Chapter 4

The U.S. Response to High-Temperature Superconductivity

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Chapter 4

The U.S. Response to High-Temperature Superconductivity

This chapter begins with a description of the Federal response to the advent of HTS. This is followed by a brief critique. An evaluation of the adequacy of this response, as well as that of U.S. industry, is presented in chapter 7.

FEDERAL POLICY

The sense of excitement in the scientific community that came with the discovery of new, high-critical-transition-temperature (T_c) superconductors was quickly transmitted to the policymaking community in Washington. To scientists, the discovery was the breaking of a long-assumed temperature barrier, which cast doubts on the validity of a widely accepted theory. To policy makers, the opportunities of HTS represented a test case of the United States' ability to quickly transfer the technology out of the laboratory and into commercial applications.

The President's Superconductivity Initiative

In July 1987, President Reagan addressed an audience of more than 1,000 at the Federal Conference on Superconductivity. In his speech, the President presented an 1 l-point agenda to promote cooperative research, to move scientific achievements more rapidly into the commercial realm, and to protect the intellectual property rights of scientists and engineers involved in superconductivity research. A list of these proposals and what has happened to them since 1987 is given in table 4-1.[1]

The legislative part of President Reagan's package, consisting of three initiatives, went to Congress in February of 1988. The first initiative proposed to relax the antitrust restrictions on joint production ventures among companies. Similar proposals have been made to promote U.S. competitiveness in several other technologies, e.g., high-definition television and semiconductor memory chips; but at this writing, the Bush Administration is still considering its position on the matter.

The second initiative proposed extending patent protection for process patents, and this was passed as part of the (Omnibus Trade and Competitiveness Act of 1988. The third initiative, which did not result in any legislation, proposed authorizing Federal agencies to withhold commercially valuable scientific and technical information from release under the Freedom of Information Act. None of these three legislative proposals was specific to HTS.

The remaining eight administrative initiatives have all been implemented in some form. Perhaps the most influential from a policy point of view was the establishment of the "Wise Men" Advisory Committee on Superconductivity (formally, the Committee to Advise the President on High Temperature Superconductivity) operating under the White House office of Science and Technology Policy. This seven-member council was comprised of experts in superconductivity from academia, industry, and government. Their report was released in December 1988.[2]

The Wise Men recommended an increase in funding of a few million dollars' to strengthen the scientific effort at universities, and the establishment of tour to six superconductivity consortia, each involving a major research university, a government laboratory, and several private industry members. These consortia are to be focused on applied HTS research. and are thereby distinguished from the more basic research-oriented consortia supported by the National Science Foundation. Since the report was published, the debate over HTS and U.S. competitiveness has largely been framed in terms of the need for one kind of consortium or another.[3]

Congressional Initiatives

Omnibus Trade and Competitiveness Act (Public Law 100-418)

As noted above, only one of the President's three legislative initiatives has been passed into law: in Title IX of the Omnibus Trade and Competitiveness

[1] A private body, the Council on Superconductivity for American Competitiveness, has published a brief analysis of this initiative, called *A Progress Report and Critique of the President's Superconductivity Initiative*, November 1988.

[2] The Committee to Advise the President on High Temperature Superconductivity, *High Temperature Superconductivity: Perseverance and Cooperation on the Road to Commercialization*, December 1988.

[3] A consortium to develop superconducting electronic devices—involving MIT, Lincoln Labs, IBM, and AT&T—was announced in April 1989 that closely follows the Wise Men's model.

Table 4-l-President's 1987 Superconductivity Initiatives

Proposal	Action
Legislative:	
Amend the National Cooperative Research Act to permit joint production ventures.	Did not result in any legislation. New proposals presently under consideration at the Justice Department.
Amend patent laws to increase process patent protection.	Passed as part of the Omnibus Trade and Competitiveness Act of 1988.
Exempt commercially valuable information developed at Federal laboratories from disclosure under the Freedom of Information Act.	No action; this was deemed politically impractical.
Administrative:	
Establish "Wise Men" advisory group (President's Advisory Council on Superconductivity).	Formed in February 1988; reported to the President and disbanded December 1988. Recommended establishment of four to six superconductivity consortia involving major research universities, companies, and government laboratories.
Establish Superconductivity Research Centers at Federal laboratories.	Four centers established, three at DOE's Argonne, Lawrence Berkeley, and Ames laboratories, and one for electronic applications of HTS at NIST/Boulder.
Accelerate implementation of Executive Order 12591 on technology transfer from Federal laboratories and cooperative research.	Ongoing; three Superconductivity Pilot Centers established in 1988 at Argonne, Oak Ridge, and Los Alamos to conduct joint research with industry.
Accelerate processing of patent applications.	Patent "fast track" established at the Office of Patents and Trademarks, but only 10 to 15 percent of HTS patent applications were submitted under this procedure.
NIST to accelerate standards development for HTS.	Ongoing, but small effort.
Reprogram fiscal year 1987 funds into superconductivity R&D; place high priority on superconductivity for fiscal years 1988 and 1989.	Virtually the entire HTS budget is reprogrammed money; to make funds available, programs in LTS, advanced ceramics, and other materials R&D were cut.
Accelerate military development of electronics and sensor applications, including prototype devices.	Ongoing; DARPA and SDIO have applications-oriented HTS development programs in place.
Seek reciprocal opportunities to participate in joint R&D programs with Japan under the Agreement on Cooperation in Science and Technology.	At this writing, a variety of joint projects are under negotiation.

KEY: DARPA: Defense Advanced Research Projects Agency
DOE: Department of Energy
NIST: National Institute of Standards and Technology
SDIO: Strategic Defense Initiative Organization

SOURCE: Office of Technology Assessment, 1990.

Act, patent coverage was extended to process patents. Title V also has a number of provisions affecting superconductivity, including the establishment of a National Commission on Superconductivity. Table 4-2 presents the sections of the Omnibus Trade and Competitiveness Act that are relevant to superconductivity, and to technology generally.

National Superconductivity and Competitiveness Act of 1988 (Public Law 100-697)

Passed in the waning hours of the l00th Congress, the National Superconductivity and Competitiveness Act of 1988 called for a 5-year National Action Plan for Superconductivity—to be presented to Congress in August 1989—that would define national goals for HTS and delegate responsibilities to the various Federal agencies to achieve them. This Act stresses the importance of a long-term commitment to developing superconductor applications, since these are seen to be 10 to 20 years away. The Office of Science and Technology Policy (OSTP) was given responsibility for coordinating the Plan with the National Critical Materials Council (NCMC) and the National Commission on Superconductivity (the same Commission mandated in the Omnibus Trade Act). A yearly report is required by Congress detailing the implementation of the Plan, as well as a program of international cooperation in superconductivity.

But the preparation of the Action Plan did not work out as Congress intended. The National Commission was appointed, but had no formal charter, and so did not participate in the drafting of the Plan. The National Critical Materials Council had no active members. The 'Plan' that emerged in

Table 4-2—Provisions of the Omnibus Trade and Competitiveness Act of 1988

	Requirement	Action by the Administration
On superconductivity:		
Report of the President	President must submit budget proposals regarding advanced materials with FY90 budget request.	No action.
National Commission on Superconductivity	To form, report, and disband by December 1989. Report to include: the state of U.S. competitiveness in superconductivity, foreign activities, impacts *on* U.S. national security of potential dependence on foreign procurement, options for tax incentives, possible benefits of exemptions from antitrust laws.	Formal charter delayed; first meeting Oct. 19, 1989.
National Critical Materials Council (NCMC)	Mandates staff increase; continues funding.	No active members during 1988 and 1989.
On technology generally:		
Intellectual property rights	Strengthens existing protections of intellectual property rights.	None required.
National Institute of Standards and Technology	Renames the National Bureau of Standards; increases responsibility for aiding U.S. industry in competing in manufacturing, creates a new post within the Commerce Department for technology policy.	Renaming occurred; technology policy appointment remains unfilled as of March 1990.
Technology extension centers	Requires NIST to assist in establishing regional technology transfer centers.	Three extension centers created.
Clearinghouses	Commerce Department is mandated to develop a clearinghouse of State and local initiatives for transferring Federal technology; second clearinghouse of State and local initiatives to enhance U.S. competitiveness.	Plan awaiting approval.
Competitiveness Policy Council	To advise the President on long-term strategies for U.S. competitiveness.	Council created, chaired by Vice President,
National Academy of Sciences	To review strengths and limitations of existing collaborations where the Federal Government is a partner.	In planning stages.
Education and training	Establish foreign language assistance programs, awards in technology education,	NSF program for language training under development.

KEY: NCMC: National Critical Materials Council
NIST: National Institute of Standards and Technology
NSF: National Science Foundation

SOURCE: Office of Technology Assessment, 1990.

December 1989 explicitly recognized the need for greater Federal coordination and for a cross-agency budgetary analysis of spending in various research areas; but it did not contain budget recommendations, nor the 5-year perspective that Congress wanted.[4]

FEDERAL GOVERNMENT PROGRAMS

The Federal Superconductivity Budget

Federal funding for HTS R&D rose from $45 million in fiscal year 1987 to an estimated $129 million in fiscal year 1989. In fiscal year 1990, funding stayed virtually constant (see table 4-3). From 1987 to 1989, LTS R&D funding rose from $40 million to $58 million.[5] Thus, in 1989, about two-thirds of government superconductivity R&D funding went to HTS.

Although the Department of Energy (DOE) and the Department of Defense (DoD) spent about the same amount on superconductivity overall in 1989, (both HTS and LTS), DoD had the biggest budget for HTS R&D, with a 45 percent share. DOE was second with 30 percent, and about 20 percent was allocated by the National Science Foundation (NSF). The National Aeronautics and Space Administration (NASA) and the Department of Commerce (through the National Institute of Standards and Technology, NIST) made up most of the rest, with the Department of the Interior and the Department of Transportation each spending less than 1 percent.

[4] "The National Action Plan on Superconductivity Research and Development," Executive Office of the President, Office of Science and Technology Policy, December 1989.

[5] Report compiled by the Federal Coordinating Committee on Science, Engineering, and Technology/Committee on Materials/Subcommittee on Superconductivity, "Federal Research Programs in Superconductivity," March 1989.

Table 4-3-Federal R&D in Superconductivity ($ thousands)[a]

	Fiscal year 1988[b]	Fiscal year 1989b (estimate)	Fiscal year 1 990' (estimate)
High-temperature:			
DoD	43,700	58,000	61,800
DOE	26,238	38,493	34,100
NSF	16,600	22,400	25,800
NASA	3,300	4,900	5,900
DOC (NIST)	2,800	4,800	2,800
DOT	50	150	—
DOI	100	100	—
Total HTS	92,788	128.843	130,400
Low-temperature:			
DoD	16,100	15,000	13,200
DOE	28,627	36,073	79,300[d]
NSF	3,800	3,800	3,000
NASA	2,650	3,050	2,000
DOC (NIST)	570	470	470
DOT	0	0	0
DOI	0	0	0
Total LTS	51,747	58,393	98,000
Total HTS+LTS	**144,535**	**187,226**	**228,400**

[a]Does not include funding for procurement of superconducting wire, magnets, and devices or funding of the superconductivity projects in the Small Business Innovation Research program.

[b]Federal Coordinating Committee on Science, Engineering, and Technology/ Committee on Materials/Subcommittee on Superconductivity, "Federal Research Programs in Superconductivity," March 1989.

[c]D. Allan Bromley, Director, Office of Science and Technology Policy, testimony before the Subcommittee on Transportation, Aviation, and Materials, House Committee on Science, Space, and Technology, Feb. 21, 1990.

[d]The large increase over 1989 is due to development problems with the SSC magnets, which required redesign.

KEY: DOC: Department of Commerce
DoD: Department of Defense
DOE: Department of Energy
DOI: Department of the Interior
DOT: Department of Transportation
NASA: National Aeronautics and Space Administration
NIST: National Institute of Standards and Technology
NSF: National Science Foundation

SOURCE: Compiled by the Office of Technology Assessment, 1990.

Table 4-4 gives a breakdown of where this HTS research was performed in fiscal year 1988. About 45 percent was performed in Federal laboratories, 30 percent in universities, and 25 percent in industry.[6] The wisdom of allocating more HTS R&D resources to Federal laboratories than to all of the Nation's universities is discussed in chapter 7.

Key Superconductivity Programs

Department of Defense (DoD)

The various defense agencies have had a long history of support for superconductivity. DoD began funding superconductivity research in the late 1940s, with the establishment of the Office of Naval Research at the end of World War 11.[7] Subsequently, the Air Force has supported research in sensors, airborne generators and signal processing, and the Navy in magnetic and electromagnetic/infrared (EM/IR) detectors and ship propulsion research, among other projects. Most of the defense agencies have supported some type of superconducting electronics research, and often were the only Federal agencies to do so. Nevertheless, most of the defense programs in LTS had been completed or scaled back before the discovery of HTS.[8]9 After the discovery of HTS, many new programs were initiated to explore its potential for defense applications. Table 4-5 highlights some ongoing programs within DoD.

The Defense Advanced Research Projects Agency (DARPA) program, which accounted for over 40 percent of DoD's HTS R&D in fiscal year 1989, deserves special mention because it is unique in focusing on HTS materials processing and prototype applications development.[10] DARPA supports some 40 contractor teams working on dual-use projects (i.e., those with civilian as well as military applications).

Department of Energy (DOE)

DOE sponsored many programs in LTS prior to the discovery of HTS (see ch. 3); DOE also sponsored LTS conductor development for particle accelerator magnets such as those at Fermilab, and

[6]This breakdown can be used to estimate how many full-time-equivalent researchers were conducting HTS research in these institutions in 1988. Dividing each agency's funding totals by its average funding per senior-level researcher yields an estimate of 430 researchers working full-time on HTS in Federal labs, and 220 full-time-equivalent researchers in universities (not including graduate students). See Technology Management Associates, *The Federal Sector Effort in Superconductivity*, contractor report prepared for the Office of Technology Assessment, Nov. 15, 1988, p. 29.

[7]Kenneth Flamm, "Government's Role in Computers and Superconductors," contractor report prepared for the Office of Technology Assessment, March 1988, pp. 43-47.

[8]Congressional Research Service contractor report for Congress, "Commercialization of Technology and Issues in the Competitiveness of Selected U.S. Industries: Semiconductors, Biotechnology, and Superconductors," 88-486 SPR, June 1988.

[9]One exception is the Strategic Defense Initiative Organization Superconducting Magnetic Energy Storage (SMES) program, designed to provide power to ground-based lasers for ballistic missile defense (see ch. 3). If this program proceeds on schedule to produce a prototype SMES system by 1994, it will comprise a significant fraction of the Department of Defense superconductivity budget in the early 1990s.

[10]For a description of the DARPA program, see Defense Advanced Research Projects Agency, *High-Temperature Superconductors*, a report on the DARPA High-Temperature Superconducting Ceramic (HTSC) Technology Program, February 1989.

Table 4-4-Performers of HTS Research-Summary by Agency (Fiscal Year 1988)

	HTS budget outlavs ($ millions)	Performed by		
		Federal lab	University	Industry
Department of Energy				
Energy research	15.3	12.2	3.1	0.0
Conservation and renewable energy	4.9	4.9	0.0	0.0
Fossil energy	0.3	0.3	0.0	0.0
Defense programs	7.2	7.2	0.0	0.0
Total	$27.7			
Department of Defense				
Air Force	7.0	2.0	4.5	0.5
Navy	9.0	3.9	3.0	2.1
Army	2.0	2.0	0.0	0.0
Strategic Defense Initiative Organization	12.0	3.0	1.0	8.0
Defense Advanced Research Projects Agency	18.0	2.5	2.5	13.0
Total	48.0			
Department of Commerce (National institute of Standards and Technology)				
institute of Materials Science and Engineering	1.0	1.0	0.0	0.0
National Engineering Laboratory	1.1	1.1	0.0	0.0
National Measurement Laboratory	0.7	0.7	0.0	0.0
Total	2.8			
National Aeronautics and Space Administration				
Office of Aeronautics and Space Technology	2.6	1.6	0.5	0.5
Commercialization	0.5	0.5	0.0	0.0
Total	3.1			
National Science Foundation	14.5	0.0	14.5	0.0
Department of the Interior	0.1	0.1	0.0	0.0
Department of Transportation	0.0	0.0	0.0	0.0
National Institutes of Health	0.0	0.0	0.0	0.0
Total HTS	96.2 (loo%)	43.0 (45%)	29.1 (30%)	24.1 (25%)

NOTE: These estimates were made before the more precise figures in table 4-3 became available, but are accurate to within 5 percent.

SOURCE: Technology Management Associates, "The Federal Effort in Superconductivity," contractor report prepared for the Office of Technology Assessment, Nov. 15, 1988, p. 27

more recently, the Superconducting Super Collider. See table 4-6 for a descnption of the more important DOE superconductivity programs.

Superconductivity Research Centers—Inaccordance with President Reagan's Superconductivity Initiative, DOE's Office of Basic Energy Sciences established three HTS Research Centers, at Argonne National Lab, Lawrence Berkeley Lab, and Ames Lab. A fourth center for electronics applications was established at NIST/Boulder. These Research Centers were assigned complementary missions for I-ITS: Argonne concentrates on bulk materials for wires and cables; Lawrence Berkeley focuses on theory and on fabrication of thin films for electronic devices; and Ames concentrates on basic materials research and has responsibility for gathering and disseminating information on HTS. These Research Centers have also formed research teams with other national laboratories; e.g., Argonne works with Ames and Brookhaven labs on bulk applications. The Argonne Center involves about 50 researchers, and has links to both the State of Illinois Institute for Superconductivity and the National Science Foundation Science & Technology Center (see below), making it one of the largest concentrations of HTS expertise in the world. The Research Centers continue to be supported by funds reprogrammed from other areas,

Superconductivity Pilot Centers—In September 1988, DOE's Office of Conservation and Renewable Energy announced the establishment of three Superconductivity Pilot Centers, at Argonne, Oak Ridge, and Los Alamos National Laboratories. The Pilot Centers are intended to bring the enormous expertise

Table 4-5-Department of Defense Superconductivity Programs

Agency	Estimated fiscal year 1989 funds ($ millions)	Comments
High-temperature:		
DARPA	25.0	43% of DoD HTS R&D. A unique program focusing on HTS materials processing. Most of the funding goes to small firms.
SDIO	14.1	24% of DoD HTS R&D. Highly applications-oriented; includes radar, radio frequency cavities, antennae, and shielding.
Navy	9.7	17% of DoD HTS R&D. Abroad-based R&D program, built around a 5-yearplan.
Air Force	7.0	12% of DoD HTS R&D. A broad-based R&D program including processing and characterization. Applications include sensors, communications.
Army	2.2	4% of DoD HTS R&D. A broad-based R&D program including processing, theory, and characterization. Applications include sensors and electromagnetic launchers.
Total HTS	58.0	
Low-temperature:		
DARPA	6[a]	R&D on compact synchrotrons for x-ray lithography.
SDIO	8.0	53% of DoD LTS R&D.
	(11.4[a])	Superconducting Magnetic Energy Storage engineering test model: design competition.
Navy	4.7	31% of DoD LTS R&D. Historically the main DoD LTS supporter,
Air Force	1	Includes superconducting airborne generator project.
Army	0	No LTS R&D.
NSA	1.3	Superconducting electronics.
Total LTS	15.0	
Total LTS & HTS	73.0	

[a]Not in budget total.

KEY: DARPA: Defense Advanced Research Projects Agency
DoD: Department of Defense
NSA: National Security Agency
SDIO: Strategic Defense Initiative Organization

SOURCE: Report compiled by the Federal Coordinating Committee on Science, Engineering, and Technology/Committee on Materials/Subcommittee on Superconductivity, "Federal Research Programs in Superconductivity," March 1989.

and unique facilities of these National Laboratories to bear on problems of interest to commercial industry. Funded at a level of $6 million in fiscal years 1989 and 1990,[11] the Pilot Centers are supporting joint research projects with industry—generally on a 50-50 basis. They differ from the Research Centers in that they are intended to develop stronger ties to industry, to provide a gateway to the other laboratories' programs in superconductivity, and to be a testing ground for new experiments in technology transfer.

In the past, U.S. companies have been reluctant to work with Federal laboratories, because of the enormous amount of red tape involved. The Pilot Centers are structured so as to avoid these problems, offering expedited contracting procedures, greater protection of intellectual property, easier access to patents, and exclusive licenses for jointly developed technologies. At this writing all three Pilot Centers have signed agreements with major U.S. companies involved in HTS research.

National Science Foundation (NSF)

In addition to its individual grant programs, NSF sponsors various collaborative superconductivity research efforts including: Materials Research Laboratories, Materials Research Groups, the Bitter National Magnet Laboratory, the Wisconsin and Cornell synchrotrons centers, and a new supercon-

[11]The Bush Administration has slated the Pilot Centers for an increase to $15 million in its FY 91 budget request.

Table 4-6---Department of Energy Superconductivity Programs

Programs	Estimated fiscal year 1989 funds ($ millions)	Comments
High-temperature: [a]		
Basic Energy Sciences	16.8	44% of total DOE HTS R&D. Focused on basic research; DOE's largest HTS program.
Energy Storage & Distribution	12.9	34% of total HTS R&D. Includes funding for Pilot Centers.
All other HTS R&D	8.8	Mostly defense programs.
Total HTS	38.5	
Low-temperature: [b]		
High Energy and Nuclear Physics	27.4	76% of DOE LTS R&D. Includes wire, magnet, and materials projects.
All other LTS R&D	8.7	Mostly fusion magnets.
Total LTS	36.1	
Total HTS & LTS	**74.6**	

[a]Not including Small Business Innovation Research grants (SBIRs)
[b]Not including procurements or SBIRs

SOURCE: Federal Coordinating Committee on Science, Engineering, and Technology/Committee on Materials/Subcommittee on Superconductivity, "Federal Research Programs in Superconductivity," March 1989.

ductivity Science and Technology Center at the University of Illinois (see table 4-7.)[12]

Although total NSF funding for HTS R&D has increased steadily, virtually all of these increases have gone to support research at large centers such as S&T Center at the University of Illinois. Funding for individual investigator grants appears to have remained static, despite an increasing number of outstanding research proposals. This situation is discussed further in chapter 7.

Department of Commerce

All of the Department of Commerce efforts in superconductivity take place within the National Institute of Standards and Technology (NIST). NIST (formerly the National Bureau of Standards) has provided U.S. superconductivity standards since 1969, and developed the standard volt based on an array of 19,000 LTS Josephson Junctions, among other projects. The main standards research is carried out at the Boulder, Colorado facility. Though modest in size, this program provides the crucial function of improving the quality of reported superconductivity data, enabling meaningful comparisons of data among different researchers and organizations. NIST has a small but well-regarded superconducting electronic devices program and was designated a Superconductivity Research Center for Electronic Applications in President Reagan's initiative. Table 4-8 provides a breakdown for the NIST superconductivity budget for 'fiscal year 1988 as well as totals for fiscal year 1989.[13]

Coordination Within Federal Agencies

Department of Defense (DoD)

The Department of Defense has devoted greater attention to coordination of its HTS programs than any other agency. The Defense Superconductivity Research and Development (DSRD) Working Group, chaired through the Office of the Secretary of Defense (OSD), is the formal DoD-wide coordinating committee. In 1987, the DSRD Working Group prepared a study of possible uses for HTS in military applications.[14] This study included approxirnations of the costs of research projects in each of the applications. According to the OSD, the report

[12]The objective of the S&T Centers is to take advantage of opportunities in science and technology that are too complex or too demanding of resources to be carried out by any one organization. They are structured to include a Federal laboratory and several industry partners, and are managed by a university. Besides the University of Illinois, the Superconductivity S&T Center also includes Northwestern University, the University of Chicago, and Argonne National Lab. It is to be funded at $24.5 million over 5 years. In fiscal year 1989, two new Materials Research Groups in superconductivity were begun at the Universities of Wisconsin and Minnesota at a total cost of about $900,000 per year.

[13]A breakdown was not available for fiscal year 1989 data.

[14]Department of Defense, DSRD Working Group, "Superconductivity Research and Development Options," July 1987.

Table 4-7-National Science Foundation Superconductivity Programs

Special programs	Estimated fiscal year 1989 funds ($ millions)	Comments
High-temperature:		
Individual grants	9	
Young Investigators program	1	Superconductivity R&D theory/experiment.
Science and Technology Center (STC)	4.3	Cooperative HTS R&D.
Materials Research Labs and Groups	5.4	MIT, Stanford, U. Illinois, Northwestern, U. Chicago, Harvard, Cornell, U. Minnesota, U. Wisconsin.
User facilities	3.5	Bitter National Magnet Lab, synchrotrons facilities.
Total HTS	23.2	
Low-temperature:		
Individual grants	2.3	
Materials Research Labs and Groups	0.2	
User facilities and instrumentation	0.5	
Total LTS	3.0	
Total LTS + HTS	**26.2**	

SOURCE: Willlam Oosterhuls, National Science foundation, personal communication, February 1990.

served its initial coordination function well and now needs updating.

The Navy, which has the largest superconductivity program of the three services, also has the most extensive coordination mechanisms.[15] A Naval Consortium for Superconductivity has been established to coordinate R&D efforts, and in 1989 the Navy developed a 5-year plan for superconductivity.[16]

Department of Energy (DOE)

The main DOE coordinating body for materials is the Energy and Materials Coordinating Committee; its Subcommittee on Superconductivity is charged with the internal coordination of superconductor R&D in DOE. At Ames Laboratory, the Center for Basic Scientific Information distributes a widely read biweekly newsletter, High-T_C Update, including a bibliography of the latest HTS preprints. The DOE National Laboratories have held a series of conferences broadcast nationally by satellite that have made the latest HTS results available to other researchers. At DOE's Office of Scientific and Technical Information, located in Oak Ridge, Tennessee, a computer database has been established to provide up-to-date technical information on superconductivity to U.S. industry. Called the 'Superconductivity Information System," it offers a bulletin board, electronic mail, a database of work in progress, a preprints database, a database of all DOE-sponsored research, and printed copy of database searches.

Coordination of HTS activities also takes place under the auspices of the Superconductivity Coordinating Committee on Electric Power. This group is made up of the Electric Power Research Institute, various electric utilities, and numerous Federal agencies, including DOE, NSF, and NIST.

National Aeronautics and Space Administration (NASA)

Internal coordination of both HTS and LTS research programs is provided through the NASA Superconductivity Working Group, chaired out of the Office of Aeronautics and Space Technology and the Information Sciences and Human Factors Division. Contacts with the larger industrial and scientific community are maintained through the Space Systems Technical Advisory Committee, a review team for HTS, with members from industry and universities as well as other governmental organiza-

[15] These include the Naval Research Advisory Council (a body of industry experts that reviews the overall Navy R&D program annually); an extensive workshop program through the Office of Naval Research (ONR) for potential contractors; and coordination with the Strategic Defense Initiative Organization and DARPA.

[16] The plan, called the ''Navy Superconductivity Program,'' was prepared by the Naval Consortium for Superconductivity, the Office of Naval Research, and the Office of Naval Technology, and released on May 15, 1989.

Table 4-8--National Institute of Standards and Technology Superconductivity Programs

Programs	Fiscal year 1988 funds[a] ($ millions)	Comments
High-temperature:		
Materials preparation	0.5	Includes phase diagrams.
Structure determination and characterization	0.7	Includes neutron scattering.
Property measurements	0.9	Includes standards and electronic structure measurements.
Fabrication and devices	0.7	Includes thin films and electronics.
Total HTS	2.8[a]	
Low-temperature:		
Total LTS	0.5	Includes JJs, SQUIDS, standard volt, and measurement standards.
Total HTS and LTS	**3.3**	

[a]There was a 1-year increase of $2 million for HTS in fiscal year 1989 (giving an overall total of $5.3 million for superconductivity), but a large part of these funds was spent to repair damage from a fire in a clean room used to fabricate superconducting electronics.
KEY JJ: Josephson Junction; SQUID: Superconducting Quantum interference Device
SOURCE: Federal Coordinating Committee on Science, Engineering, and Technology/Committee on Materials/Subcommittee on Superconductivity, "Federal Research Programs in Superconductivity," March 1989:

tions. NASA's Technology Utilization division is in the process of forming a NASA consortium (open to any U.S. entity) for research on superconductivity and technology transfer to the private sector. It will be located at the Jet Propulsion Laboratory in Pasadena California, and is expected to begin operations in 1990.

Coordination at the National Level

The Office of Science and Technology Policy (OSTP) has been the focus of efforts to coordinate Federal HTS programs. As noted above, OSTP had responsibility for the National Action Plan on Superconductivity R&D, released in December 1989.

Committee on Materials (COMAT)

One body under the auspices of OSTP, the Committee on Materials (COMAT), has played a valuable role.[17] COMAT was instituted to coordinate materials policy among the various Federal agencies, and all agencies with significant interests in materials R&D are represented. In 1988 and 1989, the Superconductivity Subcommittee of COMAT published a comprehensive review of all Federal agency programs and budgets for both HTS and LTS R&D.[18] It has also taken a leading role in defining options for future international collaboration in HTS.

COMAT has been viewed by the Administration as the preferred body for coordinating materials policy among all of the relevant agencies. Its actual function, though, is best described as information exchange, rather than active coordination, since it does not set an overall agenda for materials R&D, has no control over agency budgets, and does not monitor or guide individual agency programs. The need for national coordination going beyond the activities of COMAT is recognized in OSTP's Action Plan.[19]

National Critical Materials Council (NCMC)

NCMC, established in 1984,[20] is charged by Congress with responsibility for overseeing the formulation of policies for "advanced" and "critical' materials. It was intended by Congress to be an active oversight body for coordinating all Federal agencies on materials policy issues. The Reagan Administration saw NCMC as redundant with existing agencies-especially COMAT—and neglected it entirely.[21] During most of 1988 and 1989, the

[17]COMAT is formally under FCCSET (Federal Coordinating Committee on Science, Engineering and Technology), established in 1976 by the National Science and Technology Policy, Organization, and Priorities Act to facilitate coordination of science and technology policy.

[18]"Federal Research Programs in Superconductivity," op. cit., footnote 5.

[19]"The National Plan on Superconductivity Research and Development," op. cit., footnote 4, p. 3.

[20]The National Critical Materials Act of 1984, Public Law 98-373.

[21]U.S. Congress, Office of Technology Assessment, *Advanced Materials by Design: New Structural Materials Technologies,* OTA-E-351 (Washington, DC: U.S. Government Printing Office, June 1988), p. 307.

Council had no active members, although its staff assisted in the preparation of the Action Plan.[22]

Coordination Among State and Federal Agencies

Many States have seen opportunities in HTS for improving local economic competitiveness. Several provide funding (generally less than $1 million) for HTS research, most of which goes to the main State universities. Often, these funds are provided within the context of broader advanced technology programs; one example is the Ben Franklin Program in Pennsylvania, which now supports several superconductivity projects. A few States have developed new programs dedicated to HTS R&D. The largest State efforts in superconductivity are in Illinois, Texas, and New York (programs in several States are outlined in table 4-9). These generally involve some cost sharing with the Federal Government. For example, the Illinois efforts complement the Federal programs awarded over the past 2 years, including the NSF S&T Center at the University of Illinois and the DOE Pilot Center at Argonne National Laboratory.

Industry Consortia

In the 1980s, the R&D consortium has become one of the most popular technology policy tools in the United States aimed at regaining lost markets and exploring new technologies. The privately sponsored Microelectronics and Computer Technology Corporation (MCC) and the more recent industry/government-sponsored Sematech have been notable examples of this trend. Inevitably, a variety of consortia have also been proposed as a means of accelerating the commercialization of HTS by U.S. firms. Since the release of the Wise Men's' Report (see above), which recommended the establishment of four to six HTS consortia focusing on applications, the number of consortia either established or planned for HTS development has skyrocketed. A partial list is given in table 4-10.

Most of these consortia are directed toward development of HTS electronic devices, and virtually all seek Federal funding. This proliferation of HTS consortia-all working in similar R&D areas—raises concerns about whether the U.S. effort will be diluted in a hodgepodge of small consortia, each below "critical mass" in size, and whether Federal funds will be wasted on duplicative research. Critics of this situation point to Japan's International Superconductivity Technology Center, a single HTS R&D consortium involving all of the major superconductivity companies under the auspices of the Ministry of International Trade and Industry (see ch. 5).

In fact, there is a kind of informal coordination taking place among the U.S. consortia. Often, for instance, members of one consortium are on the planning board of another, and researchers associated with different constellations of labs have frequent opportunities to exchange information. Ultimately, market forces and the limitations of the Federal budget will sort out which consortia will survive and which will not, but there may be a Federal role in making this process more orderly, Options to address this question are taken up in chapter 7.

International Cooperation

Many laboratories around the world have capabilities in superconductivity research comparable to those in the United States, and past international collaborative programs in LTS such as the Large Coil Task (see ch. 3) have proven to be extremely valuable.[23] Other examples include: the annual U.S.-Japan Workshop on High-Field Superconductors, which met for the sixth time in 1989; the Versailles Agreement on Advanced Materials and Standards, which has an active program for international comparisons of measurements of critical currents and alternating current losses; and the International Electrochemical Commission, which has established a Technical Committee on Superconductivity to develop international standards.

U.S. superconductivity researchers have long had informal, one-to-one collaboration with their foreign colleagues. For instance, NSF has had a bilateral agreement with Japan in place for 28 years that promotes researcher-directed collaborations in basic science. In 1987, NSF initiated a new program that is jointly funded by the United States and Japan to

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[22]On Feb. 21, 1990, D. Allan Bromley, Director of OSTP, announced the appointment of three Council members, including himself as chairman.

[23]Negotiations are continuing on foreign participation in DOE's Superconducting Super Collider Program.

Table 4-0-State Government Support for Superconductivity

State	Description of program
California	The State Department of Commerce has a program of grant awards for technology transfer of university research to commercial entities, called the Competitive Technology Program. This program receives matching private sector funds. Superconductivity project awards total $1.8 million, for a superconductivity applications center, HTS high-frequency electronic devices, and SQUID development.
Florida	The State has established the Florida Initiative, a consortium composed of 7 State universities, involving 55 principal investigators. It receives funds from a pool of $25 million provided by DARPA to the State of Florida for microelectronics research. Of this $25 million, $6.4 million goes to superconductivity R&D. Florida has shown significant interest in magnetically levitated train technology. The potential Tampa-Orlando-Miami maglev train project has been canceled; however, a short maglev line from the Orlando airport to Disney World/EPCOT Center is still under discussion.
Illinois	Illinois is home to several large federally sponsored superconductivity programs, many at Argonne National Lab. The University of Illinois is the principal site of the new NSF Science and Technology Center for Superconductivity. Some State funds are used to leverage Federal and industrial funds at Argonne and the S&T Center, but most of the funding comes from the Federal Government.
Maryland	The University of Maryland (College Park) established a Center for Superconductivity Research intended eventually to have approximately 20 full-time researchers (six faculty members). State funding is $1 million for the first year (beginning July 1988); $2 million for the second year; and $3 million for the third. Collaboration with industry is expected; negotiations are underway with utilities (for wire fabrication research), and a chemical company (for materials characterization).
New Jersey	The New Jersey Science and Technology Commission's Governor's Roundtable issued a report recommending the development of a New Jersey superconductivity program, focused on high-field magnet fabrication. The Commission recommends a State funding level of $1-2 million per year to be matched at least one-to-one by non-State sources. The State has seed funding for a fellowship program in which college seniors and first year graduate students can work in academic and industrial labs on superconductivity research.
New York	The New York State Institute for Superconductivity (NYSIS) at SUNY Buffalo was established in June 1987. Its focus is on transferring HTS technology into practical applications. It is to have 27 faculty members and over 100 graduate students and postdocs. New York State funding is $10 million and this is expected to be leveraged by Federal funds. Of this, $5 million is to be used for lab equipment and construction; $2.2 million for awards for external researchers; and $2.2 million for researchers within the Center. At this writing, 31 awards have been made, totaling $1.4 million; 16 of these have gone to SUNY Buffalo researchers, and 15 to other New York universities and businesses.
Texas	Of the several consortia located in Texas, most receive no State funding. The Microelectronics and Computer Corporation (MCC) entered into a joint superconductivity research program with the Texas Center for Superconductivity at the University of Houston (TCSUH) in 1988. TCSUH is funded at a level of $30 million over 3 years, receiving $6.5 million from the State of Texas and other funding from DARPA and Du Pont.

KEY: DARPA=Defense Advanced Research Projects Agency; MCC.Microelectroncs and Computer Corp.; NYSIS=New York State Institute on Superconductivity; SQUID= Superconducting Quantum Interference Device; SUNY. State University of New York; TCSUH=Texas Center for Superconductivity at the University of Houston

SOURCE: Office of Technology Assessment, 1990

get more U.S. researchers into Japanese laboratories.[24] Through this program, Japanese laboratories formerly closed to foreign researchers are now actively seeking foreign scientists. So far, though, this program is undersubscribed by U.S. researchers.[25]

The discovery of HTS has stimulated several international efforts to explore the potential for this technology. Examples include a series of international meetings on electric power applications of superconductivity held by the International Energy Agency,[26] and specific mention of HTS in the United States-Japan Agreement on Cooperation in Science and Technology. At this writing, several joint superconductivity projects were being negotiated under the Agreement.

Such international programs are likely to become even more important in the future. Yet Federal agency budgets to support these activities are static

[24]This program consists of three parts: the Science and Technology Agency fellowships for long-term (6 to 15 months) postdoctoral visits to Japanese government labs in which 20 spaces are reserved for National Science Foundation-chosen researchers; a similar agreement with the Ministry of Education for 20 fellowships in Japanese university labs; and a blanket $4.8 million grant from Japan to NSF for general support for the program, including initial survey visits and language training. This money could also be used to send U.S. researchers to Japanese industrial labs.

[25]Shahid S. Siddiqui, "Too Few Foreign Scientists in Japan," *Nature*, vol. 340, No. 6232, Aug. 3, 1989, p. 337.

[26]U.S. liaison is through the Department of Energy's Office of Conservation and Renewable Energy

Table 4-10--A Partial List of HTS Consortia

Consortium type	Major partners	Comments
Industrial:		
MCC Austin, TX	Bellcore, Boeing, DEC, Du Pont, Motorola, 3M, Westinghouse.	Merged in 1988 with the Texas Center for Superconductivity at the University of Houston (TCSUH, see below).
SuperChip Washington, DC	Tektronix, others to be announced.	Under the auspices of the Council on Superconductivity for American Competitiveness (CSAC); has sought $1 billion in loan guarantees from the Federal Government; has received seed money from DARPA.
Superconductor Applications, Inc. Princeton, NJ	To be announced.	To be based at David Sarnoff Laboratory under the direction of Stanford Research Institute; has received seed money from DARPA.
University-based:		
Consortium for Superconducting Electronics Cambridge, MA	AT&T, IBM, Lincoln Labs, MIT.	Most closely resembles the model proposed by the "Wise Men"; seeking up to $5 million from DARPA.
TCSUH Houston, TX	Du Pont, plus joint membership of MCC partners.	Formed in 1987 with $2.5 million from State of Texas; received $4 million from DARPA in 1988.
NSF S&T Center Urbana, IL	University of Illinois, Northwestern University, University of Chicago, Argonne National Lab.	Funded by NSF at a rate of $24.5 million over 5 years.
Lehigh University Consortium for Superconducting Ceramics Bethlehem, PA	AT&T Bell Labs, BOC Group, U.S. Navy.	12 full-time researchers.
NY State Institute on Superconductivity Buffalo, NY	SUNY Buffalo plus partners to be announced.	Initial funding of $10 million from the State of New York; expected to be supplemented with Federal funding.
National lab-based:		
Argonne Argonne, IL	Beldon Wire, Du Pont, GE, MagneTek, United Technologies.	Location of DOE Pilot Center ($2 million funding); HTS funding lab-wide is $10-12 million.
Los Alamos Los Alamos, NM	American Superconductor, AMP, Hewlett Packard, Du Pent, Rockwell.	Location of DOE Pilot Center ($2 million funding); HTS funding lab-wide is$11 million.
Oak Ridge Oak Ridge, TN	Corning Glass, Du Pent, FMC, IBM, GE, Westinghouse.	Location of DOE Pilot Center ($2 million funding); HTS funding is $6 million.
Jet Propulsion Lab Pasadena, CA	To be announced.	Under the auspices of NASA; expected to begin operations in 1990.

KEY: CSAC=Council on Superconductivity for American Competitiveness; DARPA=Defense Advanced Research Projects Agency; DOE= Department of Energy; MCC=Microelectronics and Computer Corp.; NASA=National Aeronautics and Space Administration; NSF= National Science Foundation; SUNY= State University of New York; TCSUH=Texas Center for Superconductivity and the Unversity of Houston.

SOURCE: Office of Technology Assessment, 1990.

or declining. This issue is discussed further in chapter 7.

CONCLUSIONS

The Federal response to the discovery of HTS illustrates many of the strengths and weaknesses of U.S. R&D policy as it relates to U.S. industrial competitiveness. On the whole, the response has been both substantial and timely. By fiscal year 1989, 2 years after the breakthrough, the Federal budget for HTS had grown to nearly $130 million—about the same as the budget for all other advanced ceramics R&D combined.

The Administration can point to some significant successes and even innovations. The mission agencies moved quickly to redeploy resources and researchers to HTS. The DARPA program emphasizing HTS processing is unique. The DOE Pilot Centers are experimenting with expedited mechanisms for contracting with industry and for disposition of intellectual property, and they have received positive initial reviews from prospective industry collaborators. Mechanisms for rapid exchange of technical information among researchers have been established and appear to be working well.

The Administration's approach also contains much that is familiar to critics of Federal R&D policy. DoD allocates the largest budget, and has become the principal supporter of U.S. industry programs. Much of the Federal budget goes to support research in Federal laboratories, which heretofore have not had a good track record in transferring technology to U.S. industry. And although coordination of HTS R&D programs within the mission agencies is strong, coordination at the national level is weak. Congress attempts to address this problem with legislation have met with little success.

The Federal response to the advent of HTS is perhaps best characterized as an attempt to broaden the R&D activities of the relevant agencies to address industry needs without fundamentally changing their missions or their relationships to one another. Those who had hoped that the worldwide race to develop HTS might stimulate a serious debate about a new Federal role in meeting the challenge of foreign competition in commercial technologies have clearly been disappointed.

Is the present Federal response adequate to ensure future U.S. competitiveness in HTS? This question is taken up in chapter 7, following an examination of foreign HTS programs in the next chapter, and those of private industry in chapter 6.