Jet Aircraft	Europe	U.S.	U.S.
Communications Electronics	U.S./Europe	U.S.	U.S.
Compact Disk Players	Europe	Europe	Japan
Computer Aided Design	U.S.	U.S.	U.S.
Consumer Electronics	U.S.	U.S.	Japan
Copiers	U.S.	U.S.	Japan/U.S.
Desk Top Computers	U.S.	U.S.	Japan/U.S.
Digital Watches	Europe	U.S.	Japan
DRAM Memory	U.S.	U.S.	Japan/Korea
Drugs and Pharmaceuticals	U.S.	U.S.	U.S.
Electronic Fuel Injection	U.S.	U.S.	Europe/Japan
Facsimile Machines	U.S./Europe	U.S.	Japan
Fiber Optics	U.S.	U.S.	U.S.
Flat Panel Displays	U.S.	U.S.	Japan
Fuzzy Logic	U.S.	Japan	Japan
Hand-Held Calculators	U.S.	U.S.	Japan
High Temperature Superconductors	Europe/U.S.	Japan/U.S	?
Integrated Circuit Test Equipment	U.S.	U.S.	Japan
Jet Engines	Europe	Europe	U.S.
Lithography Steppers	U.S.	U.S.	Japan
Medical Imaging Technology	Europe	U.S.	U.S.
Microprocessors	U.S.	U.S.	U.S.
Military Radars	Europe	Europe	U.S.
Notebook and Desk Top Computers	U.S.	U.S.	U.S./Japan
Numerical Control Machine Tools	U.S.	U.S.	Japan
Rocket Propulsion Technology	Europe	Europe	U.S.
Robotics	U.S.	U.S.	Japan
Satellite-Based Television Transmission	U.S.	U.S.	U.S.
Semiconducting Lasers	U.S.	U.S.	Japan
Software	U.S.	U.S.	U.S.
Super computers	U.S.	U.S.	U.S.
Television Sets	U.S.	U.S.	Japan
Video Games	U.S.	U.S.	Japan
VCRs	U.S.	U.S.	Japan

The "competitiveness problem" offered an opportunity for those who have historically exploited the public's vulnerability to external threat arguments to shift their threat model from the Soviet Union to Japan and more recently to other Asian nations. Finally, it offers many opportunities to use war and battle metaphors, struggle and conflict clichés, and rhetoric that

[6] These data were compiled by James Gover when he worked in the Office of Senator Roth as an IEEE Competitiveness Fellow.

presents Japan and Germany as utopian nations.[7] Data and analysis found little utility in competitiveness rhetoric. Unfortunately, much of the misdirected rhetoric is founded on the incorrect assumption that international trade, like war, is a zero sum game that produces winners and losers instead of winners and winners. ***In reality, in most instances war has produced losers and losers and in most cases international trade produces winners and winners. War and international trade are not bedfellows.***

It is generally agreed that the market losses highlighted in Table I stemmed from:

- Lack of emphasis on manufacturing equipment and processes, especially:
  (1) the application of quality principles to manufacturing,
  (2) inattention to process R&D and production tool R&D in comparison to product R&D,
  (3) weak linkage between science and technology innovation and production processes,
  (4) failure to make modeling-intensive, deterministic design methodology part of our nation's technology infrastructure;

- Preference for niche products with high profit margins accompanied by abandonment of commodity products with low profit margins that foreign competitors are sometimes willing to sell at prices below their manufacturing cost, and

- A national regulatory environment that was perceived to disadvantage the U.S. as a site for manufacturing commodity products which resulted in U.S. companies either abandoning these products or moving their manufacturing off-shore. (While the U.S. regulatory system can be improved, it is no more dysfunctional than the regulatory systems of other industrialized nations.)

- A business strategy tied to monopoly products rather than products with open standards that worked in harmony[8] with the products of competitors.

Pfeffer explains U.S. companies loss of the consumer electronics market in the 1980s as resulting from these companies strategic decisions.

> *First, U.S. manufacturers of televisions, radios, and similar appliances believed they could contract out manufacturing. But because manufacturing and product design are closely interrelated, soon these firms were also contracting out important parts of the design process, retaining a marketing and distribution function. This process creates competitors, and the Japanese and Korean firms that did first the manufacturing and then the product development soon decided to move into marketing and distribution and thereby take over the entire market.*[9]

Companies Response to the "Competitiveness Problem"

The intensity of international competition and the desire to avoid the market losses highlighted in Table I caused U.S. companies to introduce many changes in their organization, management, and structuring of R&D. Major changes include:

- Central corporate research laboratories (CCRLs) were downsized in companies that compete in industry sectors where commercialization is driven by the need to improve existing products and processes (over 75% of international trade). R&D continues to be moved to manufacturing facilities in companies' business units. In addition, CCRLs in companies where competition is driven by product and process improvements are

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[7] According to OECD and World Bank data, GDP per person in Germany ranks 14th in the world and GDP per person in Japan ranks 8th in the world when adjusted for purchasing power parity. The U.S. ranks 2nd. The Economist, "Leagues Apart", April 26, 1997, p. 53.

[8] Arno Penzias, Harmony: Business, Technology, and Life After Paperwork, Harper Business, 1995.

[9] Jeffrey Pfeffer, "Will the Organization of the Future Make the Mistakes of the Past?", in The Organization of the Future, editors Frances Hesselbein, Marshall Goldsmith, and Richard Beckhard, The Drucker Foundation, 1997, p.47.

required to seek most of their funding from business units. Formal technology transfer processes such as moving an R&D team into a product environment are being used to shorten transfer time.[10]

- R&D projects are designed to support companies' business strategies both directly and by nurturing the technology infrastructure required by companies to sustain those core technologies that differentiate them from competitors.

- Preference is being given to R&D that can be captured by the company.

- R&D laboratories are being reengineered and restructured to be compatible with the ways that each company commercializes its products. Companies are particularly improving their ability to compete in sectors where commercialization is driven by the need to improve products and processes.

- Companies look for innovation any place that it can be found with partnering, strategic alliances, collaboration, and consortia used to gain access to new technology.[11]

Today's Competitiveness Data

U.S. companies are competitive and we can find no evidence that suggests they are about to lose their ability to compete in international markets. The Council on Competitiveness recently pointed out that U.S. companies have made substantial improvements in their competitiveness over the past decade. They highlight the following:

- Global Market Share - U.S. companies share of goods increased from 9.9% in 1985 to 12.2% in 1995 while the U.S. surplus in services increased from just under $7 billion to over $80 billion over this time period. (Although productivity growth is lagging in education, healthcare, and legal services, the U.S. leads the world in shifting to a services-based economy.[12])

- Trade Deficit - The U.S. trade deficit has declined by 50% as a percentage of GDP.

- Per Capita GDP - The U.S. continues to lead the world.

- Growth in Industrial Output - The U.S. led all G-7 nations in growth in industrial output over the past 5 years.

- Budget Deficit Reduction - The U.S. has the lowest budget deficit as a fraction of GDP of any G-7 nation.

- Employment - U.S. unemployment is lower than all G-7 nations except Japan and U.S. job creation exceeds that of all G-7 nations combined.

Three out of four Council on Competitiveness members polled rated the federal government's role in strengthening the competitiveness of companies as neutral to negative.[13]

Government's Response to the "Competitiveness Problem"

Constituent Pressure:

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[10] Charles E. Bosomworth and Burton H. Sage, Jr., "How 26 Companies Manage Their Central Research", Research Technology Management, May-June, 1995, pp.32-40.

[11] James Gover, "Corporate Management of R&D - Lessons for the U.S. Government", Research Technology Management, March-April, 1995, p 35.

[12] Hamish McRae, The World in 2020, Harvard Business School Press, 1994, p27.

[13] Council on Competitiveness, Competitiveness Index 1996: A Ten-Year Strategic Assessment, October, 1996.

Congress took action during the late 1980s and early 1990s to address the "competitiveness problem". Pressure on Congress came from constituents **seeking better employment opportunities** and constituents that would directly benefit (this usually means receive public money) from these programs. *Some federal agencies declared industry to be their customer!* To emphasize that **industry, in contrast to the public, was the customer** for these programs, federal agencies tasked to manage them often stressed that they were "industry-led". To assure that they were "industry-led", Federal agencies often hired personnel from industry to manage the programs. Somehow, the fact that most constituent calls to Congress were about job creation was lost in the on-rush of R&D performers seeking funds for their favorite R&D project.

In the following, each of the programs that Congress has created or strengthened since the late 1980s to support commercial technology and solve the "competitiveness problem" is reviewed with the criticisms of critics highlighted. Most of these programs are being curtailed, among other reasons, because they are interpreted to be industrial subsidies and **public return** was rarely measured.

Federal Laboratories as Constituents
The Technology Transfer Initiative (TTI) was created so that federal laboratories could transfer technology to private companies. The Cooperative R&D Agreement (CRADA) was the legal document that formalized TTI partnerships. Congress intended that the partnerships between federal laboratories and private companies help the laboratories execute their public missions while helping companies improve their competitiveness. **Public value** would be derived by (1) improving the efficiency of federal mission R&D while (2) simultaneously creating jobs in the private sector.

Critics rarely object to the TTI in principle, but frequently claim the costs of company negotiations and transactions are excessive; question whether the overall social costs including the costs of preparing unfunded proposals exceed the social return from those that are funded; complain that some laboratories transfer technology to companies that their competitors have had to develop with their own funds; note that TTI encourages technology push from federal laboratories rather than market pull from companies; question the effectiveness of TTI execution processes in achieving the goals listed above, **particularly the public goals**; and propose that companies should pay the entire cost if they benefit from TTI. The last criticism often tacitly assumes that **public goals** are not achieved. Of course, the agency assertion, "industry is our customer", promoted this assumption.

Unfortunately, a singular measure of success for the TTI, the number of CRADAs signed between federal laboratories and companies, quickly evolved. This led laboratory technology transfer officers to sign as many CRADAs as possible so that their organization and they were perceived to be "winning" the competition. Laboratory directors were, of course, pleased with this implementation because new federal and corporate dollars were flowing into their labs. Engineers and scientists believed they could use the new funds to support their favorite projects and they would be given high marks by their management for "bringing home the bacon". By the time that the agencies had figured out that the issue was ***public outcomes***, Washington had lost interest in the TTI.

How to choose TTI partnerships so that ***public return*** is maximized, how to measure ***public return,*** how to apportion technology transfer costs between the public and private sectors, and how to adapt the R&D management style of the federal laboratory to the unique dynamics of commercialization used by the company partner[14] remain unresolved issues.

b. Companies as Constituents. Under intense lobbying pressure from companies to not just provide them with technology from federal laboratories, but give them money so they can develop the technology, (Corporate lobbyists argued that it was more efficient to give the

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[14] James Gover, "Optimizing Federal Technology Transfer to Promote Commercialization", The Journal of Technology Transfer, Vol. 19, Nos. 3-4, December 1994, pp36-50.

money directly to companies.) Congress created the Advanced Technology Program (ATP) at the National Institute of Standards and Technology (NIST). The goal of ATP has been to fund companies to conduct commercial research which will lead to breakthroughs that markets claimed to be risk-averse are unwilling to support. Thus, ATP funds R&D for profitable technology which profit-seeking investors have overlooked because of risk.

The biotechnology industry calls into question the claim that investors are risk averse. Of 250 publicly traded U.S. biotechnology firms, 13 showed a profit in 1993. In 1993, U.S. biotech stocks dropped an average of 32% and that was followed by an average drop of 29% in 1994. Yet, venture capitalists, seeking the home run, continued to make investments.[15] In 1995, U.S. firms raised nearly $30 billion through initial public offerings with $6.7 billion going to firms backed by venture capitalists. In 1995, the average U.S. venture capital fund returned 54.2% to investors.[16]

Critics challenge the assumptions that (1) the U.S. has a market failure in breakthrough R&D, (2) governments can, even with industrial advisors, find profitable technology that profit-seeking investors have ignored or overlooked,[17] and (3) that government can be sure that all companies are overlooking the technical area of interest. The idea of public funds aiding a specific company rather than an entire industry sector has also been challenged on the basis that it distorts competition in the domestic market and may not be in the best interests of the American public. In response to this concern, ATP has given preference to supporting consortia.

Past Secretary of Labor Robert Reich proposed that programs that include corporate subsidies and corporate tax breaks should be evaluated after two years to determine whether their ***benefits to society*** outweigh their costs and if the program doesn't survive the test, it should be killed. The Secretary emphasized that these programs should have the potential to aid an industry generally rather than just a single company.[18]

Dr. Lewis Branscomb, Aetna Professor in Public Policy and Corporate Management, emeritus, at Harvard University, has expanded this concept to emphasize basic technology and include states in the technology selection process for ATP,

> *The agency's ATP effort should stress basic technology in its award choices and should encourage participation by firms organized into consortia to foster the diffusion of resulting innovations. To avoid the charge that it is picking economic winners, ATP should delegate to individual states or regional coalitions of states the responsibility for nominating industries that are critical to their economic development goals and then pulling together a team drawn from industry, universities, labor, and state officials that would apply to ATP for support. ATP's role would be to focus on technical merit in making the awards. The states would also be expected to make post-project evaluations of the economic impact of the program.*[19]

Two witnesses from the high-tech industry told a Senate hearing on June 3, 1997, that the Department of Commerce's Advanced Technology Program (ATP) is doing more harm than good, and even those companies receiving ATP grants want to see the program killed. One of the witnesses, T.J. Rodgers, president and CEO of Cypress Semiconductor Corporation, produced a statement on "corporate welfare," signed by 35 chief executive officers and other senior staff officials of high-tech and venture capital firms. In the statement, they said high tax burdens hurt their companies more than government funding helps them, and they would

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[15] The Wallstreet Journal, March 28, 1995, p. B1.

[16] The Economist, "From Labs to Riches", November 9, 1996, p. 88.

[17] The Economist, "Paying for Research", June 3, 1995, p. 13.

[18] The Wallstreet Journal, "Reich Outlines Plan Of Cost-Benefit Tests For U.S. Programs", May 31, 1995, p. A8.

[19] Lewis M. Branscomb, "From Technology Politics to Technology Policy", Issues in Science and Technology, Spring 1997, p. 46.

support an end to such funding, even if it meant their own companies would lose government money. "We don't want you to take money from other people and give it to us," Rodgers said. The other witness, venture capitalist Tim Draper of Draper Fisher Associates, said the ATP should be abolished because it hurts the free market. "The government is no substitute for the market. There is no better system than the market for choosing worthy, new technologies and products," Draper said.[20]

States as Constituents

Under the rallying cry that "small businesses are the engine of economic growth", Congress created the Manufacturing Extension Partnership (MEP) at the NIST to assist in the diffusion of manufacturing technology to small manufacturers. The perceived success of manufacturing extension in Europe and Japan and the success of agriculture extension in the U.S. provided evidence of the utility of this concept. Critics rarely challenge the principle of manufacturing extension, but question the need for a 50 percent federal funding level, in contrast to state, local or industrial funding. (Most of Japan's 170 Kohsetsushi centers are operated by prefecture and municipal governments, with MITI and other national agencies providing guidance and between 10 percent and 20 percent of the funding at each center. Except for a small income from participating companies, prefecture and local governments provide the remainder of Kohsetsushi center funding.[21]).

Critics also point out that many small businesses already use advanced manufacturing technology, for example, makers of semiconductor manufacturing equipment, and can not, therefore, benefit from manufacturing extension services. Simons proposes that manufacturing extension services could have high impact in about 50,000 of the 360,000 U.S. manufacturing establishments.[22] Others note that agricultural extension was successful at least until the 1960s not just because of the services provided by the extension agent, but primarily because it linked farmers to innovation sources (land grant universities) whose federal R&D funding was by formula, not peer review.

As Branscomb points out, the taxpayer would be well served if the federal government provided core support to insure that MEP centers around the Nation remained networked. Branscomb also recommends that MEP expand their portfolio of services to include workforce training.[23]

Defense Contractors as Constituents

With defense spending being reduced from 6 percent of GDP to 3.8 percent of GDP, the concept of defense conversion was born. In this model defense contractors would receive federal funding to do commercial R&D in the hope that this would assist defense contractors transitioning into the commercial sector. As the numerous weaknesses of this concept became clear, the Technology Reinvestment Project (TRP) emerged from the debris. While TRP was a program designed to assist the DoD in making more effective use of commercial technology in defense systems during a period in which warfighting is being revolutionized by information technology[24], it retained the political baggage of defense conversion. TRP was also attacked by defense contractors that failed to win awards and some viewed TRP awards to be driven by pork.[25]

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[20] Ross Dunbar ASME Government Relations News Release, 1828 L Street, NW, Suite 906 Washington, DC 20036, June 3, 1997.

[21] Philip Shapira, "Modernizing Small Manufacturers in Japan: The Role of Local Public Technology Centers", Journal of Technology Transfer, Winter 1992.

[22] Gene R. Simons, "Industrial Extension and Innovation", in Empowering Technology, edited by Lewis M. Branscomb, The MIT Press, 1993, p. 184.

[23] Branscomb, Issues in Science and Technology, p. 46.

[24] The Economist, "A Survey of Defense Technology: The Softwar Revolution", June 10-16, 1995.

[25] Dorothy Robyn, National Economic Council, presentation at the Science and Technology Conference, sponsored by New Technology Week, February 22-24, 1995, Washington, DC.

ARPA/DARPA as Constituent
To make it easier to fund defense R&D that simultaneously helped National defense while strengthening the commercial sector, the Defense Advanced Research Projects Agency (DARPA), originally created as ARPA, again became ARPA. (It has now again become DARPA.) Most praise ARPA/DARPA for being "lean and mean", for being staffed with technically and politically astute personnel, and for having a flat hierarchy that allows decisions to be made quickly. Regardless of its title, this premier organization continues to search for technology breakthroughs that can advantage U.S. defense systems. Although ARPA/DARPA, on occasion, will fund R&D at a federal laboratory, it prefers to fund R&D at universities and private companies. The military services sometimes question the military utility of ARPA/DARPA R&D, suggest that emphasis on commercial technology interferes with ARPA/DARPA emphasis on military R&D, and propose that most of ARPA/DARPA innovations fail to find their way into military systems.

Ironically, we believe that historians will conclude that ARPA/DARPA's greatest commercial accomplishment was the initial creation of the ARPA net so that ARPA-funded researchers could increase their transfer of data files. This initial communications link was combined with other agencies' communication networks to form the Internet, a critical and growing element of the global communications infrastructure. The Internet has been the basis for the birth of an entire industrial sector, and it was not one of ARPA/DARPA's largest investments. The important lessons to learn from the Internet are (1) government can focus first on ***public need*** - the Internet was needed for interagency and agency- contractor communications - and at the same time create new markets in the commercial sector and (2) the most successful government projects are often among the least expensive.

Semiconductor Manufacturers as Constituents
In 1987 the U.S. semiconductor industry and the U.S. government feared that the U.S. loss of semiconductor manufacturing leadership to Japan not only had dire consequences for the national economy, military security was at risk as well. It was thought that Japan's rise to international preeminence in semiconductor manufacturing was aided by their government's industrial policy of targeting semiconductors and Japan's VLSI consortium was believed to have helped Japan's companies. For several years, it was thought that Japan's "Fifth Generation" Project for advanced supercomputers would lead to domination of that market. Consortia became the "silver bullet".

The SEMATECH consortium was incorporated by 14 U.S. high-tech companies and given the *national mission of restoring world leadership in semiconductor manufacturing* to the U.S. SEMATECH was funded at $100 million annually by ARPA/DARPA to match those funds provided by their members. U.S. semiconductor companies have recovered their competitive position and some analysts are predicting a grim future for Japan's semiconductor companies.[26] SEMATECH is one of the factors that have contributed to this recovery.[27]

U.S. supercomputer manufacturers, Intel, IBM, and Cray, changed the rules of competition in the early 1990s when they adopted the strategy to build parallel multiprocessors based upon commercial central processor units (CPUs). This move away from very high performance (but specialized) CPUs doomed their domestic and foreign competitors. The Japanese supercomputer companies were victims of a strong U.S. position in semiconductor CPU production. The rapid pace of CPU advancement (roughly a new commercial generation once every three years) makes each previous generation obsolete and discourages competitors from entering the market. Intel's strength in CPUs was aided by the vertical relationships developed between semiconductor manufacturers and their suppliers that was facilitated by SEMATECH. Thus, SEMATECH's contributions extend down the "food-chain" of electronics into the supercomputer arena.

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[26] William F. Finan and Jeffrey Frey, Japan's Crisis in Electronics: Failure of the Vision, Nihon Keezai Publishing Company, Japan, April, 1994.
[27] James E. Gover, "Analysis of U.S. Semiconductor Collaboration", IEEE Transactions on Engineering Management, Vol. 40, No. 2, May 1993, p.p. 104-113.

Critics of SEMATECH point out that while the U.S. position in semiconductor production and semiconductor manufacturing equipment have improved, the U.S. positions in DRAMs, lithography equipment, and semiconductor materials have not improved. T. J. Rogers claims that SEMATECH's membership fees discouraged small semiconductor manufacturers from joining the consortium. Some members of Congress are irritated that in 1987 they were told that SEMATECH would only need federal funds for 5 years, not the 10 years they actually received federal support.

Small Businesses as Constituents
Awards in the Small Business Innovative Research Program (SBIR) were increased from $50,000 for phase 1 awards and $500,000 for phase 2 awards to $100,000 for phase 1 awards and $750,000 for phase 2 awards. In addition, the total budget for SBIR was increased from 1.25 percent of each agency's extramural R&D budget to 2.5 percent (starting in 1997) of each agency's R&D budget. Thus, the SBIR program will annually direct more than $1 billion to small companies. Critics of the SBIR program challenge whether ***social return*** exceeds social cost of the program when the transactions and negotiations cost of all applicants are included, note that too many companies are unable to wean themselves from a dependency on SBIR awards (termed SBIR addiction), observe that companies that successfully complete phase 2 sometimes sell their technology to foreign firms or are purchased by foreign firms, and challenge the proposition that small companies are an economically relevant source of innovation.

Branscomb recommends,

> *Because the agencies fund not only research but commercialization as well, SBIR should follow a dual-use strategy, in which technological goals are demonstrably related to the agency's main mission as well as having possible broad application. NSF, for example should focus its SBIR program on technologies such as instruments, new materials, sensors, platforms, and systems for data acquisition, and information technology that will enhance the Nation's S&T research capacity.*[28]

Universities as Constituents
Universities, under immense financial pressure, determined that more federal R&D support was needed. One strategy was to challenge funding for federal laboratories in anticipation of that funding going directly to universities.[29] Another university strategy has been to persuade Congress to increase the budget for basic research. Recognizing the financial difficulties faced by many universities and the fact that the education of America is fundamental to our Nation's future, Congress doubled the budget of the National Science Foundation by increasing it from $1.6 billion in 1987 to $3.2 billion in 1995, a time period when federal R&D was static.[30] Congress has long subscribed to the linear model of innovation (scientific inquiry followed by technological application, and then commercialization); thus, federal R&D emphasis on basic research is thought to trigger this innovation process and ultimately lead to great and profound commercial products.

Critics explain that the linear model of innovation has been thoroughly discredited. Critics also note that to advance technology that is increasingly becoming more complex[31] requires multi-disciplinary project teams rather than individual researchers as is commonly found in universities. Some critics argue that pumping more research money into universities aggravates rather than solves the root cause of universities' problems - lack of productivity

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[28] Branscomb, Issues in Science and Technology, pp. 46-47.

[29] Government, University-Industry Research Roundtable, Future National Research Policies Within the Industrialized Nations, April, 1992, p 9.

[30] Christopher Roosa, Majority Staff, U.S. House of Representatives Science Committee, Subcommittee on Basic Research, Chairman, Congressman Steven Schiff, NM-1, provided these data.

[31] Robert W. Rycroft and Don E. Kash, "Complex Technology and Community: Implications for Policy and Social Science", Research Policy 23 (1994), pp. 613-626, North Holland.

improvement. The number of Ph.Ds graduating annually from U.S. institutions exceeds the market required for modest salary growth by 25 percent. It is argued that increasing university research will result in further growth in the number of Ph.D. graduates. Unable to find private sector employment, many will seek a career in university research. The latter creates a growing demand for more public funds to support even more university research.[32] Positive feedback loops lead to system instability.

What Would Companies Like Government to Do?

Workforce Training

Every survey of companies reveal that they are more concerned about workforce training, regulations, and access to foreign markets than other issues. Companies are currently spending between $50 billion and $60 billion each year on workforce training and are concerned that level is inadequate. From a public perspective, it is preferable to keep the U.S. workforce well-trained, employed and off the social security rolls until they reach the late 60s and early 70s.

Boskin and Lau have pointed out,

> *The failure of education and training to keep up with the demand for higher individual skills and competence, especially in the bottom half of the labor force, may now be acting as a bottle neck that reduces the economy's ability to translate technological advances into improved productivity. If this is correct, it raises the question, in the context of very scarce federal budget dollars, as to whether efforts to improve education, training, and school-to-work transitions at the lower end of the labor force ought not to be given higher priority than additional dollars for R&D targeted to industrial purposes.*[33]

A recent analysis of the top ten trends in industry listed the following[34]:

- Skill requirements will continue to increase in response to rapid technological change.
- The American workforce will be significantly more educated and more diverse.
- Corporate restructuring will continue to reshape the business environment.
- Corporate training departments will change dramatically in size and composition.
- Advances in technology will revolutionize the way training is delivered.
- Training professionals will focus more on interventions in performance improvement.
- Integrated high-performance work systems will proliferate.
- Companies will transform into learning organizations.
- Organizational emphasis on human performance management will accelerate.

The business sector has recognized the advanced training needs of industry as an enormous opportunity. For example, Lehman Brothers[35] has just held its second annual symposium to

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[32] Daniel S. Greenburg, "So Many Ph.D.s", The Washington Post National Weekly Edition, July 10-16, 1995, p. 29.

[33] Michael J. Boskin and Lawrence J. Lau, "Contributions of R&D to Economic Growth", in Technology, R&D and the Economy, edited by Smith and Barfield, the Brookings Institution and the American Enterprise Institute, 1996.

[34] Laurie J. Bassi, George Benson, and Scott Cheney, "The Top Ten Trends", Training and Development, The American Society for Training and Development, pp. 28-42, July, 1996.

study these opportunities and to recommend investments which might yield high profits for corporate training organizations. Most universities have failed to recognize this opportunity and contact their matriculated graduates (now in business and in need of additional education) only for alumni news, homecoming, and to solicit contributions.

Corporate Management

The Industrial Research Institute annually surveys their members to identify the biggest problems faced by R&D managers. The poll taken in the spring of 1996 identified the following concerns. The number in parentheses is the percentage of the 242 members polled that listed that category as their biggest problem.

- **Managing** R&D for business growth (15.2%),
- Integrating **strategic** technology **planning** with corporate business strategy (14.3%),
- **Balancing** long-term and short-term R&D needs and focus (13.5%),
- **Measuring** and **improving** R&D productivity and effectiveness (11.8%),
- Making innovation happen (9.3%),
- Reducing R&D cycle-time (8.0%),
- **Selling** R&D internally or externally (6.3%),
- **Management** of global R&D (3.8%),
- **Leadership** of R&D within the corporation(3.8%), and
- **Managing** the R&D portfolio (2.1%),.[36]

Note that the leading company concerns are almost entirely management issues - managing, strategic planning, balancing, measuring and improving, selling, leadership, etc.

R&D partnerships between companies, federal labs and universities can address both short-term and long-term R&D needs and allow companies to extend their focus on short-term needs, reduce product and process cycle time through advancement of the computational and modeling sciences, increase the overall frequency of innovation, and help companies gain access to external sources of R&D.

Other Company Concerns

In addition to concerns about the U.S. education system and the growing company investment in education and training, U.S. companies are annually spending and passing on to their customers regulatory costs that range between $600 billion and $800 billion per year and they are annually spending about $200 billion on health insurance for their employees. The corporate benefits of a 20 percent reduction in health care costs or a 20 percent reduction in regulatory costs or a better educated workforce dwarf a few billion dollars of federal support for corporate R&D.

Summary

By the mid 1980s there was great and growing concern throughout the U.S. that U.S. companies were experiencing difficulties in international competition. Pressure on Congress to take action came from constituents seeking jobs and companies that would directly benefit (this usually means receive public money) from programs that Congress might initiate. The fact that most constituent calls to Congress were about job creation was lost in the on-rush of

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[35] Lehman Brothers, Second Annual Education Industry Conference, February 11, 1997, New York, NY.

[36] Data provided to Paul Johnson, IEEE-USA, by R. Burkart, IRI.

R&D performers seeking funds for their favorite R&D project. In response, Congress created the Advanced Technology Program, the Technology Transfer Initiative, and the Technology Reinvestment Project, expanded the responsibilities of ARPA/DARPA, increased funding for the Small Business Initiative, expanded the Manufacturing Extension Partnership, funded SEMATECH, and increased NSF funding for basic research at universities. Many of these programs were later criticized for being industrial welfare and several were cut-back or stopped. Retrospective analysis shows that few of these programs addressed the root cause of competitiveness difficulties. In fact, by the time most of these programs were in place, U.S. companies were well on their way to correcting their competitiveness problems. In addition, few were relevant to companies' often expressed concerns about workforce training, regulatory costs, and access to foreign markets. Twenty percent reductions in health care costs, regulatory costs, and education costs could annually pump $500 billion into the U.S. economy and make companies operating in the U.S. much more competitive in international markets.