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OFFICE OF CABINET AFFAIRS STAFFING MEMORANDUM

Date: 4-15-91

Due by: Fly I

Subject: OMB Circulation; H. Science Subcommittee on Technology
Subcommittee Markup on Amer. Technology
 From: Holly Williamson Preemice Act

	ACTION	CONCUR	FYI		ACTION	CONCUR	FYI
HOLIDAY	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	FITZHENRY ^{see p. 50-52}	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
DANZANSKY	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	MCMUNN	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ADAIR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	PORTER	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
BUCHHOLZ	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	SCHALL	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
CASSE ^{see p. 50-52}	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	SECHLER	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
EVANS	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	WETHINGTON	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
FARRAR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	WILLIAMSON	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
GUNN	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
HEIMBACH	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
JACKSON	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments:

Fly I.

file: Science + Technology (S&T)



EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

APR 12 1991

LEGISLATIVE REFERRAL MEMORANDUM

LRM #M-155

TO: Legislative Liaison Officer:

COMMERCE - Michael A. Levitt - 377-3151 - 324
CEA - Francine Obermiller - 395-5036 - 242
STATE - Will Davis - 647-4463 - 225
TRANSPORTATION - Tom Herlihy - 366-4687 - 226
EDUCATION - John Kristy - 401-2670 - 207
OPM - James N. Woodruff - 606-1424 - 331
OSTP - Damar Hawkins - 456-6272 - 288
USTR - David Weiss - 395-3475 - 223
TREASURY - Richard S. Carro - 566-8523 - 228
JUSTICE - Paul McNulty - 514-2061 - 217
ENERGY - Bob Rabben - 586-6718 - 209
DEFENSE - Samuel T. Brick, Jr. - 697-1305 - 325
COMPET. COUNCIL - - 456-6614 -
NCLIS - Jane Williams - 254-3100 - 278
NASA - Martin P. Kress - 453-1948 - 219
NSF - Charles H. Herz - 357-9435 - 248
GSA - Lonnie P. Taylor - 501-0563 - 237
AGRICULTURE - Marvin Shapiro - 382-1272 - 312
HHS - Frances White - 245-7760 - 328
EPA - Thomas C. Roberts - 382-5414 - 326

SUBJECT: H. SCIENCE SUBCOMMITTEE ON TECHNOLOGY
Subcommittee Markup on American Technology
Preeminence Act of 1991

The subcommittee markup and 3 amendments that were adopted are attached. The Department of Commerce is preparing a views letter on this bill for submission to the full Science Committee. It will be circulated for comment shortly.

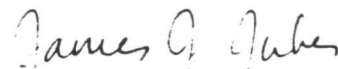
DEADLINE: Thursday APR 18 1991

The Office of Management and Budget requests the views of your agency on the above subject before advising on its relationship to the program of the President, in accordance with OMB Circular A-19.

Please advise us if this item will affect direct spending or receipts for purposes of the "Pay-As-You-Go" provisions of Title XIII of the Omnibus Budget Reconciliation Act of 1990.

Questions should be referred to **Constance BOWERS (395-3457)**, the legislative analyst/attorney for this item.

You may respond to this request for views by: (1) faxing us the attached response sheet; (2) if the response is simple (e.g., concur/no comment), leaving a message with the secretary of the above-named analyst/attorney; (3) calling the analyst/attorney; or (4) sending us a memo or letter.



JAMES J. JUKES (for)
Assistant Director for
Legislative Reference

CC:

David Gold

Nancy Schwartz

Ken Kelly

Al Hubbard

Holly Williamson

Rob Chess

Boyden Gray

Bob Damus

Ken Schwartz

Norine Noonan

Greg Henry

Bill Coleman

Bob Ridout

Bruce McConnell

Tom Dorsey

Joe Hezir

Cora Beebe

Rob Fairweather

AMERICAN TECHNOLOGY PREEMINENCE ACT OF 1991

Background and Summary

The Subcommittee on Technology and Competitiveness will mark up an updated version of the American Technology Preeminence Act of 1990, which was introduced by Members of the Science, Space, and Technology Committee during the 101st Congress after a series of over twenty hearings related to the status of U.S. technological competitiveness in the world marketplace. The updated version of the bill authorizes appropriations for the Department of Commerce's Technology Administration programs totaling \$347,500 for FY 1992, and includes funding for the Office of the Under Secretary for Technology, the National Institute of Standards and Technology, the Advanced Technology Program, and the National Technical Information Service (NTIS). The draft bill also authorizes funding levels for fiscal year 1991 totaling \$289,728.

For fiscal year 1992, the Administration has proposed \$5 million for the Office of the Under Secretary for Technology, which represents an \$800,000 increase over FY 1991 appropriated funds; 0 funding for the National Technical Information Service; and \$248 million for the National Institute of Standards and Technology, compared to \$215 million in FY 1991, which includes \$201.8 million for the traditional intramural laboratory research programs and \$46.2 million for the extramural outreach programs mandated in the Trade Bill to help U.S. industry to become more competitive. Of the \$46.2 million, the Advanced Technology Program has been frozen at the FY 1991 level of \$35.9 million, the State Technology Extension Program, funded at \$1.3 million in FY 1991, has been phased out, and the Manufacturing Technology Centers, funded at \$11.9 million in FY 1991, has been decreased to \$10.3 million. Other decreases totaling, \$750,000, include -\$600,000 for the building and fire research centers, and -\$150,000 to phase out the non-energy-related inventions program.

For fiscal year 1992, the Subcommittee draft bill proposes \$9 million for the Office of the Under Secretary for Technology, which includes \$1.5 for the Japanese Technical Literature Program, \$1 million for the Clearinghouse on State and Local Initiatives, \$1.5 million for the National Technical Information Service to carry out its modernization plan, and \$6 million for the Office of the Under Secretary. For fiscal year 1991, \$6.5 million is proposed.

For the National Institute of Standards and Technology, the Subcommittee draft bill for fiscal year 1991 includes \$166.2 million for the intramural programs and \$117 million for the extramural programs, including \$100 million for the Advanced Technology Program. For fiscal year 1992, \$211 million is proposed for the intramural programs and \$127.5 million for the extramural programs, including \$100 million for the Advanced Technology Program. This reflects the concern of various Committee Members that NIST has been grossly underfunded over the years, given its major responsibilities for support of this Country's industrial base. During the 1980s, NIST programs have been frozen more often than not without adjustments for inflation, and in terms of real purchasing power they have shrunk significantly. NIST's metrology research provides the measurement base American business needs

to manufacture the quality products now required to compete in the world marketplace. It also reflects the Administration's decision that NIST's long-term budget should double by 1996. NIST'S own budget proposal to the Department of Commerce recommended \$436.5 million for NIST, including \$110 million for the Advanced Technology Program.

The American Technology Preeminence Act also establishes a Presidential Commission on Reducing Capital Costs for Emerging Technology to recommend legislative changes to lower the cost of capital in developing technologies; a Commission on Research, Development Technology Utilization and Government Procurement Policy to recommend changes in government purchasing law; establishes a High Resolution Information Systems Board to increase the cooperation of Government and industry in high resolution information systems; strengthens the biennial OSTP report which identifies critical civilian technologies which will be important to the U.S. economy during the ten years following the report; and authorizes a number of studies to address technology policy issues. Recommended language and technical changes have also been made to the bill to conform it to present public law.

COMPETITIVENESS BILL SUMMARY
AMERICAN TECHNOLOGY PREEMINENCE ACT OF 1991

Title I.

This title authorizes each of the programs of the Technology Administration. For the activities of the Office of the Under Secretary For Technology, \$6.5 million is authorized for FY 1991, which includes \$1.3 million for the Office of the Under Secretary, \$2.7 million for Technology Policy, \$1.0 million for Japanese Technical Literature, \$1.0 million for the Clearinghouse on State and Local Initiatives and \$500,000 for the modernization of the National Technical Information Service. For FY 1992, \$9.0 million is authorized which includes, \$1.6 million for the Office of the Under Secretary, \$3.4 million for Technology Policy, \$1.5 million for Japanese Technical Literature, \$1.0 million for the Clearinghouse on State and Local Initiatives, and \$1.5 million is provided for the modernization of the National Technical Information Service. For the National Institute of Standards and Technology (NIST), the authorization levels for the intramural scientific and technical research and services activities are \$166.2 million for FY 1991 and \$211 million for FY 1992, and for the extramural industrial technology services program, \$117 million for FY 1991 and \$127.5 million for FY 1992, which includes \$15 million in FY 1991 and \$25 million in FY 1992 for Regional Centers for the Transfer of Manufacturing Technology with the assumption that new centers will be started each of the two fiscal years; \$2 million in FY 1991 and \$2.5 million in FY 1992 is provided for the State Technology Extension Program; and \$100 million is authorized for each of the 1991 and 1992 fiscal years for the Advanced Technology Program. This title also provides start-up matching finds for a program to place U.S. standards experts in developing nations to make sure that those nation's standards codes permit the marketing of U.S.-designed products. The fire research and building technology programs are combined for administrative purposes only, with separate budget accounts to be maintained, and a report on the results of the combination is required. A provision authorizing NIST and the Federal Aviation Administration to undertake a joint research program to develop an all-fire resistant aircraft cabin interior has been added. The NIST Organic Act is amended to provide NIST with authority to manage its scientific and technical fellowship programs and to recruit and employ highly qualified foreign nationals who have advanced degrees from U.S. universities and have filed to become U.S. citizens. The National Advisory Commission on Semiconductors is extended through FY 1992.

- Title II.** *This title is cited as the "Emerging Technologies and Advanced Technology Program Amendments Act of 1991 and provides statutory language for assistance to solve generic technology and manufacturing problems in emerging technology fields including high resolution information systems and advanced materials research and development, but specific spending levels are not designated for specific technologies. Conditions under which a company can participate in the Advanced Technology Program are set out. A comprehensive report is required 4 years after enactment of the law of the activities of the Advanced Technology Program.*
- Title III.** *This title makes the funding for the Federal Laboratory Consortium permanent, extends federal patent law to the legislative branch, and authorizes appropriated funds to carry out administrative responsibilities under the Malcolm Baldrige Quality Improvement Act.*
- Title IV.** *A Presidential Commission on Reducing Capital Costs for Emerging Technology is established to develop legislative recommendations to increase the competitiveness of U.S. industry by encouraging investment in quality, product and process improvements, and new product development and marketing. A report to the President and the Congress is required one year after enactment of the Act.*
- Title V.** *This title establishes a High Resolution Information Systems Board within the Office of Science and Technology Policy to increase the cooperation of Government and industry in high resolution information systems. This title strengthens the biennial OSTP report which identifies critical civilian technologies which will be important to the U.S. economy during ten years following the report. It also requires reports on quality, on competitive research, on international standards, and on coordination of high resolution information system purchases by the Government. A Commission on Research, Development, Technology Utilization, and Government Procurement Policy, which will make recommendations on how to change governmental purchasing law and procedures to ensure that emerging technologies are encouraged through these purchases, is established. This title also requires the Department of Commerce to study the feasibility of creating a Federal On-line Information Product Catalog to be an authoritative register of governmental information products and services disseminated by the Federal government and to assist agencies and the public in locating Federal government information. The National Academies are asked to undertake a review of U.S. activities related to testing and certification of products made for export.*
- Title VI.** *This title requires NIST to implement a voluntary accreditation program to be used in the evaluation and*

detection of lead in paint films, soil and dust, and to establish performance criteria and standards for lead paint encapsulants and strippers within 2 years of enactment of this Act.

H. Science S/c on Technology ^{ELC}
4/10/91 Markey

102D CONGRESS
1ST SESSION

H. R. _____

IN THE HOUSE OF REPRESENTATIVES

Mr. VALENTINE introduced the following bill; which was referred to the Committee on _____

A BILL

To enhance the position of United States industry through application of the results of Federal research and development, and for other purposes.

1 Be it enacted by the Senate and House of Representatives
2 of the United States of America in Congress assembled,

4/10/91 H. Science Subcommittee on
2 Technology Markup

1 SECTION 1. SHORT TITLE.

2 This Act may be cited as the "American Technology
3 Preeminence Act of 1991".

4 TITLE I--DEPARTMENT OF COMMERCE RESEARCH AND TECHNOLOGY

5 SEC. 101. SHORT TITLE.

6 This title may be cited as the "Technology
7 Administration Authorization Act of 1991".

8 SEC. 102. STATEMENT OF POLICY.

9 Congress finds that in order to help United States
10 industries to speed the development of new products and
11 processes so as to maintain the economic competitiveness of
12 the Nation, it is necessary to strengthen the programs and
13 activities of the Department of Commerce's Technology
14 Administration and National Institute of Standards and
15 Technology.

16 SEC. 103. TECHNOLOGY ADMINISTRATION.

17 (a) FISCAL YEAR 1991.--There are authorized to be
18 appropriated to the Secretary of Commerce (hereafter in this
19 Act referred to as the "Secretary"), to carry out the
20 activities of the Under Secretary for Technology (hereafter
21 in this Act referred to as the "Under Secretary") and the
22 Assistant Secretary for Technology Policy, \$6,500,000 for
23 fiscal year 1991, which shall be available for the following
24 line items:

1 (1) Office of the Under Secretary, \$1,300,000.

2 (2) Technology Policy, \$2,700,000.

3 (3) Japanese Technical Literature, \$1,000,000.

4 (4) Clearinghouse on State and Local Initiatives on
5 Productivity, Technology, and Innovation, \$1,000,000.

6 (5) National Technical Information Service, \$500,000
7 to carry out the modernization plan described in section
8 212(f)(3)(D) of the National Technical Information Act of
9 1988 (15 U.S.C. 3704b(f)(3)(D)).

10 (b) FISCAL YEAR 1992.--There are authorized to be
11 appropriated to the Secretary, to carry out the activities of
12 the Under Secretary and the Assistant Secretary for
13 Technology Policy, \$9,000,000 for fiscal year 1992, which
14 shall be available for the following line items:

15 (1) Office of the Under Secretary, \$1,600,000.

16 (2) Technology Policy, \$3,400,000.

17 (3) Japanese Technical Literature, \$1,500,000.

18 (4) Clearinghouse on State and Local Initiatives on
19 Productivity, Technology, and Innovation, \$1,000,000.

20 (5) National Technical Information Service,
21 \$1,500,000 to carry out the modernization plan described
22 in section 212(f)(3)(D) of the National Technical
23 Information Act of 1988 (15 U.S.C. 3704b(f)(3)(D)).

24 (c) OPERATING COSTS.--Operating costs for the National
25 Technical Information Service associated with the

1 acquisition, processing, storage, bibliographic control, and
2 archiving of information and documents shall be recovered
3 primarily through the collection of fees.

4 (d) REPORT AND CERTIFICATION TO CONGRESS.--within 90 days
5 after the date of enactment of this Act, the Secretary of
6 Commerce shall submit to Congress a report which--

7 (1) describes the Department of Commerce's response
8 to the Inspector General's Report No. ATD-024-0-001;

9 (2) includes a revised detailed modernization plan
10 for the National Technical Information Service;

11 (3) contains a business plan for the National
12 Technical Information Service which includes detailed
13 profit and loss analysis for groups of products and
14 services and for major market segments; and

15 (4) certifies that the National Technical Information
16 Service has--

17 (A) employed a chief financial officer who is a
18 certified public accountant with experience in the
19 dissemination of scientific and technical
20 information; and

21 (B) begun taking reasonable steps toward
22 strengthening its accounting system in response to
23 the Inspector General's report described in paragraph
24 (1).

25 (e) TECHNICAL AMENDMENT.--Section 5422(a) of the Omnibus

1 Trade and Competitiveness Act of 1988 (15 U.S.C. 4603a(a))
2 and section 273(c)(4) of the National Defense Authorization
3 Act for Fiscal Years 1988 and 1989 (15 U.S.C. 4603(c)(4)) are
4 each amended by striking ``Economic Affairs`` and inserting
5 in lieu thereof ``Technology``.

6 SEC. 104. NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY.

7 (a) FISCAL YEAR 1991.--(1) There are authorized to be
8 appropriated to the Secretary, to carry out the intramural
9 scientific and technical research and services activities of
10 the National Institute of Standards and Technology (hereafter
11 in this Act referred to as the ``Institute``), \$166,228,000
12 for fiscal year 1991, which shall be available for the
13 following line items:

- 14 (A) Electronics and Electrical Measurements,
15 \$21,273,000.
- 16 (B) Manufacturing Engineering, \$8,266,000.
- 17 (C) Chemical Science and Technology, \$18,617,000.
- 18 (D) Physics, \$25,522,000.
- 19 (E) Materials Science and Engineering, \$26,495,000.
- 20 (F) Building and Fire Research, \$9,821,000.
- 21 (G) Computer Systems, \$11,819,000.
- 22 (H) Applied Mathematics and Scientific Computing,
23 \$5,847,000.
- 24 (I) Technology Assistance, \$8,978,000.
- 25 (J) Research Support Activities, \$29,590,000.

1 (2)(A) Of the total of the amounts authorized under
2 paragraph (1), \$2,000,000 are authorized only for steel
3 technology.

4 (B) Of the amount authorized under paragraph (1)(I)--

5 (i) \$150,000 are authorized only for the evaluation
6 of nonenergy-related inventions and related technology
7 extension activities;

8 (ii) \$250,000 are authorized only for Institute
9 participation in the pilot program established under
10 subsection (e); and

11 (iii) \$1,700,000 are authorized only for the
12 Institute's management of the extramural funding programs
13 authorized under section 105.

14 (C) Of the total amount authorized under paragraph
15 (1)(J), \$7,223,000 are authorized only for the technical
16 competence fund.

17 (b) FISCAL YEAR 1992.--(1) There are authorized to be
18 appropriated to the Secretary, to carry out the intramural
19 scientific and technical research and services activities of
20 the Institute, \$211,000,000 for fiscal year 1992, which shall
21 be available for the following line items:

22 (A) Electronics and Electrical Measurements,
23 \$34,000,000.

24 (B) Manufacturing Engineering, \$13,500,000.

25 (C) Chemical Science and Technology, \$22,000,000.

1 (D) Physics, \$27,000,000.

2 (E) Materials Science and Engineering, \$30,000,000.

3 (F) Building and Fire Research, \$12,300,000.

4 (G) Computer Systems, \$16,000,000.

5 (H) Applied Mathematics and Scientific Computing,
6 \$6,500,000.

7 (I) Technology Assistance, \$11,000,000.

8 (J) Research Support Activities, \$38,700,000.

9 (2)(A) Of the total of the amounts authorized under
10 paragraph (1), \$2,000,000 are authorized only for steel
11 technology.

12 (B) Of the amount authorized under paragraph (1)(I)--

13 (i) \$500,000 are authorized only for the evaluation
14 of nonenergy-related inventions and related technology
15 extension activities;

16 (ii) \$250,000 are authorized only for Institute
17 participation in the pilot program established under
18 subsection (e); and

19 (iii) \$2,700,000 are authorized only for the
20 Institute's management of the extramural funding programs
21 authorized under section 105.

22 (C) Of the total amount authorized under paragraph
23 (1)(J), \$7,565,000 are authorized only for the technical
24 competence fund.

25 (c) TRANSFERS.--(1) Funds may be transferred among the

1 line items listed in subsection (a)(1) and among the line
2 items listed in subsection (b)(1), so long as the net funds
3 transferred to or from any line item do not exceed 10 percent
4 of the amount authorized for that line item in such
5 subsection and the Committee on Commerce, Science, and
6 Transportation of the Senate and the Committee on Science,
7 Space, and Technology of the House of Representatives are
8 notified in advance of any such transfer.

9 (2) The Secretary may propose transfers to or from any
10 line item listed in subsection (a)(1) or subsection (b)(1)
11 exceeding 10 percent of the amount authorized for such line
12 item, but such proposed transfer may not be made unless--

13 (A) a full and complete explanation of any such
14 proposed transfer and the reason therefor are transmitted
15 in writing to the Speaker of the House of
16 Representatives, the President of the Senate, and the
17 appropriate authorizing Committees of the House of
18 Representatives and the Senate, and

19 (B) 30 calendar days have passed following the
20 transmission of such written explanation.

21 (d) RELATION TO OTHER AUTHORIZATIONS.--Except for
22 authorizations provided in the Omnibus Trade and
23 Competitiveness Act of 1988 (Public Law 100-418; 102 Stat.
24 1448) and the Steel and Aluminum Energy Conservation and
25 Technology Competitiveness Act of 1988 (15 U.S.C. 5101 et

1 seq.), this Act contains the complete authorizations of
2 appropriations for the Institute for fiscal year 1992.

3 (e) PILOT PROGRAM.--Pursuant to the authorizations
4 contained in subsections (a)(1)(I) and (b)(1)(I), the
5 Secretary is authorized to pay the Federal share of the cost
6 of establishing and carrying out a pilot program under
7 section 112 of the National Institute of Standards and
8 Technology Authorization Act for Fiscal Year 1989 (15 U.S.C.
9 272 note). The purpose of the pilot program is to assist a
10 country or countries that have requested assistance from the
11 United States in the development of comprehensive industrial
12 standards by providing the continuous presence of United
13 States personnel on-site for a period of 2 or more years to
14 provide such assistance and by providing, as necessary,
15 additional technical support from within the Institute. Such
16 funds may be obligated for such purpose only to the extent of
17 matching funds from sources outside the Federal Government.

18 (f) CONSTRUCTION OF FACILITIES.--Section 14 of the
19 National Institute of Standards and Technology Act (15 U.S.C.
20 278d) is amended by striking ``herein:`` and all that
21 follows, and inserting in lieu thereof ``herein``.

22 (g) FIRE AND BUILDING PROGRAMS.--The fire research and
23 building technology programs of the Institute shall be
24 combined for administrative purposes only, and separate
25 budget accounts for fire research and building technology

1 shall be maintained. No later than December 31, 1991, the
2 Secretary, acting through the Director of the Institute,
3 shall report to Congress on the results of the combination,
4 on efforts to preserve the integrity of the fire research and
5 building technology programs, on the long-range basic and
6 applied research plans of the two programs, on procedures for
7 receiving advice on fire and earthquake research priorities
8 from constituencies concerned with public safety, and on the
9 relation between the combined program at the Institute and
10 the United States Fire Administration.

11 (h) AIRCRAFT FIRE RESEARCH.--(1) The Secretary, acting
12 through the Director of the Institute, and the Administrator
13 of the Federal Aviation Administration shall jointly prepare
14 a plan for a research program to develop the fire technology
15 and materials necessary for the development of an all fire
16 resistant aircraft cabin interior. Such plan shall include
17 funding requirements, a brief description of the necessary
18 research projects, and a schedule for completion of each such
19 research project, and shall be submitted to the Congress
20 within 1 year after the date of enactment of this Act.

21 (2) Subject to the availability of appropriations, the
22 Secretary, acting through the Director of the Institute, and
23 the Administrator of the Federal Aviation Administration
24 shall jointly carry out the research program described in the
25 plan prepared under paragraph (1).

1 (1) EDUCATIONAL PROGRAMS.--(1) Section 18 of the National
2 Institute of Standards and Technology Act (15 U.S.C. 278g-1))
3 is amended by striking the period at the end of the first
4 sentence and inserting in lieu thereof `` , and to United
5 States citizens for research and technical activities on
6 Institute programs.``.

7 (2) Section 17 of the National Institute of Standards and
8 Technology Act (15 U.S.C. 278g) is amended by adding at the
9 end the following new subsection:

10 ``(d) For any scientific and engineering disciplines for
11 which there is a shortage of suitably qualified and available
12 United States citizens and nationals, the Secretary is
13 authorized to recruit and employ in scientific and
14 engineering fields at the Institute foreign nationals who
15 have been lawfully admitted to the United States for
16 permanent residence under the Immigration and Nationality Act
17 and who intend to become United States citizens. Employment
18 of a person under this paragraph shall not be subject to the
19 provisions of title 5, United States Code, governing
20 employment in the competitive service, or to any prohibition
21 in any other Act against the employment of aliens, or against
22 the payment of compensation to them.``.

23 SEC. 105. EXTRAMURAL PROGRAMS OF THE INSTITUTE.

24 (a) FISCAL YEAR 1991.--In addition to any sums otherwise
25 authorized under this Act, there are authorized to be

1 appropriated to the Secretary, to carry out the extramural
2 industrial technology services programs of the Institute
3 created under sections 25, 26, and 28 of the National
4 Institute of Standards and Technology Act (15 U.S.C. 278k,
5 2781, and 278n), \$117,000,000 for fiscal year 1991, which
6 shall be available for the following line items:

7 (1) Regional Centers for the Transfer of
8 Manufacturing Technology, \$15,000,000.

9 (2) State Technology Extension Program (carried out
10 under section 5121(d) of the Omnibus Trade and
11 Competitiveness Act of 1988), \$2,000,000.

12 (3) Advanced Technology Program, \$100,000,000.

13 (b) FISCAL YEAR 1992.--In addition to any sums otherwise
14 authorized under this Act, there are authorized to be
15 appropriated to the Secretary, to carry out the extramural
16 industrial technology services programs of the Institute
17 created under sections 25, 26, and 28 of the National
18 Institute of Standards and Technology Act (15 U.S.C. 278k,
19 2781, and 278n), \$127,500,000 for fiscal year 1992, which
20 shall be available for the following line items:

21 (1) Regional Centers for the Transfer of
22 Manufacturing Technology, \$25,000,000.

23 (2) State Technology Extension Program, \$2,500,000.

24 (3) Advanced Technology Program, \$100,000,000.

25 (c) LIMITATION.--No funds are authorized under this

1 section for any project under the extramural programs of the
2 Institute which have not been competitively reviewed through
3 the merit review processes required by the National Institute
4 of Standards and Technology Act (15 U.S.C. 271 et seq.).

5 (d) AMENDMENTS TO EXTENSION PROGRAM.--Section 5121(b) of
6 the Omnibus Trade and Competitiveness Act of 1988 (15 U.S.C.
7 2781 note) is amended by striking paragraph (5).

8 (e) ADVISORY COMMITTEE.--Section 5142(f) of the Omnibus
9 Trade and Competitiveness Act of 1988 (15 U.S.C 4632(f)) is
10 amended by striking ``and 1990`` and inserting in lieu
11 thereof ``1990, 1991, and 1992``.

12 **SEC. 106. SALARY ADJUSTMENTS.**

13 In addition to any sums otherwise authorized by this Act,
14 there are authorized to be appropriated to the Secretary for
15 fiscal years 1991 and 1992 such additional sums as may be
16 necessary to make any adjustments in salary, pay, retirement,
17 and other employee benefits which may be provided for by law.

18 **SEC. 107. AVAILABILITY OF APPROPRIATIONS.**

19 Appropriations made under the authority provided in this
20 Act shall remain available for obligation, for expenditure,
21 or for obligation and expenditure for periods specified in
22 the Acts making such appropriations.

23 **SEC. 108. BUY-AMERICAN PROVISIONS.**

24 (a) RESTRICTIONS ON CONTRACT AWARDS.--No contract or
25 subcontract made with funds authorized under this title may

1 be awarded for the procurement of an article, material, or
2 supply produced or manufactured in a foreign country whose
3 government unfairly maintains in government procurement a
4 significant and persistent pattern or practice of
5 discrimination against United States products or services
6 which results in identifiable harms to United States
7 businesses, as identified by the President pursuant to
8 subsection (g)(1)(A) of section 305 of the Trade Agreements
9 Act of 1979 (19 U.S.C. 2515(g)(1)(A)). Any such determination
10 shall be made in accordance with such section 305.

11 (b) PROHIBITION AGAINST FRAUDULENT USE OF "MADE IN
12 AMERICA" LABELS.--If it has been finally determined by a
13 court or a Federal agency that any person intentionally
14 affixed a label bearing a "Made in America" inscription, or
15 an inscription with the same meaning, to any product sold in
16 or shipped to the United States that is not made in the
17 United States, that person shall be ineligible to receive any
18 contract or subcontract from the Department of Commerce,
19 pursuant to the debarment, suspension, and ineligibility
20 procedures in subpart 9.4 of chapter 1 of title 48, Code of
21 Federal Regulations.

22 (c) BUY-AMERICAN REQUIREMENT.--(1) The Secretary is
23 authorized to award to a domestic firm a contract for the
24 purchase of goods that, under the use of competitive
25 procedures, would be awarded to a foreign firm, if--

1 (A) the final product of the domestic firm will be
2 completely assembled in the United States;

3 (B) when completely assembled, more than 50 percent
4 of the final product of the domestic firm will be
5 domestically produced; and

6 (C) the difference between the bids submitted by the
7 foreign and domestic firms is not more than 6 percent.

8 (2) This subsection shall not apply to the extent to
9 which--

10 (A) in the opinion of the Secretary, after taking
11 into consideration international obligations and trade
12 relations, such applicability would not be in the public
13 interest;

14 (B) in the opinion of the Secretary, after
15 consultation with the Secretary of Defense, compelling
16 national security considerations require otherwise; or

17 (C) the President determines that such an award would
18 be in violation of the General Agreement on Tariffs and
19 Trade or an international agreement to which the United
20 States is a party.

21 (3) This subsection shall apply only to contracts made
22 for which--

23 (A) amounts are authorized by this title to be made
24 available; and

25 (B) solicitations for bids are issued after the date

1 of enactment of this Act.

2 (4) The Secretary, before January 1, 1993, shall report
3 to the Congress on contracts covered under this subsection--

4 (A) entered into with foreign firms pursuant to a
5 determination made under paragraph (2) of this
6 subsection; and

7 (B) awarded to domestic firms pursuant to paragraph
8 (1) of this subsection, in fiscal years 1991 and 1992.

9 (5) For purposes of this subsection--

10 (A) the term ``domestic firm'' means a business
11 entity that is incorporated in the United States and that
12 conducts business operations in the United States; and

13 (B) the term ``foreign firm'' means a business entity
14 not described in subparagraph (A).

15 TITLE II--ADVANCED TECHNOLOGY PROGRAM AMENDMENTS

16 SEC. 201. EMERGING TECHNOLOGIES RESEARCH AND DEVELOPMENT.

17 (a) SHORT TITLE.--This title may be cited as the
18 ``Emerging Technologies and Advanced Technology Program
19 Amendments Act of 1991''.

20 (b) FINDINGS AND PURPOSES--(1) The Congress finds that--

21 (A) technological innovation and its profitable
22 inclusion in commercial products are critical components
23 of the ability of the United States to raise the living
24 standards of Americans and to compete in world markets;

25 (B) maintaining viable United States-based high

1 technology industries is vital to both the national
2 security and the economic well-being of the United
3 States;

4 (C) the Department of Commerce has reported that the
5 United States is losing or losing badly, relative to
6 Japan and Europe, in many important emerging technologies
7 and risks losing much of the \$350 billion United States
8 market and \$1 trillion world market expected to develop
9 by the year 2000 for products based on emerging
10 technologies;

11 (D) it is in the national interest for the Federal
12 Government to encourage and, in selected cases, provide
13 limited financial assistance to industry-led private
14 sector efforts to increase research and development in
15 economically critical areas of technology;

16 (E) joint ventures are a particularly effective and
17 appropriate way to pool resources to conduct research
18 that no single company is likely to undertake but which
19 will create new generic technologies that will benefit an
20 entire industry and the welfare of the Nation;

21 (F) it is vital that industry within the United
22 States attains a leadership role and capability in
23 development, design, and manufacturing in fields such as
24 high-resolution information systems, advanced
25 manufacturing, and advanced materials; and

1 (G) the Advanced Technology Program, established
2 under section 28 of the National Institute of Standards
3 and Technology Act (15 U.S.C. 278n), is the appropriate
4 vehicle for the United States Government to provide
5 limited assistance to joint development within the United
6 States of new high technology capabilities in fields such
7 as high-resolution information systems, advanced
8 manufacturing technology, and advanced materials, and can
9 help encourage United States industry to work together on
10 problems of mutual concern.

11 (2) The purposes of this section are--

12 (A) to strengthen the Advanced Technology Program
13 created under section 28 of the National Institute of
14 Standards and Technology Act (15 U.S.C. 278n), and to
15 provide improved guidelines for the allocation of
16 Advanced Technology Program funds appropriated under the
17 authorizations contained in section 105 of this Act;

18 (B) to promote and assist in the development of
19 advanced technologies and the generic application of such
20 technologies to civilian products, processes, and
21 services;

22 (C) to improve the competitive position of United
23 States industry by supporting industry-led research and
24 development projects in areas of emerging technology
25 which have substantial potential to advance the economic

1 well-being and national security of the United States,
2 such as high-resolution information systems, advanced
3 manufacturing technology, and advanced materials; and

4 (D) to support projects that range from idea
5 exploration to prototype development and address long-
6 term, high-risk areas of technological research,
7 development, and application that are not otherwise being
8 adequately developed by the private sector, but are
9 likely to yield important benefits to the Nation.

10 (c) ADVANCED TECHNOLOGY PROGRAM.--Section 28 of the
11 National Institute of Standards and Technology Act (15 U.S.C.
12 278n) is amended--

13 (1) in subsection (b)(1)(B), by inserting ``through
14 grants, cooperative agreements, or contracts`` after
15 ``such joint ventures``;

16 (2) in subsection (b)(2), by inserting ``provide
17 grants to and`` before ``enter into contracts``;

18 (3) by amending subsection (d)(2) to read as follows:

19 ``(2) In the case of joint ventures, the Program
20 shall not make an award unless the award will facilitate
21 the formation of a joint venture or the initiation of a
22 new research and development project by an existing joint
23 venture.``;

24 (4) in subsection (d)(3), by striking ``cooperative
25 agreement`` both places it appears and inserting in lieu

1 thereof ``award``;

2 (5) by amending subsection (d)(7) to read as follows:

3 ``(7) Each agreement with any business or joint
4 venture that receives an award under this section shall
5 specify a test, as mutually agreed to by the Secretary
6 and the recipient, for determining whether the venture or
7 project shall be deemed to have been a commercial success
8 and providing that in such event there will be
9 appropriate recoupment to the Federal Government. Such
10 recoupment shall not exceed the principal amount, with
11 reasonable interest, of any monetary awards provided to
12 such recipient under the Program. The Secretary shall
13 issue regulations establishing guidelines for agreement
14 provisions stating the circumstances under which a
15 venture or project will be found to be a commercial
16 success and the general procedures and terms for
17 recoupment in such cases.``;

18 (6) by adding at the end of subsection (d) the
19 following new paragraphs:

20 ``(10) A company shall be eligible to receive
21 financial assistance under this section only if--

22 ``(A) the Secretary finds that the company's
23 participation in the Program would be in the economic
24 interest of the United States, as evidenced by
25 investments in the United States in research,

1 development, and manufacturing (including, for
2 example, the manufacture of major components or
3 subassemblies in the United States); significant
4 contributions to employment in the United States; and
5 agreement with respect to any technology arising from
6 assistance provided under this section to promote the
7 manufacture within the United States of products
8 resulting from that technology (taking into account
9 the goals of promoting the competitiveness of United
10 States industry), and to procure parts and materials
11 from competitive suppliers; and

12 `` (B) either--

13 `` (i) the company is a United States-owned
14 company; or

15 `` (ii) the Secretary finds that the company
16 has a parent company which is incorporated in a
17 country which affords to United States-owned
18 companies opportunities, comparable to those
19 afforded to any other company, to participate in
20 any joint venture similar to those authorized
21 under this Act; affords to United States-owned
22 companies local investment opportunities
23 comparable to those afforded to any other
24 company; and affords adequate and effective
25 protection for the intellectual property rights

1 of United States-owned companies.

2 “(11) Grants, contracts, and cooperative agreements
3 under this section shall be designed to support projects
4 which are high risk and which have the potential for
5 eventual substantial widespread commercial application.
6 In order to receive a grant, contract, or cooperative
7 agreement under this section, a research and development
8 entity shall demonstrate to the Secretary the requisite
9 ability in research and technology development and
10 management in the project area in which the grant,
11 contract, or cooperative agreement is being sought.

12 “(12)(A) Title to any intellectual property arising
13 from assistance provided under this section shall vest in
14 a company or companies incorporated in the United States.
15 The United States may reserve a nonexclusive,
16 nontransferable, irrevocable paid-up license, to have
17 practiced for or on behalf of the United States, in
18 connection with any such intellectual property, but shall
19 not, in the exercise of such license, publicly disclose
20 proprietary information related to the license. Title to
21 any such intellectual property shall not be transferred
22 or passed, except to a company incorporated in the United
23 States, until the expiration of the first patent obtained
24 in connection with such intellectual property.

25 “(B) For purposes of this paragraph, the term

1 `intellectual property` means an invention patentable
2 under title 35, United States Code, or any patent on such
3 an invention.

4 ``(C) Nothing in this paragraph shall be construed to
5 prohibit the licensing to any company of intellectual
6 property rights arising from assistance provided under
7 this section.'';

8 (7) by amending subsection (e) to read the follows:

9 ``(e) The Secretary may, 30 days after notice to
10 Congress, suspend a company or joint venture from receiving
11 continued assistance under this section if the Secretary
12 determines that the company, the country of incorporation of
13 the company or a parent company, or the joint venture has
14 failed to satisfy any of the criteria set forth in subsection
15 (d)(10), and that it is in the national interest of the
16 United States to do so.''; and

17 (8) by inserting after subsection (e) the following
18 new subsections:

19 ``(f) When reviewing private sector requests for
20 Department of Commerce assistance to proposed joint ventures,
21 and when monitoring the progress of assisted joint ventures,
22 the Secretary shall, as appropriate, coordinate with the
23 Secretary of Defense and other senior Federal officials to
24 ensure cooperation and coordination in Federal technology
25 programs and to avoid unnecessary duplication of effort. The

1 Secretary is authorized to work with the Secretary of Defense
2 and other appropriate Federal officials to form interagency
3 working groups or special project offices to coordinate
4 Federal technology activities.

5 (g) In order to analyze the need for and value of joint
6 ventures in specific technical fields, to evaluate any joint
7 ventures requesting the Secretary's assistance, or to monitor
8 the progress of any joint venture which receives Federal
9 funds pursuant to the authorizations contained in this
10 section, the Secretary, the Under Secretary, and the Director
11 may organize and seek advice from such industry advisory
12 committees as they consider useful and appropriate.

13 (h) Up to 10 percent of the funds appropriated for
14 carrying out this section may be used for standards
15 development and technical activities by the Institute in
16 support of the purposes of this section.

17 (i) As used in this section--

18 (1) the term 'high-resolution information systems'
19 means equipment and techniques required to create,
20 transmit, receive, display, process, record, store,
21 recover, and play back high resolution images and
22 accompanying sound;

23 (2) the term 'advanced manufacturing technology'
24 means numerically-controlled machine tools, robots,
25 automated process control equipment, computerized

1 flexible manufacturing systems, associated computer
2 software, and other technology for improving
3 manufacturing and industrial processes;

4 `` (3) the term `advanced materials' means a field of
5 research including the study of composites, ceramics,
6 metals, polymers, superconducting materials, materials
7 produced through biotechnology, and materials production
8 technologies, including coated systems, that provide the
9 potential for significant advantages over existing
10 materials;

11 `` (4) the term `joint venture' means any group of
12 activities, including attempting to make, making, or
13 performing a contract, by two or more persons for the
14 purpose of--

15 `` (A) theoretical analysis, experimentation, or
16 systematic study of phenomena or observable facts;

17 `` (B) the development or testing of basic
18 engineering techniques;

19 `` (C) the extension of investigative finding or
20 theory of a scientific or technical nature into
21 practical application for experimental and
22 demonstration purposes, including the experimental
23 production and testing of models, prototypes,
24 equipment, materials, and processes;

25 `` (D) the collection, exchange, and analysis of

1 research information;

2 `` (E) the production of any product, process, or
3 service; or

4 `` (F) any combination of the purposes specified
5 in subparagraphs (A), (B), (C), (D), and (E),
6 and may include the establishment and operation of
7 facilities for the conducting of research, the conducting
8 of such venture on a protected and proprietary basis, and
9 the prosecuting of applications for patents and the
10 granting of licenses for the results of such venture;

11 `` (5) the term `United States-owned company' means a
12 company that has majority ownership or control by
13 individuals who are citizens of the United States; and

14 `` (6) the term `foreign-owned company' means a
15 company other than a United States-owned company.'`.

16 (d) EFFECTIVE DATE.--The amendments in subsection (c)
17 shall take effect immediately upon enactment; however, the
18 amendments shall not apply to applications submitted in
19 response to the Federal Register Invitation for Proposals
20 dated July 24, 1990, or awards or other assistance granted
21 pursuant to that notice.

22 (e) MANAGEMENT COSTS.--Section 2 of the National
23 Institute of Standards and Technology Act (15 U.S.C. 272) is
24 amended by adding at the end thereof the following new
25 subsection--

1 under subparagraph (A), for any fiscal year, only if the
2 amount so transferred by that agency (as determined under
3 such subparagraph) would exceed \$10,000.''.
4

5 (b) Section 11(e)(8) of the Stevenson-Wydler Technology
6 Innovation Act of 1980 (15 U.S.C. 3710(e)(8)) is repealed.

7 **SEC. 302. COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENTS.**

8 (a) Section 12(d)(i) of the Stevenson-Wydler Technology
9 Innovation Act of 1980 (15 U.S.C. 3710a(d)(1)) is amended by
10 inserting ``intellectual property,`` after ``equipment,``
11 both places it appears.

12 (b) Within 6 months after the date of enactment of this
13 Act, the Secretary shall report to the Congress on the
14 advisability of authorizing a new form of cooperative
15 research and development agreement which would permit Federal
16 contributions of funds.

17 **SEC. 303. DEFINITION OF FEDERAL AGENCY.**

18 Section 4(8) of the Stevenson-Wydler Technology
19 Innovation Act of 1980 (15 U.S.C. 3703(8)) is amended by
20 inserting `` , as well as any agency of the legislative branch
21 of the Federal Government`` after ``of such title``.

22 **SEC. 304. QUALITY IMPROVEMENT.**

23 The Secretary is authorized to use appropriated funds to
24 cover the cost of the Malcolm Baldrige National Quality Award
25 program to the extent such funds are needed in addition to
the funds specified under section 17(f) of the Stevenson-

1 Wydler Technology Innovation Act of 1980 (15 U.S.C.
2 3711a(f)).

3 SEC. 305. UNDER SECRETARY.

4 Section 5(c) of the Stevenson-Wydler Technology
5 Innovation Act of 1980 (15 U.S.C. 3704(c) is amended--

6 (1) by redesignating paragraphs (13) and (14) as
7 paragraphs (14) and (15), respectively; and

8 (2) by inserting after paragraph (12) the following
9 new paragraph:

10 `` (13) serve as a focal point for discussions among
11 United States companies on topics of interest to industry
12 and labor, including discussions regarding manufacturing
13 and discussions regarding emerging technologies; ``.

14 TITLE IV--NATIONAL COMMISSION ON REDUCING CAPITAL COSTS FOR
15 EMERGING TECHNOLOGY

16 SEC. 401. NATIONAL COMMISSION ON REDUCING CAPITAL COSTS FOR
17 EMERGING TECHNOLOGY.

18 (a) ESTABLISHMENT AND PURPOSE.--There is established a
19 National Commission on Reducing Capital Costs for Emerging
20 Technology (hereafter in this section referred to as the
21 ``Commission``), for the purpose of developing
22 recommendations to increase the competitiveness of United
23 States industry by encouraging investments in research, the
24 development of new process and product technologies, and the
25 production of those technologies.

1 (b) ISSUES.--The function of the Commission shall be to
2 address the following issues:

3 (1) How has the overall cost of capital paid by
4 United States companies differed during the past decade
5 from that paid by companies in other industrial economies
6 such as Germany, Japan, and the United Kingdom?

7 (2) To what extent has the cost of capital faced by
8 technology companies differed from the overall cost of
9 capital in each of these nations during the same period?

10 (3) To what extent do high capital costs in general
11 inhibit investment in projects with long-term payoffs,
12 such as the development and commercialization of new
13 technology?

14 (4) To what extent does the structure of the
15 financial services industry in the United States affect
16 the flow of capital to advanced technology investment,
17 and to what extent do current practices in the equity
18 markets raise the cost of capital and inhibit the
19 availability of capital to fund research and development,
20 purchase advanced manufacturing equipment, and fund other
21 investments necessary to commercialize advanced
22 technology?

23 (5) In what ways do Government regulations influence
24 the cost of capital in the United States?

25 (6) To what extent have national differences in

1 capital costs facilitated the foreign acquisition of
2 technology-based United States companies?

3 (7) What macroeconomic and other policies would
4 promote greater investment in advanced manufacturing
5 techniques, in research and development, and in other
6 activities necessary to commercialize and produce new
7 technologies?

8 (8) What specific policies should the Federal
9 Government follow in order to reduce the cost of capital
10 for United States companies to levels that are near
11 parity with those faced by the Nation's principal trading
12 partners?

13 (c) MEMBERSHIP.--(1) The Commission shall be composed of
14 9 members who are eminent in such fields as advanced
15 technology, manufacturing, finance, and international
16 economics and who are appointed as follows:

17 (A) 3 individuals appointed by the President, one of
18 whom shall be the Vice President and shall chair the
19 Commission.

20 (B) 3 individuals appointed by the Speaker of the
21 House of Representatives, 1 of whom shall be appointed
22 upon the recommendation of the minority leader of the
23 House of Representatives.

24 (C) 3 individuals appointed by the President pro
25 tempore of the Senate, 2 of whom shall be appointed upon

1 the recommendation of the majority leader of the Senate
2 and 1 of whom shall be appointed upon the recommendation
3 of the minority leader of the Senate.

4 (2) Each member shall be appointed for the life of the
5 Commission. A vacancy in the Commission shall be filled in
6 the manner in which the original appointment was made.

7 (d) PROCEDURES.--(1) The chairman shall call the first
8 meeting of the Commission within 90 days after the date of
9 enactment of this Act.

10 (2) Recommendations of the Commissions shall require the
11 approval of three-quarters of the members of the Commission.

12 (3) The Commission may use such personnel detailed from
13 Federal agencies as may be necessary to enable it to carry
14 out its duties.

15 (4) Members of the Commission, other than full-time
16 employees of the Federal Government, while attending meetings
17 of the Commission while away from their homes or regular
18 places of business, shall be allowed travel expenses in
19 accordance with subchapter I of chapter 57 of title 5, United
20 States Code.

21 (e) REPORTS.--The Commission shall, within 1 year after
22 the date of enactment of this Act, submit to the President
23 and Congress a report containing legislative and other
24 recommendations with respect to the issues addressed under
25 subsection (b).

1 (f) CONSULTATION.--The Commission shall consult, as
2 appropriate, with the Commission on Technology and
3 Procurement established by section 504 of this Act.

4 (g) TERMINATION.--The Commission shall terminate 6 months
5 after the submission of its report under subsection (e).

6 (h) AUTHORIZATION OF APPROPRIATIONS.--There are
7 authorized to be appropriated to carry out this section such
8 sums as may be necessary for the fiscal years 1991 and 1992.

9 TITLE V--STUDIES AND REPORTS

10 SEC. 501. HIGH-RESOLUTION INFORMATION SYSTEMS ADVISORY BOARD.

11 (a) ESTABLISHMENT AND PURPOSE.--The Director of the
12 Office of Science and Technology Policy shall establish
13 within that office a High-Resolution Information Systems
14 Advisory Board (hereafter in this section referred to the
15 ``Board``) to monitor and, as appropriate, foster the
16 development of United States-based high-resolution
17 information systems industries.

18 (b) DEFINITION.--As used in this title, the term ``high-
19 resolution information systems`` means the equipment and
20 techniques required to create, store, recover, and play back
21 high-resolution images and accompanying sound.

22 (c) FUNCTIONS.--The Board shall--

23 (1) collect and analyze information on the range of
24 factors which will determine whether United States-based
25 high-resolution information systems industries will

1 develop and become competitive, including such factors as
2 technology policies, specialized financial problems,
3 international standards and foreign trade practices,
4 Federal regulations and procurement policies, and
5 licensing practices;

6 (2) identify areas where appropriate cooperation
7 between the Federal Government and the private sector,
8 including Government support for industry-led joint
9 research and development ventures, would enhance United
10 States industrial competitiveness in this area, and
11 provide advice and guidance for such cooperative efforts;

12 (3) provide guidance on what Federal policies and
13 practices, particularly in such areas as procurement and
14 the transfer of federally-funded research, are necessary
15 to help establish United States-based high-resolution
16 information systems industries;

17 (4) provide advice on the coordination of Federal
18 defense and civilian activities to maximize and assist
19 with the transfer of technologies in the field of high-
20 resolution information systems into commercial products;
21 and

22 (5) generally develop recommendations for guiding
23 Federal agency activities related to the development of
24 United States-based high-resolution information systems
25 industries.

1 (d) MEMBERSHIP AND PROCEDURES.--(1)(A) The Board shall be
2 composed of 13 members, 7 of whom shall constitute a quorum.

3 (B) The Director of the Office of Science and Technology
4 Policy, the Secretary, the Director of the Defense Advanced
5 Research Projects Agency, and the Administrator of the
6 National Aeronautics and Space Administration, or their
7 designees, shall serve as members of the Board.

8 (C) The President, acting through the Director of the
9 Office of Science and Technology Policy, within 90 days after
10 the date of enactment of this Act, shall appoint as
11 additional members of the Board--

12 (i) 5 members from the private electronics
13 manufacturing sector, drawn from such sectors as
14 semiconductors, display equipment, computers, consumer
15 electronics, and telecommunications, with 1 member also
16 representing labor;

17 (ii) 3 members from the private nonmanufacturing
18 sector, including 1 representative from the transmission
19 delivery systems sector and 2 representatives drawn from
20 such areas as the software industry, the entertainment
21 industry, and the investment community; and

22 (iii) 1 member from academia.

23 At least 1 member appointed under this subparagraph shall be
24 from small business.

25 (2) The Director of the Office of Science and Technology

1 Policy or the Director's designee shall chair the Board.

2 (3) The chairman shall call the first meeting of the
3 Board within 30 days after the appointment of members is
4 completed.

5 (4) The Board may use such personnel detailed from
6 Federal agencies as may be necessary to enable it to perform
7 its functions.

8 (5) Members of the Board, other than full-time employees
9 of the Federal Government, while attending meetings of the
10 Board or otherwise performing duties of the Board while away
11 from their homes or regular places of business, shall be
12 allowed travel expenses in accordance with subchapter I of
13 chapter 57 of title 5, United States Code.

14 (6) The Board shall submit to the President and Congress
15 a report of its activities once every year after its
16 establishment.

17 (e) AUTHORIZATION OF APPROPRIATIONS.--There are
18 authorized to be appropriated to carry out this section such
19 sums as may be necessary for the fiscal years 1991 and 1992.
20 SEC. 502. MAJOR SCIENCE AND TECHNOLOGY PROPOSALS.

21 (a) REPORT.--The National Science and Technology Policy,
22 Organization, and Priorities Act of 1976 is amended by adding
23 at the end of title II the following new section:

24 MAJOR SCIENCE AND TECHNOLOGY PROPOSALS

25 SEC. 209. The Director shall monitor and report

1 annually to Congress on each major science and technology
2 project in which more than one country is participating and
3 which has a total estimated cost greater than
4 \$1,000,000,000.''. .

5 **SEC. 503. BIENNIAL NATIONAL CRITICAL TECHNOLOGIES REPORT**
6 **AMENDMENTS.**

7 Section 603 of the National Science and Technology
8 Policy, Organization, and Priorities Act of 1976 (42 U.S.C.
9 6683) is amended--

10 (1) in subsection (a), by inserting `` , but shall
11 include the most economically important emerging civilian
12 technologies during the 10-year period following such
13 report, together with the estimated current and future
14 size of domestic and international markets for products
15 derived from these technologies'' after ``may not exceed
16 30'';

17 (2) in subsection (b), by striking ``national
18 security and'' and inserting in lieu thereof ``national
19 security or'';

20 (3) by redesignating subsection (d) as subsection
21 (e); and

22 (4) by inserting after subsection (c) the following
23 new subsection:

24 ``(d) Each such report shall include--

25 ``(1) an identification of the types of research and

1 development needed to close any significant gaps or
2 deficiencies in the technology base of the United States,
3 as compared with the technology bases of major trading
4 partners; and

5 `` (2) a list of the technologies and markets targeted
6 by major trading partners for development or capture.``.

7 SEC. 504. RESEARCH, DEVELOPMENT, TECHNOLOGY UTILIZATION, AND
8 GOVERNMENT PROCUREMENT POLICY.

9 (a) ESTABLISHMENT OF COMMISSION.--The Secretary, in
10 consultation with the Administrator of the Office of Federal
11 Procurement Policy, shall establish a Commission on
12 Technology and Procurement (hereafter in this section
13 referred to as the ``Commission``), for the purposes of
14 analyzing the effect of Federal Government procurement laws,
15 procedures, and policies on the development of advanced
16 technologies within the United States and making
17 recommendations on how Federal policy could be changed to
18 promote further the development of advanced technologies.

19 (b) ISSUES.--The Commission shall address the following
20 issues:

21 (1) To what extent, if any, should Federal Government
22 technology purchase strategies be used to give domestic
23 suppliers a competitive advantage in new generations of
24 existing technologies and in initial market penetration
25 for new technologies?

1 (2) Under what conditions can Federal Government
2 purchases of advanced technology-based products be based
3 on performance specifications rather than on product
4 specifications? Should Federal Government procurement
5 first look to the commercial markets for products that
6 will meet performance specifications before purchasing a
7 unique product that has to be developed?

8 (3) How can the Federal Government procurement laws,
9 practices, and procedures be used as a strategic tool to
10 foster the use of emerging technologies?

11 (4) How can the Federal Government ensure that its
12 suppliers adopt the principles embodied in the Malcolm
13 Baldrige National Quality Award?

14 (5) Should Federal Government procurement practices
15 include cooperative efforts between the supplier and the
16 Federal entity to develop products so as to be more
17 easily marketed on a commercial basis? Should a program
18 for the exchange of technical personnel to foster
19 innovation in product development be part of such
20 practices?

21 (6) To what extent, if any, should Federal Government
22 documents specify standards that are beneficial to
23 domestic suppliers, aid the compatibility of advanced
24 technologies, and speed the commercial acceptance of
25 those technologies, and what would be the role of the

1 Institute in such an effort?

2 (7) To what extent should worldwide, state of the art
3 technology be required in Federal Government procurement?

4 (c) MEMBERSHIP AND PROCEDURES.--(1) The Commission shall
5 be composed of 15 members, 8 of whom shall constitute a
6 quorum.

7 (2) The Secretary, the Administrator of the Office of
8 Federal Procurement Policy, the Director of the Office of
9 Science and Technology Policy, the Secretary of Defense, and
10 the Administrator of General Services, or their designees who
11 serve in executive level positions, shall serve as members of
12 the Commission.

13 (3) The Secretary shall appoint as members of the
14 Commission, from among individuals not employed by the
15 Federal Government--

16 (A) 4 members who are eminent in advanced technology
17 businesses representing manufacturing and services
18 industries, including at least 1 member representing
19 labor;

20 (B) 3 members who are eminent in the fields of
21 technology and international economic development; and

22 (C) with the concurrence of the Administrator of the
23 Office of Federal Procurement Policy, 3 members who are
24 eminent in the field of Federal Government procurement.

25 (4) The Secretary shall appoint a Commission chairman

1 from among the members of the Commission. The chairman shall
2 call the first meeting of the Commission within 90 days after
3 the date of enactment of this Act.

4 (5) The Secretary and the Administrator of the Office of
5 Federal Procurement Policy shall provide such staff as may be
6 required by the Commission to carry out its responsibilities.

7 (6) Members of the Commission, other than full-time
8 employees of the Federal Government, while attending meetings
9 of the Commission or otherwise performing duties of the
10 Commission while away from their homes or regular places of
11 business, shall be allowed travel expenses in accordance with
12 subchapter I of chapter 57 of the title 5, United States
13 Code.

14 (d) REPORTS. (1) The Commission shall, within 1 year after
15 the date of enactment of this Act, submit to the Secretary,
16 the Administrator of the Office of Federal Procurement
17 Policy, the President, and Congress a report containing
18 preliminary recommendations with respect to the issues
19 addressed under subsection (b).

20 (2) The Commission shall, within 2 years after the date
21 of enactment of this Act, submit to the Secretary and
22 Congress a final report containing final recommendations with
23 respect to the issues addressed under subsection (b).

24 (e) CONSULTATION.--The Commission shall consult, as
25 appropriate, with the National Commission on Reducing Capital

1 Costs for Emerging Technology.

2 (f) TERMINATION.--The Commission shall terminate 6 months
3 after the submission of its final report under subsection
4 (d)(2).

5 (g) AUTHORIZATION OF APPROPRIATIONS.--There are
6 authorized to be appropriated to carry out this section such
7 sums as may be necessary for the fiscal years 1991, and 1992,
8 and 1993.

9 SEC. 505. REPORT ON INFORMATION COLLECTION AND DISSEMINATION.

10 (a) REPORT.--Within 270 days after the date of enactment
11 of this Act, the Secretary shall report to the Committee on
12 Science, Space, and Technology of the House of
13 Representatives and the Committee on Commerce, Science, and
14 Transportation of the Senate on the feasibility of
15 establishing and operating a Federal Online Information
16 Product Catalog (FEDLINE) at the National Technical
17 Information Service which would serve as a comprehensive
18 inventory and authorizative register of information products
19 and services disseminated by the Federal Government and
20 assist agencies and the public in locating Federal Government
21 information. Information protected from public disclosure
22 shall not be included. In studying the concept, the
23 Secretary, acting through the Under Secretary and the
24 Director of the National Technical Information Service, shall
25 consult with officials from appropriate Government agencies,

1 including the Office of Management and Budget, the National
2 Archives, the Government Printing Office, and the Institute,
3 and with representatives of the public, for their views on
4 the optimal composition and format of FEDLINE. Such report
5 shall contain cost estimates and possible funding sources for
6 establishing and operating FEDLINE and shall list any changes
7 in law and regulation that would be required if FEDLINE were
8 to be implemented.

9 (b) FUNDING.--The Director of the National Technical
10 Information Service may retain and use all monies received,
11 including receipts, revenues, and advanced payments and
12 deposits, to fund obligations and expenses through the end of
13 fiscal year 1992.

14 (c) ELECTRONIC FORMAT.--Section 212(e)(5) of the National
15 Technical Information Act of 1988 (15 U.S.C. 3704b(e)(5)) is
16 amended by inserting `` , including producing and
17 disseminating information products in electronic format ``
18 after ``engineering information``.

19 **SEC. 506. REPORT ON ADVANCED MANUFACTURING AND QUALITY.**

20 Within 1 year after the date of enactment of this Act,
21 the Secretary shall submit to Congress a report on the
22 feasibility and advisability of establishing, in affiliation
23 with the Institute, a Quality Institute and a privately-
24 funded foundation to support that Quality Institute. As part
25 of such report, the Secretary shall consider whether it is

1 feasible and advisable for such Quality Institute to--

2 (1) conduct workshops and company tours to share with
3 managers, engineers, and production employees in the
4 United States advanced techniques for improving
5 manufacturing and service organization, quality, and
6 productivity, including team-oriented organizational
7 approaches to managing production and service technology
8 and corporate research and development;

9 (2) help develop and disseminate model curricula on
10 quality which might be used by educational institutions
11 to provide training to students and manufacturing and
12 service company employees; and

13 (3) carry out such other purposes as the Secretary
14 may recommend.

15 SEC. 507. FUNCTIONS OF COUNCIL.

16 (a) INTERAGENCY RESEARCH PLANS.--Section 102(a)(6) of the
17 National Science and Technology Policy, Organization, and
18 Priorities Act of 1976 (42 U.S.C. 6602(a)(6)) is amended to
19 read as follows:

20 `` (6) The development and implementation of long-
21 range, interagency research plans to support policy
22 decisions regarding identified national and international
23 concerns, and for which a sustained and coordinated
24 commitment to improving scientific understanding or
25 technology will be required.``.

1 (b) COUNCIL.--Section 401 of the National Science and
2 Technology Policy, Organization, and Priorities Act of 1976
3 (42 U.S.C. 6651) is amended to read as follows:

4 MEMBERSHIP AND FUNCTIONS OF COUNCIL

5 SEC. 401. (a) The Federal Coordinating Council for
6 Science, Engineering, and Technology (hereafter in this Act
7 referred to as the 'Council') shall be composed of the
8 Director, who shall be Chairman of the Council, and 1
9 representative of each of the Federal departments and
10 agencies which the President shall designate. Each such
11 representative shall be an official of policy rank appointed
12 by the head of the Federal department or agency designated.

13 (b) The Council shall consider problems and
14 developments in the fields of science, engineering, and
15 technology and related activities affecting more than 1
16 Federal agency, and shall recommend policies and other
17 measures designed to--

18 (1) provide more effective planning and
19 administration of Federal scientific, engineering, and
20 technological programs;

21 (2) identify research needs, including areas
22 requiring additional emphasis;

23 (3) achieve more effective utilization of the
24 scientific, engineering, and technological resources and
25 facilities of Federal agencies, including the elimination

1 of unwarranted duplication; and

2 `` (4) further international cooperation in science,
3 engineering, and technology.

4 `` (c) The Council may be assigned responsibility for
5 developing long-range and coordinated plans for scientific
6 and technical research which involve the participation of
7 more than 2 Federal agencies. Such plans shall--

8 `` (1) identify research approaches and priorities
9 which most effectively advance scientific understanding
10 and provide a basis for policy decisions;

11 `` (2) provide for effective cooperation and
12 coordination of research among Federal agencies; and

13 `` (3) encourage domestic and, as appropriate,
14 international cooperation among government, industry, and
15 university scientists.

16 `` (d) The Council shall perform such other related
17 advisory duties as shall be assigned by the President or by
18 the Chairman of the Council.

19 `` (e) For the purpose of carrying out the provisions of
20 this section, each Federal agency represented on the Council
21 shall furnish necessary assistance to the Council. Such
22 assistance may include--

23 `` (1) detailing employees to the Council to perform
24 such functions, consistent with the purposes of this
25 section, as the Chairman of the Council may assign to

1 them; and

2 `` (2) undertaking, upon request of the Chairman, such
3 special studies for the Council as come within the scope
4 of authority of the Council.

5 `` (f) For the purpose of developing interagency plans,
6 conducting studies, and making reports as directed by the
7 Chairman, standing committees and working groups of the
8 Council may be established.``.

9 (c) CONFORMING AMENDMENT.--Section 207(a)(1) of the
10 National Science and Technology Policy, Organization, and
11 Priorities Act of 1976 (42 U.S.C. 6616(a)(1)) is amended by
12 striking ``established under title IV``.

13 SEC. 508. STUDY OF TESTING AND CERTIFICATION.

14 (a) CONTRACT WITH NATIONAL RESEARCH COUNCIL.--within 90
15 days after the date of enactment of this Act and within
16 available appropriations, the Secretary shall enter into a
17 contract with the National Research Council for a thorough
18 review of international product testing and certification
19 issues. The National Research Council will be asked to
20 address the following issues and make recommendations as
21 appropriate:

22 (1) The impact on United States manufacturers,
23 testing and certification laboratories, certification
24 organizations, and other affected bodies of the European
25 Community's plans for testing and certification of

1 regulated and nonregulated products of non-European
2 origin.

3 (2) Ways for United States manufacturers to gain
4 acceptance of their products in the European Community
5 and in other foreign countries and regions.

6 (3) The feasibility and consequences of having mutual
7 recognition agreements between testing and certification
8 organizations in the United States and those of major
9 trading partners on the accreditation of testing and
10 certification laboratories and on quality control
11 requirements.

12 (4) Information coordination regarding product
13 acceptance and conformity assessment mechanisms between
14 the United States and foreign governments.

15 (5) The appropriate Federal, State, and private roles
16 in coordination and oversight of testing, certification,
17 accreditation, and quality control to support national
18 and international trade.

19 (b) MEMBERSHIP.--In selecting the members of the review
20 panel, the National Research Council shall consult with and
21 draw from, among others, laboratory accreditation
22 organizations, Federal and State government agencies involved
23 in testing and certification, professional societies, trade
24 associations, small business, and labor organizations.

25 (c) REPORT.--A report based on the findings and

1. recommendations of the review panel shall be submitted to the
2 Secretary, the President, and Congress within 18 months after
3 the Secretary signs the contract with the National Research
4 Council.

5 SEC. 509. REPORT ON A STRATEGY TO STIMULATE COMPETITIVE
6 RESEARCH.

7 (a) IN GENERAL.--No later than 120 days after the date of
8 enactment of this Act, the Director of the Office of Science
9 and Technology Policy shall submit to Congress a report
10 presenting a proposed strategy for improving the university
11 research capabilities of those States which historically have
12 received relatively little Federal research and development
13 funding. The report shall particularly discuss the
14 feasibility and advisability of using the National Science
15 Foundation's Experimental Program to Stimulate Competitive
16 Research as a model for similar programs in other Federal
17 departments and agencies which fund research and development.

18 (b) ANALYSIS AND DISCUSSION.--The report shall include an
19 analysis and discussion of--

20 (1) the geographic distribution of Federal research
21 and development grants and contracts;

22 (2) current Federal efforts to stimulate competitive
23 research; and

24 (3) the feasibility and advisability of new Federal
25 programs to stimulate competitive research.

1 **SEC. 510. INTERAGENCY COORDINATION.**

2 The Secretary shall, within 180 days after the date of
3 enactment of this Act, submit to the Committee on Science,
4 Space, and Technology and the Committee on Energy and
5 Commerce of the House of Representatives and the Committee on
6 Commerce, Science, and Transportation of the Senate, a plan
7 for coordination of Commerce Department efforts with other
8 Federal agencies for activities related to high-resolution
9 information systems, including research and development
10 activities.

11 **TITLE VI--LEAD EXPOSURE HAZARDS**

12 **SEC. 601. FINDINGS.**

13 The Congress finds that--

14 (1) lead is a naturally occurring element which has
15 been used in a variety of industrial applications
16 including radiation shields, storage batteries, paint,
17 and gasoline;

18 (2) 1 in 6 United States children are victims of lead
19 poisoning, according to the Agency for Toxic Substances
20 and Disease Registry;

21 (3) lead poses a significant environmental health
22 problem since adverse effects have been conclusively
23 demonstrated at relatively low exposures;

24 (4) lead exposures to children under age 7 are of
25 greatest concern because of its association with

1 significant neurotoxic effects, including reduction in
2 intelligence, attention span deficits, and reading and
3 learning disabilities;

4 (5) a primary cause of childhood lead poisoning is
5 lead-based paint and dust in homes;

6 (6) past efforts to abate lead-based paint have
7 relied on methods which endangered workers and often
8 resulted in more available lead dust for the occupants;
9 and

10 (7) improving methods for testing and abating
11 lead-based paint offers a highly cost effective means of
12 reducing exposures and thus preventing childhood lead
13 poisoning.

14 **SEC. 602. LABORATORY ANALYSIS STANDARDIZATION.**

15 The National Institute of Standards and Technology shall,
16 within 18 months after the date of enactment of this Act,
17 recommend to the Administrator of the Environmental
18 Protection Agency technical criteria and implement a
19 voluntary accreditation program with respect to laboratory
20 analysis of lead in paint films, soil, and dust. Funds
21 required for implementing such a voluntary accreditation
22 program shall be provided to the National Institute of
23 Standards and Technology by the Administrator of the
24 Environmental Protection Agency. Funds received through fees
25 and other charges for accreditation services under such

1 program may be used by the National Institute of Standards
2 and Technology for operating costs of the program.

3 **SEC. 603. DETECTION TECHNOLOGY STANDARDIZATION.**

4 Subject to the availability of funds, the National
5 Institute of Standards and Technology shall, within 2 years
6 after the date of enactment of this Act, recommend to the
7 Administrator of the Environmental Protection Agency
8 protocols, criteria, reference materials, and minimum
9 performance standards to be used in the evaluation of
10 emerging products and techniques for detecting lead in paint
11 films and dust, including x-ray fluorescence devices, on-site
12 chemical spot testers, and laboratory methods, and to ensure
13 reliable, accurate, and effective lead detection
14 technologies.

15 **SEC. 604. STANDARDIZATION OF ABATEMENT PRODUCTS.**

16 Subject to the availability of funds, the National
17 Institute of Standards and Technology shall recommend to the
18 Administrator of the Environmental Protection Agency
19 performance criteria and standards for lead paint
20 encapsulants and for strippers within 2 years after the date
21 of enactment of this Act.

AMENDMENTS

1. **RITTER AMENDMENT:** Establishes a National Quality Council which would set national goals and priorities for Quality in business, education, and government, and requires an annual report to the President and Congress. (Replaces Sec. 506 - Report on Advanced Manufacturing and Quality)
2. **MINETA AMENDMENT:** Requires the Secretary of Commerce to identify critical industries to U.S. economy and develop a 10 year plan to ensure growth of those industries with an annual report due to Congress.
3. **VALENTINE AMENDMENT:** Returns language for pilot program for standards assistance to the language reported by the Committee on Science, Space, and Technology in 1990.

AMENDMENT TO THE SUBCOMMITTEE PRINT
OFFERED BY MR. RITTER

Page 43, line 19, through page 44, line 14, amend section 506 to read as follows:

1 SEC. 506. NATIONAL QUALITY COUNCIL.

2 (a) ESTABLISHMENT AND FUNCTIONS.--There is established a
3 National Quality Council (hereafter in this Act referred to
4 as the ``Council``). The functions of the Council shall be--

5 (1) to establish national goals and priorities for
6 Quality performance in business, education, government,
7 and all other sectors of the nation;

8 (2) to encourage and support the voluntary adoption
9 of these goals and priorities by companies, unions,
10 professional and business associations, coalition groups,
11 and units of government, as well as private and nonprofit
12 organizations;

13 (3) to arouse and maintain the interest of the people
14 of the United States in Quality performance, and to
15 encourage the adoption and institution of Quality
16 performance methods by all corporations, government
17 agencies, and other organizations; and

18 (4) to conduct an annual White House Conference on
19 Quality Performance in the American Workplace that would

1 bring together in a single forum national leaders in
2 business, labor, education, professional societies, the
3 media, government, and politics to address Quality
4 performance as a means of improving United States
5 competitiveness.

6 (b) MEMBERSHIP.--The Council shall consist of not less
7 than 17 nor more than 20 members, appointed by the President
8 of the United States by and with the advice and consent of
9 the Senate. Members shall include--

10 (1) at least 2 but not more than 3 representatives
11 from manufacturing industry;

12 (2) at least 2 but not more than 3 representatives
13 from service industry;

14 (3) at least 2 but not more than 3 representatives
15 from national Quality not-for-profit organizations;

16 (4) two representatives from education, one with
17 expertise in elementary and secondary education, and one
18 with expertise in post-secondary education;

19 (5) one representative from labor;

20 (6) one representative from professional societies;

21 (7) one representative each from local and State
22 government;

23 (8) one representative from the Federal Quality
24 Institute;

25 (9) one representative from the National Institute of

1 Standards and Technology;

2 (10) one representative from the Department of
3 Defense;

4 (11) one representative from a civilian Federal
5 agency not otherwise represented on the Council, to be
6 rotated among such agencies every 2 years; and

7 (12) one representative from the Foundation for the
8 Malcolm Baldrige National Quality Award.

9 (c) TERMS.--The term of office of each member of the
10 Council appointed under paragraphs (1) through (7) of
11 subsection (b) shall be 2 years, except that when making the
12 initial appointments under such paragraphs, the President
13 shall appoint not more than 50 percent of the members to 1
14 year terms. No member appointed under such paragraphs shall
15 serve on the Council for more than 2 consecutive terms.

16 (d) CHAIRMAN AND VICE CHAIRMAN.--The President shall
17 designate one of the members initially appointed to the
18 Council as Chairman. Thereafter, the members of the Council
19 shall annually elect one of their number as Chairman. The
20 members of the Council shall also annually elect one of their
21 members as Vice Chairman. No individual shall serve as
22 Chairman or Vice Chairman for more than 2 consecutive years.

23 (e) EXECUTIVE DIRECTOR AND EMPLOYEES.--The Council shall
24 appoint and fix the compensation of an Executive Director,
25 who shall hire and fix the compensation of such additional

1 employees as may be necessary to assist the Council in
2 carrying out its functions. In hiring such additional
3 employees, the Executive Director shall ensure that no
4 individual hired has a conflict of interest with the
5 responsibilities of the Council.

6 (f) FUNDING.--There is established in the Treasury of the
7 United States a National Quality Performance Trust Fund, into
8 which all funds received by the Council, through private
9 donations or otherwise, shall be deposited. Amounts in such
10 Trust Fund shall be available to the Council without further
11 appropriation for the purpose of carrying out the functions
12 of the Council under this Act.

13 (g) CONTRIBUTIONS.--The Council may not accept private
14 donations from a single source in excess of \$25,000 per year.
15 Private donations from a single source in excess of \$10,000
16 per year may be accepted by the Council only on approval of
17 two-thirds of the Council.

18 (h) ANNUAL REPORT.--The Council shall annually submit to
19 the President and the Congress a comprehensive and detailed
20 report on--

21 (1) the progress in meeting the goals and priorities
22 established by the Council;

23 (2) the Council's operations, activities, and
24 financial condition;

25 (3) contributions to the Council from non-Federal

1 sources;

2 (4) plans for the Council's operations and activities
3 for the future; and

4 (5) any other information or recommendations the
5 Council considers appropriate.

AMENDMENT TO THE SUBCOMMITTEE PRINT
OFFERED BY MR. MINETA

Page 38, after line 11, insert the following new section:

1 SEC. 504. CRITICAL INDUSTRIES.

2 (a) IDENTIFICATION OF INDUSTRIES AND DEVELOPMENT OF
3 PLAN.--The Secretary shall--

4 (1) identify those civilian industries in the United
5 States that are necessary to support a robust
6 manufacturing infrastructure and critical to the economic
7 security of the United States;

8 (2) list the major research and development
9 initiatives being undertaken, and the substantial
10 investments being made, by the Federal Government,
11 including its research laboratories, in each of the
12 critical industries identified under paragraph (1); and

13 (3) develop a 10-year plan outlining the major public
14 and private efforts, including research and development,
15 needed to ensure the growth and stability of each
16 critical industry identified under paragraph (1).

17 (b) INITIAL REPORT.--The Secretary shall submit a report
18 to the Congress within 1 year after the date of enactment of
19 this Act on the actions taken under subsection (a).

1 (c) ANNUAL UPDATES.--The Secretary shall annually submit
2 to the Congress an update of the report submitted under
3 subsection (b). Each such update shall--

4 (1) describe the status of each identified critical
5 industry, including the advances and declines occurring
6 since the most recent report;

7 (2) identify any industries that should be added to
8 the list of critical industries; and

9 (3) recommend measures, including research and
10 development, necessary to ensure the continued successful
11 development of each identified critical industry.

Redesignate subsequent sections accordingly.

Amendment by Mr. Valentine

On page 9, lines 15 through 17, strike the last sentence of paragraph (e) and insert in lieu thereof:

"Such funds shall be made available for such purpose only to the extent that matching funds are received by the National Institute of Standards and Technology from sources outside the Federal Government."

Justification - The sentence being replaced by the amendment was written to make the statute match existing practice with regard to matching funds for the pilot program. In the opinion of some committee members, it does not accomplish its stated goal. Therefore, my amendment would return this section to the universally accepted language our committee reported last year. The amendment is offered without prejudice and if more appropriate language can be developed by full committee, it will be offered at that time.

BUDGET SUMMARY: TECHNOLOGY ADMINISTRATION AUTHORIZATION
(In Thousands of Dollars)

Budget Activity	Administration		Subcommittee	
	FY 1990	FY 1991	FY 1992	FY 1992
	APPROP.	APPROP.	REQUEST	AUTH.
	AUTH.	AUTH.	AUTH.	AUTH.

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

Intramural Program						
(Scientific & Technical Research & Services)						
Electronics & electrical engineering	16,197	21,273	33,595	21,273	34,000	
Manufacturing engineering	6,233	8,266	12,617	8,266	13,500	
Chemical science and technology	16,914	18,617	20,822	18,617	22,000	
Physics	24,752	25,522	26,475	25,522	27,000	
Materials science & engineering	23,157	26,495	28,671	26,495	30,000	
Building & fire research	11,271	9,821	10,632	9,821	12,300	
Computer systems	9,440	11,819	15,048	11,819	16,000	
Applied math & scientific computing	5,599	5,847	6,088	5,847	6,500	
Technology assistance	7,379	8,978	10,094	8,978	11,000	
Research support activities	<u>24,306</u>	<u>29,590</u>	<u>37,798</u>	<u>29,590</u>	<u>38,700</u>	
SUBTOTAL	145,248	166,228	201,840	166,228	211,000	
Extramural Program						
(Industrial Technology Services)						
Advanced Technology Program	9,892	35,900	35,900	100,000	100,000	
Manufacturing Technology Centers	7,419	11,900	10,300	15,000	25,000	
State Technology Extension Program	<u>1,286</u>	<u>1,300</u>	0	<u>2,000</u>	<u>2,500</u>	
SUBTOTAL	18,597	49,100	46,200	117,000	127,500	
TOTAL NIST APPROPRIATIONS	163,845	215,328	248,040	283,228	338,500	
Other Technology Admin. Programs:						
Office, Under Secretary Technology	3,297	3,500	4,236	4,000	5,000	
Japanese Technical Literature Prog.	328	400	400	1,000	1,500	
Clearinghouse on Productivity,						
Technology and Innovation	250	300	300	1,000	1,000	
National Technical Information Service	0	0	0	500	1,500	
NIST (from above)	<u>163,845</u>	<u>215,328</u>	<u>248,040</u>	<u>283,228</u>	<u>338,500</u>	
GRAND TOTAL	167,720	219,528	252,976	289,728	347,500	

File 507

REPORT OF THE PRESIDENT TO THE CONGRESS

ON FEDERAL POLICIES, BUDGETS, AND

TECHNICAL ACTIVITIES

IN

SEMICONDUCTORS

★ ★ ★

FIBER OPTICS

★ ★ ★

SUPERCONDUCTING MATERIALS &

★ ★ ★

ADVANCED MANUFACTURING



REPORT OF THE PRESIDENT TO THE CONGRESS

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IN

SEMICONDUCTORS,

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&

ADVANCED MANUFACTURING

I. INTRODUCTION

The Omnibus Trade and Competitiveness Act of 1988 mandated this report by the President to the Congress on policies and budget proposals regarding Federal research in semiconductors and semiconductor manufacturing technology, fiber optics and optoelectronic technology generally, superconducting materials, and advanced manufacturing technologies.

The Federal Government's role in research and development of technologies, like the four covered in this report, is evolving. For example, in December, 1989, the Administration published The National Action Plan on Superconductivity Research and Development (hereafter referred to as The Superconductivity Plan). This plan outlines the special steps that the Executive Branch will take to coordinate superconductivity activities. The President's FY 1991 budget request included a budget cross-cut of research and development on robotics, high performance computing, semiconductors, advanced imaging technologies, and superconductivity. These two documents — the President's Budget and the Superconductivity Plan — articulate the evolving government role in technologies through Federal funding of R&D, coordination of research activities, and creation of policies to ensure an economic environment in which firms can commercialize technologies developed by industry, universities, Federal laboratories, or other sources. This report reflects the logic of those two documents and adds a discussion of the management and organizational challenge to the private sector of these technologies, as well as a description of the program activities by Federal agencies in the four technologies.

II. THE FEDERAL ROLE IN R&D

The evolution of the four technologies covered in this report is today driven predominantly by commercial applications. Nonetheless, the Federal Government has an important role to play. The Superconductivity Plan cited three areas where there is a role for the Federal Government: R&D funding, coordination of R&D, and R&D-related policies.

A. Federal R&D Funding Policy

The President's fiscal year 1991 budget request includes the following comprehensive statement of R&D funding policy which bears directly on the issue of Government support for the four technologies covered in this report:

"Traditionally, the Federal Government has supported R&D in two areas, first, to meet its own direct needs—where it is the principal user (e.g., defense-related R&D)—and, second, to meet broader national needs (e.g., basic research in all areas, measurements and standards R&D, health-related R&D). In instances where the Federal Government is the ultimate market for the R&D results, R&D funding decisions must be made on the basis of Government needs and requirements. Thus, funding levels for defense R&D and civil space R&D activities are determined in the context of their respective national security and civil space objectives and requirements. The actual R&D activities, however, should be managed in such a way as to encourage commercial applications of the R&D as well. The second category of R&D, for which the Government is not the principal market, includes both basic research and generic applied research. Federal investment in such R&D is warranted to capture the public good benefit. The Administration believes that Federal support for this type of R&D should be based on several fundamental criteria:

- o there should be "externalities" associated with the R&D (e.g., pollution clean-up, basic research);
- o there should be benefits to broad segments of the economy simultaneously (e.g., health research, agricultural research); and
- o the private sector is without sufficient incentives to capture enough of the benefits to make such R&D investments worthwhile. In such cases there should be private support (e.g. joint ventures or cost-sharing) commensurate with the expected benefits to the private parties."

Federal agencies fund R&D to meet their own direct needs where they are the principal user. In other cases, Federal support is for pre-competitive research that meets all the criteria established for direct Federal funding, specifically, that the research is in the interest of the public welfare and the private sector is unable to capture sufficient benefits to make private investment economic.

Most research necessary for technological advance, however, is funded by the private sector and is not pre-competitive. Firms may be unwilling to share their research results with their competitors, and they may be able to protect their technology from unauthorized use through patents or other intellectual property protection. Nonetheless, firms may still want to cooperate with some competitors or with their suppliers or customers in order to share the costs and risks of developing a new product or process. The Federal Government has other policies to foster such private sector cooperation, in particular, the policies that reduce the antitrust uncertainties regarding R&D joint ventures.

B. Coordination of Federal R&D

The Federal Government can play an important coordinating role in technologies in which several Federal agencies actively fund R&D to meet their own direct needs as well as to meet broader national needs. In exercising its coordinating role for technologies with broad commercial application, however, the Government needs to be careful about imposing its own judgments about competing technical alternatives. For example, the Government's programmatic needs may represent only a small and specialized segment of the potential market for a technology. Federal policies must also respect the prudence of taking diverse approaches to the same goal.

The Superconductivity Plan establishes a coordinating role for the Office of Science and Technology Policy (OSTP). OSTP will provide leadership in the national superconductivity effort. The OSTP Director will work to assure that all parts of the Government program form a coherent whole, well balanced between basic and applied research. Also, the National Com-

mission on Superconductivity plans to publish a report containing its assessment and recommendations for a Federal approach to superconductivity.

OSTP, through the Federal Coordinating Council for Science, Engineering and Technology (FCCSET), is considering a similar role for the other three technologies in this report—semiconductors, fiber optics and opto-electronics, and advanced manufacturing. Such a coordinating role will aid the early R&D stages of the innovation process, when corporate proprietary interests are at a minimum.

The government can also act as a catalyst in bringing together the expertise of the Federally funded laboratories, universities, and industry in partnership for the creation of new technology. Where the technology has potential impact on several industries, this coordinating role can also help the private sector organize itself for timely utilization of the technology. As The Superconductivity Plan notes, "This new catalytic role derives from the very nature of this technology."

The Nation's success in commercializing technologies ultimately depends on the private sector to make the critical decisions on how much capital, time, and effort to invest. The Government's ability to help coordinate appropriate R&D at pre-competitive stages will be enhanced by private sector leadership in organizing itself for effective teamwork. Without private sector initiative, government involvement in the process risks introducing time delays and weakening incentives for firms to commercialize the technology. In addition, where Government funding focuses on pre-competitive technology, domestic firms that are actively involved in the process will be able to exploit it sooner and more effectively. At present, it appears that domestic firms have shown less interest in acquiring technologies supported by Federal funds than foreign firms.

C. Other Policies Affecting Technological Innovation

In addition to its responsibilities in the funding and conduct of Federal R&D programs, the Government has continuing responsibility for

fostering an economic and business climate that will remove unnecessary obstacles to the commercialization of technologies. Government policies affecting technological innovation are mainly generic rather than technology specific, because they are intended to encourage innovation in a broad range of areas. Technologies are so dynamic that it is difficult, especially for non-commercial parties, to predict in advance which ones will succeed. Even for the application, there are sometimes competing technologies. For example, there is competition among advanced materials—composites, advanced ceramics, and polymers—to perform the same functions. A specific example is the battle over the relative merits of, and trade-offs among, silicon, gallium arsenide, and diamond material for certain uses of semiconductors.

1. Current Policy Initiatives: Several policy initiatives under current consideration would foster a conducive economic environment for technological innovation. Appropriate action on these policy initiatives would provide a basis for consistent and stable research in the private sector by reducing the inherent risks and uncertainties in these activities, promoting the exchange of information across national boundaries, providing consistent Government R&D support, and protecting the environment. These initiatives include:

a. Research and Experimentation Tax Credit: Administration initiatives in support of tax credit law reform will aid the commercialization of technologies. The President has proposed changes to the present tax credit to encourage U.S. industry to invest in long-term research. The changes include making the R&E tax credit permanent, thereby providing some degree of certainty in making long-term resource commitments; extending the credit to cover expenditures by startup firms, which will help encourage venture capital investment in these enterprises; and establishing a two-tier structure for the tax credit, thus encouraging both rapid growth in R&D expenditures as well as sustained commitments.

b. International Cooperation: It is difficult, if not impossible, for a single firm to be technologi-

cally self-sufficient. Some analysts believe self-sufficiency is impractical even for a single nation. While the normal functioning of science bodies provides for information exchange among scientific investigators, it is appropriate for the U.S. Government to foster that exchange by establishing close contact with basic research efforts in the rest of the world, particularly Japan and Europe. The U.S.-Japan Agreement in Cooperation in Science and Technology, for example, provides a framework for new relationships for cooperation on research and development in coming years. The Agreement includes provisions to establish a balanced and equitable partnership in joint undertakings, to assure comparable access to facilities and activities supported or sponsored by the government, and to provide for adequate and effective protection of intellectual property rights. The Federal government, through a variety of programs, is encouraging U.S. scientists and engineers to participate in R&D efforts in Japan and to take Japanese language training.

c. Science and Technology Base: Developing and maintaining a science and technology base is vital to the future of our Nation. In order to maintain this base, steady, predictable support is needed. A more stable research environment would be created by multi-year authorizations and two-year appropriations cycles. Such an approach would help researchers devote more of their time to research, and less of their time to satisfying paperwork requirements. The public and private sectors should work cooperatively in both basic and applied research, each pursuing their legitimate goals. This cooperation will, if successful, shorten the cycle of innovation. A shortened innovation cycle would allow earlier market entry which is a major factor in competing in international markets.

2. Other Related Policy Initiatives: In addition to these five initiatives, President Bush recently announced his support for legislation to reduce the antitrust uncertainty that may unnecessarily discourage some joint production ventures and to reform our cumbersome and expensive product liability system. Also, the Administration will encourage the conduct of R&D by transnational companies by proposing to make

permanent the rules for allocation by such companies of R&D expenditures and will propose changes in those rules.

3. Existing Policies to Encourage Innovation: A number of recent legislative and executive actions either directly or indirectly affect the climate for the development and commercialization of technology. These are:

- o The President's Superconductivity Initiative (1987)—an eleven point directive to bring focus to the Federal actions in support of superconductivity, some of which, like the proposal to expand the National Cooperative Research Act of 1984 to include some types of joint production ventures, would apply to all technologies.
- o The National Superconductivity and Competitiveness Act of 1988—directs a number of actions related to the development and commercialization of superconductivity.
- o The Omnibus Trade and Competitiveness Act of 1988—a wide ranging law which includes among many other things provisions for the oversight of superconductivity and semiconductors and to strengthen generally the contribution of technology to competitiveness.
- o The Federal Technology Transfer Act (1986) amending the Stevenson-Wylder Act (1980); Executive Order 12591 (1982) Facilitating Access to Science and Technology; The University and Small Business Patent Procedure Act (1980) (amended by the Trademark Clarification Act (1984); and The National Competitiveness Technology Transfer Act (1989)—which taken together constitute a system to encourage the commercialization of Federally-funded research.
- o The National Cooperative Research Act of 1984; the Antitrust Enforcement Guidelines for International Operations (1988); and the proposed Cooperative Production Act of 1990—reduces the uncertainty related to collaborative R&D, and potentially joint manufacturing, by groups of companies, which should have procompetitive benefits as markets become increasingly globalized.
- o The Small Business Innovation Development Act (1982)—established the Small Business Innovation Research (SBIR) program to provide seed funding to launch innovations which have short-term prospects for commercialization.
- o The Title V Report (1989); The OECD General Framework of Principles for International Cooperation in Science and Technology (1988); and the Head of State Agreement for Science and Technology Cooperation (1988)—established a framework for equitable, balanced international technology cooperation including protection of intellectual property.
- o The Council on Competitiveness (1989) and The Economic Policy Council Working Group on Research, Development, Technology and Innovation (1989)—led by the Vice President and Secretary of Commerce respectively, these two mechanisms were established by President Bush to improve competitiveness and technological innovation.
- o The Science and Technology Centers Program (1989); The Regional Centers for the Transfer of Manufacturing Technology (1988); and The Engineering Research Centers Program (1985)—have created twenty-eight university-based centers to develop new knowledge and to transfer advanced technology to industry.
- o Department of Defense Funding for SEMATECH and the National Center for Manufacturing Sciences—encourage private sector-led cooperative approaches to semiconductor manufacturing technology and advanced manufacturing technology.

D. Federal Technology Research Budgets: Fiscal Years 1988 through 1990: The following tables summarizing Federal funding for R&D for the four technologies, by agency, for fiscal years 1988 through 1990. The budget data collected for this report were based on a unique set of definitions, a unique process for data collection, and on the budget pro-

jections during the 1989 fiscal year. For this reason these numbers do not track with, nor should they be compared to, the budget crosscuts prepared for subsequent budgets. Funding for research for fiber optics (and photonics generally), superconducting materials, and advanced manufacturing R&D show steady growth.

TABLE 1. Funding of semiconductor, fiber optics, superconducting materials, and advanced manufacturing research and development (dollars in millions) by agency:

Agency	1988	1989	1990
Semiconductor R&D			
Energy	48	48	48
Defense	404	416	423
NSF	32	34	36
NASA	3	4	4
Commerce	3	3	3
Semiconductor Total	\$490	\$505	\$514
Fiber Optic and Optoelectronic R&D			
Energy	9	10	10
Defense	80	118	116
NSF	13	14	16
NASA	7	4	4
Commerce	2	2	5
Fiber Optic Total	\$111	\$148	\$151
Superconducting Materials R&D			
Energy	69	138	165
Defense	60	73	72
NSF	20	26	29
NASA	4	6	6
Commerce	3	3	4
Superconducting Total	\$156	\$246	\$276
Advanced Manufacturing R&D			
Defense	154	170	173
Commerce	3	3	3
Advanced Manufacturing Total	\$157	\$173	\$176

Note: The budget numbers shown in the table for advanced manufacturing do not include funding for robotics, and therefore do not show several agencies which have budgets in that area. The President's FY 1991 budget request contains a complete crosscut on robotics funding. A data collection for advanced manufacturing R&D funding, including robotics, is planned for the President's FY 1992 budget request.

The budget data collected for this report were based on a unique set of definitions, a unique process for data collection, and on the budget projections during the 1989 fiscal year. For this reason these numbers do not track with, nor should they be compared to, the budget crosscuts which have been prepared for subsequent budgets.

A description of the Federal programs for each technology, by agency, is included in the Appendices.

It is important to note that the agency programs are responsive to agency missions. In the case of program agencies like Defense, this often translates into support for specialized needs which would not be met by industry in the normal course of business. These budget figures and the programs which they represent should not be viewed as comprehensive or integrated R&D strategies for the technologies. However, agency programs are designed by scientists and engineers with an awareness of work being done by others. Also, there is increasing interaction between government laboratories and the private sector. Currently, there are more than 500 cooperative agreements in effect which are encouraged by the Federal Technology Transfer Act of 1986, Executive Order 12591 (1987), and the National Competitiveness Technology Transfer Act (1989). These include the Department of Energy's Superconductivity Pilot Program which is partially supported by the private sector.

1. Related Fiscal Year 1991 Budget Initiatives: The President's current technology budget crosscut was a one-time survey that covered a different set of technologies than those in this report. Where similar technologies were included, the R&D crosscut and this report generally used different definitions. The numbers, therefore, are not comparable with the figures in this report.

The proposed FY 1991 R&D expenditures for related crosscut technologies were \$537 million for semiconductor technology, \$215 million for superconductivity, \$469 million for high-performance computing, \$118 million for advanced imaging technologies whose reporting excluded most fiber-optic and optoelectronic R&D), and \$192 million for robotics (which is excluded from the current report's definition of advanced manufacturing technology). These amounts reflect percentage increases over estimated FY 1990 spending of 2 percent for semiconductors, 5 percent for high-performance computing, and 28 percent for robotics. No change in spending for advanced imaging technologies was proposed. The proposal included a 6 percent drop in R&D funding for superconductivity due to the progress of the Superconducting Super Collider (SSC) magnet from research into prototype pro-

duction which is reflected as a \$100 million increase (or 46 percent) in the SSC budget.

The 1991 budget request included funds for two programs at the Department of Commerce's National Institute of Standards and Technology to encourage the development and transfer to the private sector of a wide range of advanced technologies. The budget proposed \$10 million for the new Advanced Technology Program (ATP) to support a number of ventures doing generic, pre-competitive research in promising technologies. The budget also proposed \$5 million for grants to the Regional Manufacturing Technology Centers that will transfer advanced manufacturing technologies to medium and small-sized businesses.

The budget request also included an increase of \$222 million (or 26 percent) for science and engineering education in five agencies.

III. PRIVATE SECTOR'S ROLE IN INNOVATION

The private sector has the principal role in innovation and in identifying and utilizing technologies for commercial products and processes. Even in meeting the Government's own direct needs, the Government relies principally on the private sector to undertake the development process and encourages these activities to be managed in such a way as to allow commercial applications of the R&D as well. The Federal Government and the private sector share the responsibility for supporting appropriate pre-competitive research on generic enabling technologies. However, the Administration believes that it is not an appropriate role for the Federal Government to develop specific commercial products whether they are based on technologies developed with Federal R&D support or not. Moreover, where appropriate the private sector must take an active role in directing innovation process from the outset to ensure that R&D fits market needs. As stated in the background materials to The Superconductivity Plan:

"The multidisciplinary nature of the technology and the fact that the benefits from commercialization will accrue over such a long term may make it difficult for individual

firms to justify capitalizing the basic R&D expenses required for commercialization. Generic technical advances cut across industrial sectors and markets. With fierce international competition, time will be critical in transferring the technology into marketable products—with successful commercialization dependent on concurrent research, design, manufacturing, and marketing....

"Because of the time pressure for concurrent effort across the spectrum from research to applications, and the diversity of industries involved, the management challenge is great. The Nation's success in commercializing superconductivity ultimately depends on the private sector, which must make the critical decisions on how much capital, time, and effort to invest."

The firm that can be first to the market with new products based on developments in one of these areas can reap major commercial rewards. Innovation and commercialization have become time critical. Time criticality, combined with high cost and long lead-time, technical complexity, and the potential for multiple uses in many industries, may have important implications for the management of innovation. In many high-technology areas:

- o Technological advances may not be specific to one industry;
- o Existing products and technologies are made obsolete before their useful life is over, as firms shorten product life cycles to compete in international markets;
- o Increasingly the private sector has to identify specific products to meet specific market opportunities before undertaking R&D;
- o Successful and timely innovation may require the capabilities of many firms from different industries and other organizations combined in coordinated, concurrent efforts.
- o Returns on expensive investments in generic enabling technologies by firms often can only be maximized — and in

some cases investments may only be recouped — if the results are used in several applications, often in different industries.

Different firms address these innovation and commercialization challenges differently. Some firms view the traditional linear, sequential innovation management practice as the best formula. Some other firms have begun to look at alternative forms of innovation. One alternative that is receiving increased attention is a systems management approach that integrates the innovation and commercialization stages. These two approaches are illustrated in Figure 1 for optoelectronics devices.

In the sequential model, R&D precedes product design. After product design, manufacturing processes are established at which point the product is marketed. Through marketing, the firm begins to receive feedback from current and/or potential users and redesign of the product or design of the next generation of products begins. Under this model, the firm often approaches a single application at a time, rather than looking simultaneously at multiple applications.

Using the systems approach in the optoelectronics device example, a firm would simultaneously work on chip design, materials, processing technology, and manufacturing equipment in conjunction with its suppliers. At the same time, the firm would work with multiple applications and users. Suppliers and users — whether internal or external to the firm — become "stakeholders" in the commercialization process.

In a systems approach, the firm may undertake a multi-industry, multifirm joint venture of noncompeting firms to develop, manufacture, and use the new product(s). The systems approach will allow initial design input from the several users, planned parallel tracks of R&D, parallel development of applications in conjunction with the R&D, and early and simultaneous entry into many markets. Some American firms such as Xerox, AT&T, Motorola, and Hewlett-Packard which have switched to this model of managing innovation inside the firm, have created new products in approximately

half the time and at half the cost of those using the sequential model. This approach allows the developmental costs to be shared by all the stakeholders. Also, the users represent an initial market for the product, potentially allowing the producer to achieve economies of scale and price competitiveness more rapidly. In short, it can reduce risk for all members of the joint venture. This approach may offer a means for firms to collaborate where large investments associated with high-technology products may exceed individual firm resources.

Many American firms are unfamiliar with this systems model. Although it is commonly associated in the U.S. only with single application, government-led, defense and space projects, it is being used by many foreign firms for multiple application, private sector-led, innovation efforts aimed primarily at commercial markets.

IV. OVERVIEW OF TECHNOLOGIES

A. Semiconductors and Electronics Technologies

Semiconductors are the basic component of the electronics industry. They are integral to the electronic systems which make possible parts of the nation's defense, communication systems, transportation, medical care, banking, manufacturing, etc. The world market for semiconductor devices is \$50 billion and for semiconductor manufacturing, test, and assembly equipment is \$8.6 billion. U.S. production of semiconductor devices was \$20 billion in 1988 and is presently growing at 8 percent annually. U.S. production of semiconductor production equipment was \$3.8 billion in 1988.

Advanced semiconductor technology is evolving toward even more complex semiconductor devices with smaller feature sizes. The evolving technology is resulting in changes in processing and quality control, in materials technology, in device design, and in packaging, especially:

- o Improvements in processing and quality control necessary for new processing technologies like x-ray lithography,

- o Greater materials purity required as the feature sizes of integrated circuits are reduced,
- o Better computer models for predicting the solid-state effects of the boundaries of regions within the devices, and
- o Better ways of dealing with heat dissipation.

Five agencies carry out selected research and development programs in the general area of semiconductor technology to meet their specific missions.

The Department of Energy carries out research on semiconductors and semiconductor manufacturing technology which are important to several of its missions including solar energy, the weapons program, basic energy sciences research, and high energy physics research.

The Department of Defense programs focus on many special manufacturing problems, one of the most important of which involves microcircuit reliability in hostile (i.e., combat) environments. Recently SEMATECH, an industry consortium to rebuild U.S. excellence in semiconductor manufacturing was established. It will spend \$250 million per year for a minimum of five years and is funded by 14 member companies, the U.S. Government through the Department of Defense, and the State of Texas.

The National Aeronautics and Space Administration addresses problems unique to its mission. For example, the objective of its gallium arsenide (GaAs) technology development program is to develop GaAs digital integrated circuit technology for its unique, high data rate, signal processing applications such as: robotic vision, high resolution imagery spectrum and the geodynamic laser ranging system instruments.

The Semiconductor Metrology Program in the Department of Commerce's National Institute of Standards and Technology provides needed generic measurement methods and services, national reference standards, carefully evaluated reference data, and technical consultation on measurement technology and theory. These support research, development, and

manufacturing; promote equity in domestic and international markets; and aid international competitiveness of the Nation's manufacturers and users of semiconductor materials, fabrication equipment, and devices.

The National Science Foundation provides funding to universities to conduct basic research and to train students in the field of semiconductor technology. Among the research areas supported are packaging materials technology, dielectrics, silicon technology and devices, compound semiconductor technology and devices, device processing techniques, and integrated electronics.

B. Fiber Optics and Optoelectronics Technologies

Photonics is the name given to the generation, control and use of photons (light); it is the optical analog of electronics. Photonic or electro-optic devices and systems can have a large bandwidth which means that huge amounts of data can be quickly switched and transmitted.

Photonic devices could replace many electronic devices but are currently not nearly as well developed or cost-effective. The main commercial applications for photonics are for information transmission and optical sensing. A third, optical computing, is in the exploratory stage.

Photonic-based systems are becoming the system of choice for many high-data-rate uses like long distance telephone and data networks. Even such short-haul uses as communication between racks of equipment in a large switching system or computer and between components of in-home high fidelity stereo systems are being taken over by photonic systems.

A photonic information transmission system has three basic components: an electro-optic input device, a transmission medium and an electro-optic output device. While the transmission technology is mature, advances in the technology used in electro-optic input and output devices can be important to key devices proposed for high definition television receivers and for many advanced displays.

The high speed and high noise immunity of photonic systems make them a natural consider-

ation for computing applications. Several basic devices necessary for a completely photon-based system are either not yet available, or are not cost-effective. However, many laboratories worldwide have strong R&D efforts on photonic computer devices and components.

The world market for optical fiber communication systems components reached \$3.2 billion per year in 1989 and has been growing at about 25 percent per year. The world market for systems is considerably greater. For example, the worldwide investment in undersea lines alone is expected to reach \$8.5 billion for the eight-year period 1988-1996.

Five agencies carry out selected research and development programs in the general area of fiber optics and optoelectronic technologies to meet their specific missions.

The Department of Energy conducts research under its weapons program which includes the synthesis, characterization and processing of glasses; investigations of non-linear optical properties of materials; and the effects of impurities on the optical properties of disordered materials. The goals are to improve the performance of these materials for use as components in diagnostic instrumentation to do real-time monitoring of complex experiments for weapons testing.

The Department of Defense's programs are aimed primarily at the proliferation of defense systems which will rely on fiber optics in the next decade. Today's fiber optics research will provide ships, aircraft, and undersea communications with higher bandwidth capabilities at lower cost than metallic cable approaches. In addition, fiber optical sensors will provide a new class of gyroscopes as well as acoustic, magnetic sensors for inertial navigation and antisubmarine warfare.

The National Science Foundation supports university research efforts in optical fiber technology for communications, sensing, and switching applications; a number of academic research projects on optical phenomena for applications in optical computing, processing, logic, displays, imaging, and others; and on semiconductor devices that exhibit photoelectric or op-

toelectronic properties. This support is intended to advance the basic science and to educate students in electro-optic technology.

The National Aeronautics and Space Administration has several programs in fiber-optic and electro-optics research and development for applications in space and aeronautics.

The Department of Commerce's R&D program, which is carried out in the laboratories of NIST, provides the base of consistent physical measurements and standards required to support the development and utilization of optical fiber telecommunications. In addition, the program encompasses the measurement of the special characteristics of fibers used for sensors and evaluation of prototype sensors for current, voltage, magnetic field, and other quantities.

C. Superconducting Material

Superconductivity is a material property characterized by zero electrical resistance and other related phenomena. One of the most significant scientific breakthroughs of recent decades, the achievement of high temperature superconductivity, was made in 1986, when ceramics, based on perovskite systems, were found to exhibit superconductivity at temperatures which were significantly higher than was ever observed in earlier work. Because superconductivity has the potential for application in a wide variety of products, it has attracted a great deal of interest.

The most notable commercial success to date is the magnet used for Magnetic Resonance Imaging (MRI), which with other medical applications of superconductivity have great market potential.

The development of high energy particle accelerators has led to the construction of many large and successful superconducting bending and focusing magnets. The Tevatron, at the Fermi Laboratory, features a ring of superconducting magnets 5 km in circumference. The Superconducting Super Collider (SSC) will be similar but ten times bigger. Perhaps the most significant potential application of large superconducting magnets is to controlled thermonuclear fusion.

In the electric power industry, superconducting magnetic energy storage (SMES) is a potential near term application of superconductivity with important economic benefits.

Five agencies carry out selected research and development programs in the general area of superconductivity to meet their specific missions. **The Department of Energy** carries out research and development on high temperature superconductors primarily in support of three program missions: Basic Energy Sciences, Conservation and Renewable Energy, and Defense Programs. The Department's research program in low-temperature superconductivity is needed primarily because superconducting magnets are required to advance the performance of expensive experimental devices utilized in magnetic fusion energy and high energy and nuclear physics.

The Department of Defense's program in high temperature superconductivity involves synthesis, processing and fabrication of materials; pre-commercial manufacturing science issues; and conceptual device development. Large-scale, low-temperature superconductivity technology is relatively mature, but there has been only modest application in military systems. Research and development is continuing to support such applications as sensors, analog electronics, digital electronics, electric drivesystems for ships (and possibly land vehicles and aircraft), electric generators, electric energy storage systems for directed energy weapons, and directed energy weapons.

The National Science Foundation supports research in universities to bring a wide variety of experimental techniques to the study of new high-temperature superconductors; to bring experience in chemistry to the synthesis of solid state oxide superconductors; to understand bulk properties, thin films, and superconducting devices; to understand physical limitations of superconductors such as critical temperatures and fields; to understand metallic and structural behavior of superconductors and the microscopic behavior of superconducting properties; to expand knowledge of superconductor processing, modification, and synthesis and characterization of superconducting ceramic oxides; and to apply both low-temperature and high-temperature superconductors.

The National Aeronautics and Space Administration has instituted a program in high-temperature superconductivity for applications in space and aeronautics. The high-temperature superconductor program includes benefit studies of typical aerospace applications. The research is directed at characterization of new high-temperature superconducting materials for unique aeronautics and space applications including the effects of vacuum and space radiation.

The Department of Commerce (NIST) provides measurement technology and data in superconductor electrical and mechanical properties, composition and structure analysis, processes, and superconducting electronics. Earlier work in superconducting electronics has led to the national standard for voltage being based on the performance of superconducting devices.

D. Advanced Manufacturing Technologies

Historically, design, manufacturing, and measurement have been separate processes. Conceptually, a designer would design a system and reduce its individual parts to drawings, or blueprints, to communicate the essential features of the design to the machinist who would make the parts. The machinist would cut a part on a milling machine, stopping periodically to check dimensions with calipers and gauges. As manufacturing techniques became more and more efficient, the measurement process consumed an ever-greater percentage of the total work required to produce a part. In addition, retooling to respond to design changes became increasingly expensive.

The development of modern computer systems has stimulated the beginning of a fundamental change in the manufacturing process which affects the design, fabrication, and the measurement of the part. This change, which has been called "concurrent engineering" is, in its simplest terms, the development of the product and its manufacturing, quality control, distribution, and repair process simultaneously. For a selected application in the Department of Defense's acquisition of a weapons system, it has been estimated that concurrent engineering produced reductions of 50 percent in the number of

engineering design changes, 40 to 60 percent in the manufacturing costs, and 75 percent in the scrap and re-work of manufactured products. This last effect is particularly significant because some surveys have shown that, in the U.S., one-third of the work force in manufacturing industries is engaged in re-work; that is, correcting out-of-tolerance parts made by the other two-thirds.

Two agencies carry out selected research and development programs in the general area of advanced manufacturing to meet their specific missions. The Department of Defense's primary goal in its research and development programs in advanced manufacturing is to improve the productivity and responsiveness of the defense industrial base. The primary Department of Defense program in this area is its MANTECH program. While the Department of Defense funds R&D in advanced technology, the contractors are normally expected to invest in the capital equipment necessary to implement that technology.

The Department of Commerce (NIST) has two principal goals for its advanced manufacturing program. One is to supply U.S. industry with this radically new way of making precisely machined parts with dimensions that can be referenced to national measurement standards which are maintained at the NIST. The second is to support the modernization of American manufacturing by providing the technical information necessary to develop standardized interfaces between various types of equipment. NIST is also using its laboratories as a test bed for research on the next generation of knowledge-based manufacturing systems and is carrying out technology transfer activities in the area of advanced manufacturing.

V. CONCLUSION

The Administration continues to support R&D to meet direct Government needs as well as research on pre-competitive enabling technologies in most current high-technology areas, including semiconductor, opto-electronics and fiber optics, superconducting materials, and advanced manufacturing. The Administration's policies with respect to technological innovation identify appropriate roles for the Government and for the private sector.

Traditionally, the Federal Government has supported R&D for two reasons, as stated in the President's FY 1991 Budget: first, to meet its own direct needs—where it is the principal consumer—such as defense and civilian space R&D; and second, to meet broader national needs such as new and better means of diagnosis and treatment of disease, agricultural productivity, and pollution clean-up.

In the first case, where the Federal Government is the ultimate consumer for the R&D results, funding levels and decisions are made on the basis of Government programmatic objectives, needs and requirements. The Government relies principally on the private sector to undertake the development process and encourages these activities to be managed in such a way as to allow commercial applications of the R&D as well.

The second category of R&D requires Federal support in the interests of public welfare where the private sector is unable to capture sufficient benefits to make private R&D investments economic. Federal support of fundamental scientific research is the prototypical, essential investment in the Nation's scientific and technological future. This fundamental research is a necessary part of the knowledge base required for the Federal Government to meet its own direct needs and objectives in the future and for the private sector to create new products and processes.

However, the Administration believes that it is not an appropriate role for the Federal Government to develop specific commercial products, even where based on technologies developed with Federal R&D support. Commercial decisions are best left to the private sector. The

private sector must take an active role in directing the innovation process from the outset to ensure that R&D fits market needs. New alternatives such as systems management may offer a means for firms to share costs and risks where large investment associated with high-technology products may exceed individual firm resources and to manage the innovation process more efficiently.

The Administration is undertaking continuing efforts to improve coordination of Federal R&D funding and improve the environment for innovation and development of commercial products by the private sector, including, *inter alia*, the Administration's proposal to make the research and experimentation tax credit permanent.

VI. APPENDICES

1. Semiconductors and Electronic Technologies

1.1 Introduction

Semiconductor products are critical elements of most high technology products and a basic element of the information technology age.

1.2 Introduction to the Technical Issue

Semiconductor manufacturing is a complex, multi-step process that simultaneously creates hundreds to thousands of copies of an integrated circuit on a semiconductor wafer that is ten to twenty centimeters in diameter. Each integrated circuit is composed of active semiconductor devices (transistors) and passive devices (resistors and capacitors). During the manufacturing process, millions of these devices are constructed simultaneously in each integrated circuit. The integrated circuits are composed of multiple layers of materials. These layers are configured to make up the devices in the circuit as well as the millions of conducting lines needed to interconnect the various devices in the circuit. More than one hundred meters of such interconnections may be created within each of the integrated circuits on a wafer. The resulting integrated circuits are cut from the wafer. Each is mounted in a plastic or ceramic package and is wired to tens to hundreds of "pins" which extend outside of the package. The pins of the package are later soldered to wired patterns embedded in printed circuit boards to form functioning products.

Advancing semiconductor technology is evolving toward even more complex semiconductor devices with smaller feature sizes. The evolution is driven by the need for more powerful semiconductor products and for reduced cost and size. The evolving technology is resulting in changes in processing and quality control, in materials technology,

in device design, and in packaging.

Improved processing and quality control requires new processing technologies, x-ray lithography as an example, which can produce finer structures and productivity improvements using existing technologies. The process of making an integrated circuit requires up to 500 steps. Most of these steps cause irreversible changes so that a single processing error can render an entire wafer useless. Measurements are usually not possible after every processing step, only some of them. The result is that additional, expensive processing steps are often applied to a wafer that has already become scrap.

Two principal classes of materials go into the manufacture of integrated circuits: (1) the starting silicon and compound semiconductor materials on which integrated circuits or individual transistors are formed, and (2) the materials introduced during subsequent processing steps to form layers and interconnecting lines. For both classes of materials, greater purity is required as the feature sizes of integrated circuits are reduced. In some cases impurity levels less than one part in a trillion are required. The seriousness of the problem is reflected in reports from U.S. manufacturers that sophisticated integrated circuit manufacturing processes that work with materials supplied by Japan sometimes do not work with U.S. materials; yet U.S. measurement methods are unable to detect the differences between the two sets of materials.

Particles that were specks at larger feature sizes are boulders to smaller feature sizes, and cause catastrophic flaws in the chips. Particles arrive in both gases and process chemicals, and are generated by process equipment, material handling, and the people who work in the process area.

As the size of semiconductor devices decreases, the solid-state effects of the boundaries of regions within the devices become significant. These effects were negligible at larger feature sizes. Computer models used in engineering design no longer correctly

predict the behavior of the devices, leading to serious difficulties in creating new integrated circuits that work properly.

As integrated circuits become more complex, so do the design requirements on their packages. More heat must be dissipated in smaller packages, more pins must be accommodated, and the sensitivity of integrated circuits to thermal stresses increases.

1.3 Funding Levels for Semiconductor Research and Development

The Federal funding for research and development in semiconductor technology is summarized in Table 1.

TABLE 1. Funding of semiconductor research and development (dollars in millions) by agency.

<u>Agency</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>
Energy	48	48	48
Defense	404	416	423
NSF	32	34	36
NASA	3	4	4
Commerce	3	3	3
Total	\$490	\$505	\$514

The budget data collected for this report was based on a unique set of definitions, a unique process for data collection, and on the budget projections during the 1989 fiscal year. For this reason these numbers do not track with, nor should they be compared to, the budget cross-cuts which have been prepared for subsequent budgets.

The agency programs are summarized in the following sections.

1.4 Department of Energy Semiconductor Program

The Department of Energy (DoE) carries out research on semiconductors and semiconductor manufacturing technology related to several DoE missions including solar energy, the weapons

program, basic energy sciences research, and high energy physics research. In addition, basic research to understand the properties and behavior of semiconductors is conducted both to broaden the knowledge base and to support the solar energy and weapons programs. The semiconductor program includes advanced processing of semiconductors, surface property measurements, research on developing new compound materials, and theoretical studies. Compound semiconductors are necessary for the integration of optical and electronic functions, and for high speed and microwave devices. Research is also directed toward development of subnanosecond, gallium arsenide, linear, photoconductive switches, and picosecond x-ray and gamma-ray radiation detectors. DoE meets with the semiconductor industry to exchange information, to make industry aware of DoE activities, and to take industry concerns into account. A workshop was held to develop a plan for the development of x-ray lithography, a process for imprinting finer features on semiconductors. The Department of Defense has provided funds to DoE's Brookhaven National Laboratory to design and build a compact synchrotron for this process. Industry has also expressed interest in DoE capabilities in compound semiconductor expertise, clean room technology, and advanced processing. DoE has funded development of a synchrotron at Louisiana State University to coordinate government efforts on x-ray lithography.

1.5 Department of Defense Semiconductor Program

1.5.1 Silicon and Gallium Arsenide Integrated Circuits. The Department of Defense (DoD) semiconductor technology program encompasses a range of fabrication technologies used to manufacture miniaturized electronic devices mainly on silicon or gallium arsenide substrates. The components of microelectronics fabrication technology may be divided into the following categories:

Wafer Preparation: The technology used for mass-production of high quality semiconductor wafers, including crystal growers, slicers, polishers, and preliminary dopant equipment.

Wafer Fabrication: The body of technologies used to fabricate integrated circuits on the prepared wafer, including lithography systems, ion-implantation machinery, thin film deposition and removal technology, clean room technology, etc.

Mask Making and Design: The "off-line" technology used to make "camera ready" circuit masks (used by lithography and doping processes), circuitry design (e.g., computer-aided design hardware and software), and device technology.

Assembly and Test: The so-called "back-end" of the microelectronic production process encapsulates the semiconductor die (or "chips") into a ceramic or plastic package (housing). This category includes the associated bonding equipment (wire bonders and die bonders) and the test machinery used for die-on-wafer testing as well as final packaged circuit testing.

Radiation Hardening: Hardening microelectronics against damage caused by high energy electrons, neutrons, protons, heavy particles, x-rays, and gamma radiation is vital to system performance in hostile radiation environments. Techniques used to accomplish that goal include special circuit designs, application of silicon-on-insulator (SOI) and silicon-on-sapphire (SOS) technology, and processing techniques to reduce radiation sensitivity of the silicon/silicon dioxide interface.

This fabrication technology has widespread use in both military and commercial applications, including computing, communications, and digital electronics. Many special manufacturing problems remain from a military point of view, however. The most important of them involves microcircuit reliability in hostile (i.e., combat) environments. Reliability problems caused by hostile environments often demand specialized manufacturing solutions that may not be available from U.S. industry. Solving these problems remains a critical aspect of DoD fabrication efforts.

DoD has extensive microfabrication technology development efforts underway. Perhaps best known is the DoD Very High Speed Integrated Circuits (VHSIC) program. Now in its final phase, the VHSIC program currently is focused upon refining the technologies required to achieve submicron (0.5 micron) feature sizes. This capability will allow fabrication of extremely dense and high-speed integrated circuits. In addition to the VHSIC program, DoD is also engaged in other silicon-based microfabrication technology R&D. In 1989, DoD agreed to support SEMATECH, an industry consortium formed to focus on advanced technology development. SEMATECH's specific program is still undergoing evaluation. DoD is also pursuing advanced lithography technology (ultra-violet, x-ray, and electron beam), and is developing radiation-hardened semiconductor devices (for both metal oxide and bipolar device types).

DoD is also developing microelectronics circuits on gallium arsenide (GaAs) substrates as well as on other compound semiconductors. DoD's Microwave and Millimeter-Wave Monolithic Integrated Circuit Program (MIMIC) is focused upon the development and production of affordable, reliable, analog circuits for use as sensors and signal processors in the front-ends of electronic warfare, radar, smart munitions, and communication systems. These circuits, fabricated primarily from gallium arsenide, operate at frequencies from 1 to 100 GHz. Devices being used include High Electron Mobility Transistors (HEMTs), and Heterojunction Bipolar Transistors (HBTs). Other programs develop millimeter wave power devices, wafer-scale technology, molecular beam epitaxy, and superlattice technology.

1.5.2 GaAs/Compound Semiconductor Materials. Gallium arsenide and other compound semiconductors (such as indium phosphide, indium antimonide, and mercury-cadmium-telluride) have historically played important roles in microwave and millimeter wave circuit devices as well as roles at other frequencies (eg., infrared and

optical). While these materials have well known potential for still other applications (such as high speed, radiation resistant, integrated circuits), fabrication difficulties prevented the realization of these potential applications. Since 1980, major technology advances have led to greatly improved GaAs materials. Preparation at the molecular level has recently permitted fabrication of the first truly microelectronic integrated circuits on non-silicon substrates. GaAs technology is expected to become competitive with silicon-based microelectronics, and promises significant advantages especially for military applications.

GaAs circuits could have significant technical advantages over their silicon-based counterparts because of two intrinsic advantages GaAs has over silicon, namely, a faster electron drift velocity and inherently better resistance to radiation damage. GaAs has an electronic drift velocity nearly seven times faster than silicon, a significant advantage which can now be exploited. Thus, a GaAs integrated circuit may be many times faster than a silicon-based counterpart of similar design and complexity. Gallium arsenide materials are also inherently less susceptible to damage caused by ionizing radiation (e.g., that experienced in routine space operations or in a nuclear blast environment) than silicon.

Despite its recent breakthroughs, GaAs device fabrication technology remains relatively undeveloped compared to more than two decades of research and development in fabrication technology for silicon devices. Development and incorporation of GaAs technology into new or existing microfabrication techniques is believed to be critical if DoD is to keep pace with materials preparation advances now occurring worldwide. Such developments would also significantly affect existing applications of GaAs technology, especially in millimeter and microwave systems. Materials preparation technologies include advanced III-V compound semiconductor epitaxy, II-VI compound semiconductor epitaxy, materials handling tech-

niques, and thin film deposition processes and equipment.

GaAs now is used in solid-state active-aperture-antennas (phased arrays). The same integrated circuit elements will appear more commonly in equipment for communications, electronic warfare, and electronic intelligence, avionics, missile guidance and control, and surveillance from space in the 1990s.

Work is in progress to develop a high-pressure liquid encapsulated Czochralski (HPLEC) crystal puller fitted with a variety of sensors to allow the reproducible production of larger diameter, larger overall size (20-25 kg) boules, of gallium arsenide substrate material with the electrical properties and uniformity necessary to provide starting materials for microwave and millimeter wave devices.

Work is also in progress to improve the control and uniformity of epitaxial gallium arsenide layers. Techniques being developed include Metal Organic Molecular Beam Epitaxy (MOMBE), Molecular Beam Epitaxy (MBE), and Metal Organic Chemical Vapor Deposition (MOCVD). Strategies for the short term are primarily directed toward improving the quality and reproducibility of wafers grown one at a time. Longer range plans call for development of equipment which would allow simultaneous epitaxial growth on multiple gallium arsenide wafers.

1.6 National Science Foundation Semiconductor Program

1.6.1 Semiconductor Physics and Materials Sciences.

The National Science Foundation (NSF) support for this area has the objective of providing a fundamental understanding of the mechanical, thermal, electrical, magnetic, optical, and other properties of semiconductor materials and other materials used in making semiconductor devices. This knowledge is the cornerstone of semiconductor technology.

1.6.2 Semiconductor Chemistry. NSF supports research on photochemistry for lithography, which remains the basic technology for mass production of integrated circuits. Basic research in both surface chemistry and inorganic chemistry is supported with the objective of yielding improved techniques for depositing or etching circuits on chips. New types of semiconductors made from polymers may emerge soon from basic research in organic chemistry.

1.6.3 Semiconductor Mathematics. NSF supports academic research on theoretical mathematics such as Boolean algebra, which formed the basis for the design of the first digital computers. Today, such semiconductor-related areas as device design and modeling depend on advanced mathematics.

1.6.4 Packaging Materials. Materials used in packaging integrated circuits have a profound effect on the performance and reliability of finished semiconductor products. Packaging materials technology becomes increasingly critical in modern devices with very small circuit dimensions and high power dissipation. NSF supports basic research in ceramic packaging.

1.6.5 Dielectrics. Various dielectric (non-conducting or insulating) materials are needed in semiconductor devices for such functions as providing electrical capacitance. New or enhanced dielectric materials could increase the capability or reduce the cost of such semiconductor devices. NSF supports research in this area.

1.6.6 Silicon Technology and Devices. NSF supports basic research in semiconductors with an emphasis on projects that may result in new technologies, devices, or processes. NSF supports the Semiconductor Research Corporation, which develops programs to strengthen the U.S. industrial position in semiconductor manufacturing. In addition, the NSF provides funding for several individual investigator grants for silicon devices, development, processing and device modeling.

1.6.7 Compound Semiconductor Technology and Devices. NSF supports research on devices with applications in signal generation, signal processing, chemical sensing, frequency conversion, and power processing with an emphasis on investigations into fundamental physical phenomena. The emphasis is on experimentally based research and on devices with long-range future impact and/or areas with a lack of fundamental understanding of device operation. NSF supports work on molecular beam epitaxial growth of compound semiconductors and growth and characterization of semiconductor quantum wells and superlattices. NSF provides support for academic researchers to use the semiconductor fabrication and processing facilities of the Electronics Technology and Devices Laboratory operated by the Department of the Army.

1.6.8 Device Processing Techniques. NSF supports investigations of advanced processing techniques that permit fabrication of improved and novel solid state electronic devices, with emphasis on fundamental studies of processes that have promise in device fabrication. New resists, ion implantation, transient processing techniques using lasers, and the development of x-ray lithography are some examples. NSF supports the Cornell National Nanofabrication Facility, which is a user facility for making small-feature-size semiconductor devices for research and development.

1.6.9 Integrated Electronics. The ability to design integrated circuits that incorporate many circuit elements onto one chip draws on a wide range of engineering disciplines. NSF-funded research in this area focus on maintaining circuit quality, performance, and reliability as circuits are designed on a progressively smaller scale. Improving the interconnections and contacts between circuit elements is also of critical importance.

1.7 National Aeronautics and Space Administration (NASA)

Semiconductor activities within NASA are focused on gallium arsenide (GaAs) technology.

The objective of this program is to develop GaAs digital integrated circuit technology for onboard high data rate signal processing applications such as: Robotic Vision, High Resolution Imagery Spectrum and the Geodynamic Laser Ranging System (GLRS) instruments. The technology development plan is structured to build on the previous development of Depletion Mode (D Mode) transistor devices to develop High Electron Mobility Transistor (HEMT) low power devices.

The D Mode development was initiated in FY83 after three studies identified GaAs as the most promising technology to meet NASA's onboard processing requirements for high data rate processing, low power, high reliability and radiation tolerance. In fiscal year 1983, a project was initiated to develop an Advanced Adaptive Processor (AAP) chip set. The AAP chip set is structured around a general purpose processor. Other devices in the chip set are the random access memory and gate array which were developed by DoD. During 1987, a general purpose processor, with controller, was fabricated using DoD's GaAs pilot line. Initial testing of the wafers show a good yield of fully functional devices. These two devices were integrated in 1988 and successfully applied to image data compression.

The present effort has a goal of developing a general purpose processor using the Minimum Instruction Processing Set (MIPS) architecture by 1992. In 1989, NASA continued a program initiated the Office of Naval Research to enhance the yield of random access memory devices with an access time of 1.0 nanosecond utilizing the HEMT devices. This device will be utilized as a memory in high data rate applications.

1.8 Department of Commerce Semiconductor Program

1.8.1 Program Objectives. The Semiconductor Metrology Program (SMP) in the Department of Commerce's National Institute of Standards and Technology (NIST) provides generic measurement methods and services, national reference standards, carefully evaluated reference data, technical consultation on metrology, and theory. These

support research, development, and manufacturing; promote equity in domestic and international markets; and aid international competitiveness of the nation's manufacturers and users of semiconductor materials, fabrication equipment, and devices. The program does not include development of new commercial device designs, new processing or assembly techniques, or new manufacturing equipment, except as these may arise logically as the outcome of the basic metrology mission.

1.8.2 Technical Activities. Integrated circuit manufacture is a measurement-intensive process. Roughly a quarter of the cost of the product is due to the cost of measurement. Only the most essential problems with significant impact potential ("high leverage" issues) can be addressed by NIST's relatively small program.

Projects are selected in response to measurement needs expressed by industry, particularly those that relate to the NIST missions of improving U.S. competitiveness and promoting equity in domestic and international trade. The dissemination mechanisms enumerated below frequently establish industry contacts that contribute substantively to input for planning. The extraordinarily dynamic character of the industry demands these close ties if the NIST program is to be responsive to industrial measurement needs. Most of the technical concerns of the industry are considered in the formal planning process.

Program work ranges across the metrological research and development board, from basic investigations of the behavior of materials and structures to the development of special circuits used in characterizing performance limits of devices and processes.

Special measurement methods are required to determine the levels of dopants, defects, impurities, and structural imperfections in semiconductor materials. Many of these measurement methods also support process development and control. Resistivity measurements of dopant density in silicon wa-

fers continue to be supported and improved. Methods for measuring oxygen and carbon in silicon wafers using non-destructive infrared optical techniques are being developed. Expertise with compound semiconductors continues to be advanced. A variety of x-ray techniques for characterizing semiconductor materials and structures are being developed using a recently completed beam line at the Brookhaven National Synchrotron Light Source.

Work continues on developing integrated circuit test structures as a major tool for verifying the performance of fabrication processes and the reliability of completed circuits. Activity is focused on the analysis of test structure data using machine learning algorithms and expert systems analyses. The algorithms digest historical data on fabrication processes to derive rules for use in expert systems. The expert systems provide real-time diagnosis of difficulties arising during subsequent processing and generate prioritized lists of candidate corrective actions. Test structures can also be used for reliability determination by examining failure mechanisms such as electromigration and time-dependent dielectric breakdown.

Models and measurements to support both integrated circuits and power transistors are being developed. For integrated circuits, theoretical studies of the quantized electron states in silicon and compound semiconductors are being conducted to understand device performance better. For power transistors, measurements for characterizing performance continue to be developed. A key aim is to provide measurements that can determine non-destructively the safe operating conditions for new types of power transistors, including those based on mixed technologies.

Standards for feature-size measurements on wafers are in constant demand from the industry for controlling the dimensions of integrated circuit patterns. Past calibration tools for use with photomasks are being extended to the smaller range of dimensions

now foreseen, using electron microscopy. Work continues on the very difficult problem of measuring these small scale features on wafers in the production process.

1.8.3 Dissemination of Results to Industry. The accomplishments of the program are disseminated through a special NIST publication series for major reports of program research (about 80 have been issued); quarterly progress reports; other NIST-published reports; and about 800 journal and conference papers. All are referenced in an annual NIST List of Publications in semiconductor technology.

The program also targets information to those who need it through seminars and workshops on special topics; talks at professional meetings; videotapes; visits to industry sites; visits to NIST by engineers and researchers in industry; consultations; industrial organizations such as the Semiconductor Industries Association (SIA), Semiconductor Equipment and Materials International (SEMI), and the Electronic Industries Association (EIA); and standards development in committees of the American Society for Testing and Materials, EIA, the Institute of Electrical and Electronics Engineers, and SEMI, for example. Dissemination is also accomplished through the sale of standard reference materials, the provision of computer codes on magnetic tapes, and informal consultations.

1.8.4 Collaboration with Industry. Collaboration ranges from industry's provision of materials or technical services not otherwise available to NIST through NIST participation in interlaboratory round-robin experiments to participation in cooperative research projects. Frequently, researchers in industry and at NIST will characterize the same set of specimens as part of the process of developing a new measurement method.

1.8.5 Services for Other Agencies. Semiconductor expertise and technical advice are frequently needed by other government agencies for a variety of reasons including export controls, antitrust and merger issues,

antidumping matters, etc. Program staff with appropriate expertise are made available as needed on a reimbursable basis. Measurement problems of concern to other agencies are undertaken at their expense, subject to mutual agreement on topics, costs and deliverables. National security matters are generally addressed by the program only when specifically targeted to the semiconductor industry, such as is the case with DoD's Very-High-Speed Integrated Circuits (VHSIC) and Microwave Monolithic Integrated Circuits (MIMIC) programs, and SEMATECH.

1.8.6 Formal Evaluation of Program Effectiveness. The activities of the program are reviewed in detail annually by a panel of experts from industry and academic institutions selected and administered by the National Academies of Science and Engineering. The panel reports candidly both informally and in writing. These evaluations provide valuable guidance and have a major influence on the conduct of the program.

Formal studies have examined the effectiveness of the SMP in assisting industry from an econometric point of view. These studies concluded that from 1973 to 1977 the NIST program increased the overall industry productivity level by approximately 1 percent. [Independent evidence indicates that this amounted to 5 percent of the increase in semiconductor industry productivity during that period.] The value of these productivity benefits was from \$30 to \$50 million per year over this period. Benefit:cost ratios for those NIST semiconductor projects which have been studied range from 5:1 to 110:1.

2. Fiber Optics and Optoelectronic Technologies

2.1 Introduction

Photonics is the name given to the generation, control and use of photons (light). It is the optical analog of electronics. Photonic or electro-optic devices and systems can have a large bandwidth. This means that huge amounts of data can be quickly switched and transmitted.

Photonic devices like electronic devices have diverse uses. However, photonic devices are not nearly as well developed as electronic devices, and many uses are not, at present, cost-effective. The main commercial application for photonics is for information transmission. A second major use, optical computing, is in the exploratory stage.

Photonic-based systems are becoming the system of choice for many high-data-rate uses. For example, the long distance telephone and data network is rapidly converting to photonic based systems. Even such short-haul uses as communication between racks of equipment in a large switching system or computer and between components of in-home high fidelity stereo systems are being taken over by photonic systems.

The advanced state of photonic transmission systems and their reliability can be gauged by the fact that the trans-Pacific and trans-Atlantic cables recently put into service are photonic systems capable of carrying the equivalent of 40,000 voice transmissions simultaneously; the previous coaxial cable system has a capacity of 10,000 voice channels. In addition, photonic systems are proposed for distributing data and high definition television (HDTV) signals to the home, a potentially huge consumer market.

Photonic systems are being developed and evaluated because they promise some potential advantages over electronic systems:

- a) They have gigabit wide bandwidths and so can carry a large volume of data.
- b) They are immune to many forms of electromagnetic interference.
- c) They are difficult to intercept and tap and so give better security.

A photonic transmission system has three basic components:

- a) Electro-optic input device—the input device changes the electronic input signal to a photonic (optical) output.

Present day technology uses an electrically switchable semiconductor laser. It was the invention of the laser in the late

1950's that ushered in the photonics age. Because a laser generates a coherent almost single frequency output, the design of low attenuation, non-dispersive systems are made much easier. Semiconductor lasers are small, complex devices made primarily of the III-V elements such as gallium, arsenic, and phosphorus. The processing technology used in production is extremely complex. Presently, molecular beam epitaxy, liquid phase epitaxy, and vapor phase epitaxy, are the predominant technologies.

- b) **Transmission Medium**—the information-bearing photons are transmitted over an optical fiber. An optical fiber is usually a thin fiber of silica glass about the diameter of a human hair; i.e., about 75 micrometers that can be made in unbroken lengths of many kilometers. Fibers, even when in bundles, can be readily spliced in the field.

The fibers have extremely low attenuation and dispersion, and signals need only be amplified after many kilometers. The low attenuation and dispersion characteristics are obtained by making the fiber of several layers of extremely pure glasses of different refractive indices.

- c) **Electro-Optic Output Device**—the output device converts the modulated photon stream at the end of the optical fiber to an electronic signal. The device is usually a semiconductor photo-diode. The technology used for its manufacture is similar to that used for the input devices described above.

The technology used in electro-optic input and output devices may be critical for key devices proposed for many advanced displays.

The high speed and high noise immunity of photonic systems make them a natural consideration for computing applications. However, several basic devices necessary for a completely photo-based

system are either not readily available, or are not cost-effective. For example, there is no cost-effective photonic analog to the transistor or integrated circuit. So presently, high speed electronic devices made with silicon or gallium arsenide are used to do the switching, amplification and memory functions, with photonics being confined to data bussing. However, many laboratories worldwide have strong R&D efforts on photonic computer devices and components.

The Department of Defense (DoD), via the Defense Advance Research Programs Agency (DARPA), has funded a program aimed at providing key gallium arsenide technology devices. Also, DoD, via the Air Force and in partnership with New York State and several universities, is forming a photonics center of excellence covering all aspects of photonics. In addition, several government laboratories are doing R&D in photonic based systems.

2.2 Introduction to Technical Issue

Low loss fibers, capable of supporting very high data rates were theoretically predicted in 1968 and demonstrated by U.S. industry only a couple of years later. By the end of the 1970's these new carriers of information were already being implemented in the Northeast corridor telephone system from Boston to New York to Washington, D.C. This first demonstration was with multimode fibers transmitting laser pulses operating at wavelengths of 0.8 to 0.9 micrometers and capable of transmitting information over three channels of 90 megabits/s/channel. Since this very early demonstration the industry has moved rapidly to single mode fibers carrying laser pulses at 1.3 micrometers, where the losses are much less, and usually operate in excess of 1 gigabit/second.

High data rate single mode optical fiber networks now encompass the entire U.S. and reach to both Europe and Japan. This rapid deployment of fiber optic telecommunication systems has required very significant developments in basic and applied research and component manufac-

turing. The necessary components include laser diodes operating at 1.3 micrometers, fiber connectors, couplers, detectors, modulators, optical waveguides, optical multiplexers and demultiplexers, low loss fiber operating near the theoretical limits, and all the supporting specialized instrumentation. The systems will soon be operating at wavelengths of 1.55 micrometers where even lower losses in the fibers are possible.

The fibers themselves are capable of carrying much higher data rates than at present, even in excess of 100 gigabit/second, and in the future more sophisticated modulation schemes will realize this potential. Also coherent communications are being extensively researched and may be implemented in a few years. Coherent communications have the potential of enhanced signal-to-noise ratios and thus greater distances between repeaters where the signal must be detected, reconstructed, and again transmitted. Coherent communication also holds the promise of enabling very large numbers of channels operating at different wavelengths to be transmitted through a single fiber.

The next major thrust in fiber optic telecommunications is the transmission of information to homes and business places connected through subscriber loops and local area networks (LANs). These implementations are likely to depend heavily on integrated optics, especially modulators, wavelength-division multiplexing and demultiplexing, and optical-to-electronic interfaces. These new developments will require extensive basic and applied research and product development.

Optical fiber sensors are another major potential application of photonics. These sensors can measure temperature, pressure, electrical current, and many other phenomena. Important products being developed include hydrophones and fiber-optic gyros. These sensors are often very important for special situations such as chemical processes, shipboard and space applications. They hold much promise for medical applications. For the most part these products are in the applied research stage and require further work in the manufacturing process, engineering the components to work in harsh envi-

ronments, material properties, and general marketable product development. They hold significant promise for future markets.

2.3 Procurement Policies

Existing Federal procurement policies and regulations for items incorporating fiber optics and optical electronic technologies are the same as they are for all other items. The policies and regulations emphasize widespread dissemination of announcements for bid competitions followed by competition and bid evaluation based on lifecycle costs and performance. Procurement decisions are based on agencies' programmatic needs and not on the promotion of specific technologies. Specific procurement regulations can be found in the Federal Acquisition Regulations.

2.4 Funding Levels for Fiber Optic and Optoelectronic Research and Development

The Federal funding for fiber optic and optoelectronic research and development is summarized in Table 2.

TABLE 2. Funding of photonic research and development (dollars in millions) by agency.

Agency	1988	1989	1990
Energy	9	10	10
Defense	80	118	116
NSF	13	14	16
NASA	7	4	4
Commerce	2	2	5
Total	\$111	\$148	\$151

The budget data collected for this report was based on a unique set of definitions, a unique process for data collection, and on the budget projections during the 1989 fiscal year. For this reason these numbers do not track with, nor should they be compared to, the budget cross-cuts which have been prepared for subsequent budgets.

The agency programs are summarized in the following sections.

2.5 Department of Energy Fiber Optic Program

The DoE conducts research and development that is intended to contribute to the knowledge base used to advance the state of the art in fiber optics and optical electronic technologies and the uses of fiber optics and electro-optical components in new applications. Research under the weapons program includes the synthesis, characterization and processing of glasses; investigations of non-linear optical properties of materials; and the effects of impurities on the optical properties of disordered materials. The goals are to improve the performance of these materials for use in diagnostic instrumentation for real-time monitoring of shock waves, lasers and weapons testing. Research is also underway on the possible applications of fiber optics and electro-optical technologies to sensors, detectors, modulators, and switches with their associated electronic drivers and amplifiers. The work is expected to make possible the implementation of new and unique diagnostics and to increase the capabilities for down-hole control and monitoring of complex experiments. Other research is on infrared photocathodes and a microchannel plate intensifier.

2.6 Department of Defense Fiber Optic Program

2.6.1 Fiber Optic Communications and Sensors.

During the past decade, fiber optics has been incorporated DoD communication and sensor systems. The next decade will see a proliferation of DoD systems which rely on fiber optics to perform their functions. Today's fiber optics will provide ships, aircraft, and undersea communications with higher bandwidth capabilities at lower cost than cable approaches. Ultra low-loss fluoride fibers, with their theoretical loss of 0.001 dB/km, will permit transoceanic repeaterless links which could revolutionize undersea surveillance, long distance communications, and tethered vehicles such as fiber guided missiles. Fiber optical sensors will provide a new class of gyros as well as an acoustic, magnetic sensor for inertial navigation, antisubmarine warfare, and commercial applications. DoD's research and development efforts in fiber optics support all of these

applications as well as optical components, fiber optic cabling, and fiber coatings.

Ultra-low-loss fiber optics technology is an area of great importance to DoD. This technology consist of optical fibers fabricated with zirconium fluoride glasses. These glasses are the lowest scatter material ever produced and represent a major advance in glass chemistry. This technology is crucial to such systems as large aperture, high-gain, acoustic arrays (thousands of acoustic sensors interconnected over tens of kilometers), and long-range command guided anti-ship missiles. Continued integrations of electronic processors and controllers with fiber optical devices, improved interconnects, switches and multiplexers, and higher power, frequency tunable optical sources are important elements of this technology.

The superiority of fiber optic communication over copper-based systems can be measured by information-carrying capacity (four orders of magnitude greater for optical systems), energy loss in signal transmission (two orders of magnitude lower), error rate (one order of magnitude lower), and resistance to electromagnetic interference (EMI). Future developments in semiconductor lasers promise still greater improvements in data rate capacity and link margin.

Ultra low-loss fiber optics will support a number of critical military capabilities:

- o Wide area surveillance,
- o Undersea and tactical missile guidance (low-cost, target and aimpoint selection), and
- o Remote surveillance and tele-operated weapons platforms (removing the requirement for personnel to enter high-threat areas).

Fiber optic communication links will add a whole new range of capabilities for weapon guidance since they provide for wideband, non-line-of-sight, two-way communication. The Fiber-Optic-Guided Missile (FOG-M) is a prototype which provides a television or

infrared image to the gunner, who guides it to the target while staying in a safe location. Advances made in fiber optics technology will provide future local area voice and data communications networks with more reliability and survivability. The tactical fiber optic local area networks can satisfy the need to distribute command posts by providing high capacity interconnection.

Fiber optical sensors support major improvements in Anti-Submarine Warfare (ASW) surveillance as well as providing the basis for autonomous underwater vehicle guidance. Future acoustic towed arrays from surface ships and submarines require at least 10 times the number of acoustic channels in either multi-line or extra long arrays. Fiber acoustic sensor arrays appear to offer the best approach for this application. High-performance, high-gain planar fiber acoustic arrays offer significantly increased capabilities. Bottom-mounted acoustic fiber sensor arrays connected by fiber optic telemetry cables will play a key role in enhancing DoD's capability to counter advanced submarine threats.

There are a number of DoD programs in fiber optics, fiber optic sensors, and semiconductor lasers of various types. Applications likely to be ready for full scale engineering by the year 2000 include fiber guided missiles, fiber optic local area networks for land and sea with bandwidths in excess of 20 GHz, high speed computer interconnects using fiber optics, phased array control by an optically-fed harness to the transmit/receive elements, and intrusion detection systems made with optical fibers.

Ultra low-loss fiber optic technology is being pursued by DoD in its technology base and advanced technology demonstration programs, and can be expected to be available for incorporation in engineering developments by the mid- to late-1990s. DoD is also developing a rugged, non-kinking fiber optic cable for the FOG-M.

2.6.2 Integrated Optics. Integrated optics (photonics) encompasses the technology for

devices that use light (photons) and electronics (electrons) to perform functions that are now typically performed by electronic devices. The next 20 years will see the emergence of photonic devices in sensor, communication, and information processing systems. Photonics developments can provide major improvements in tactical and strategic systems. The DoD advanced technology developments in photonics include optical memories, optical signal processing, optical computing networks, optical control of phased arrays, integrated opto-electronic networks, and nonlinear optical processing.

Integrated optical computing offers order-of-magnitude improvements in processing speed resulting from the natural parallel architecture and high switching speeds of optical devices. In addition, integrated optical circuits eliminate many potentially troublesome connectors and increase reliability. New distributed processing architectures will exploit the absence of metallic wires and concomitant electromagnetic interference problems.

The processing rates for emerging electro-optical and infrared sensors, electronic warfare and undersea surveillance are surpassing the capabilities of electronic processing (1-10 Gbit/s). Dedicated integrated optical processors will soon be needed which act as sensor front ends to reprocess the data and reduce data rates to those compatible with current and projected electronic processors. Dedicated special purpose integrated optical processors are now in use within DoD in such front end applications.

2.7 National Science Foundation Fiber Optics Program

2.7.1 Fiber Optics. The NSF supports university research efforts in optical fiber technology for communications, sensing, and switching applications. The projects involve fundamental research and vary widely from investigations into the transmission of data to the creation of devices for integrated optics and the investigation of nonlinear optics

phenomena for possible use in optical switching devices.

2.7.2 Optical Computing. The NSF supports a number of academic research projects in the use and exploitation of optical phenomena for possible applications in optical computing, processing, logic, displays, imaging, and others. Current research indicates that these functions, carried out by light rather than electricity, offer greater speed via faster switching capability and more massive parallelism, much greater information flow, and freedom from electronic interference.

2.7.3 Photoelectric and Optoelectronic Devices and Systems. The NSF supports academic research on semiconductor devices that exhibit photoelectric or optoelectronic properties. This research is aimed at yielding optoelectronic logic devices with theoretical switching speed orders of magnitude greater than possible with electronic logic devices.

2.8 Fiber Optics and Electro/Optics Programs at NASA

The NASA has several key programs in fiber-optic and electro-optics research and development for applications in space and aeronautics. The key programs are:

- (1) Spaceflight Optical Disk Recorder (SODR),
- (2) Fiber Optic Rotation Sensor Program (FORS),
- (3) Fiber Optic Control System Integration (FOCSI),
- (4) Multi-Purpose Fiber Optic Transceiver (MFOX),
- (5) Optical Communications, and
- (6) Photonics Research.

2.8.1 Spaceflight Optical Disk Recorder High rate (300 Mbps), high capacity (80 Gbit) rewriteable optical disk drive and controller demonstration units will be developed to support an expandable system concept providing up to 1.8 Gbps data rate and greater

than 1.2 Tbit capacity. Potential applications include buffering and management of high resolution sensor data. This random file access recorder system will support selective transmission of high priority scene segments and provide data storage for higher level, non-real time processing. This activity includes development of flight prototype 14 inch media and diode laser arrays. Test bed demonstrations are planned with an early flight demonstration of a drive brassboard.

2.8.2 Fiber Optic Rotation Sensor Program. The objective of the FORS program is to develop a 10-year-lifetime, low cost, light weight, highly reliable, and high performance navigation grade optical gyroscope as part of the spacecraft inertial reference unit (IRU). The technology for the development of an IRU with these characteristics is key to future NASA missions such as the Comet Rendezvous and Asteroid Flyby (CRAF), Mars Orbiter, and Earth Orbiting platforms.

The thrust of this activity includes development of state of the art integrated optics technology using lithium niobate substrates, semiconductor lasers, and fiber optic waveguides operating with 1.3 micrometer wavelength light. Test bed and brassboard demonstrations are planned.

2.8.3 Fiber Optic Control System Integration The goal of the fiber optic control system integration program is to design, develop, test, and flight demonstrate a fiber optic integrated propulsion/flight control system for an advanced supersonic aircraft. The program consists of three phases. The first phase was to conceptualize an all fiber optic integrated control, define the sensor environment, evaluate the status of optical sensor readiness in industry, and as final output, provide a milestone chart for developing the technology to the point where it could be incorporated into production aircraft. The results of this study phase indicated that fiber optic/passive optical sensor technology was feasible and desirable. Additionally it showed that this technology will improve reliability through electromagnetic immu-

nity while providing weight reduction for the aircraft. The second phase of the program is aimed at the selection, fabrication and testing of the preferred electro-optic architecture and its integration with a set of representative sensors for both the propulsion and the flight control system. The third phase of the program will be a flight test in which the electro-optic architecture and sensor system will be installed on an aircraft to run as a piggyback experiment. Flight tests of representative sensors and associated electro-optic architecture will be conducted in the FY 1993-1994 timeframe.

2.8.4 Multi-Purpose Fiber Optic Transceiver

The objective of this program is to provide a space qualified 0.05-4 Gbits/s fiber optic transceiver for space data systems, for use on Space Station, Earth Orbiting platforms, and planetary missions. This will require the development of an all integrated circuit transceiver that is fully military and space qualified. This activity also includes the development of high speed semiconductor lasers. An initial model of this high speed fiber optic space data system will be fabricated and evaluated in 1991.

2.8.5 Optical Communications The optical communications program develops the technology base required for the optical transmission of high resolution data from deep space planetary bodies for both robotic and piloted exploration missions; and for geostationary-to-geostationary, and geostationary-to-low-earth orbit missions. This program will develop the required components for optical communications such as: high power and long lifetime lasers, high speed optical modulators, high speed detectors, ultrastable oscillators, and ground base receivers.

2.8.6 Photonics Research The photonics research program consists of the following tasks: acousto-optic spectrum analysis, spatial light modulator development, and image processing system development.

Acousto-Optic Spectrum Analysis — The objective of this research is to develop and demonstrate the technology for real time wideband, high resolution, acousto-optic spectrum analysis of RF signals. Acousto-optic spectrum analysis has potential applications in radio astronomy, radar astronomy, and any other application where a wideband RF signal or a narrowband RF signal in a large analysis bandwidth is to be analyzed in real time.

Spatial Light Modulator — This task will exploit new quantum well devices to arrive at high performance optically or electrically addressed spatial light modulators. The approach focuses on a specific SLM based on modulation (switching) of the gain in optical amplifiers.

Image Processing System — This research focus on the development of an intelligent optical vision system that is able to perform optical pattern recognition and feature extraction. A new real-time updatable holographic writer will be developed for use in this vision system to accommodate NASA's planetary and outer space exploration needs.

2.9 The Department of Commerce Optical Fiber Program

The Department of Commerce R&D program is carried out in the laboratories of the National Institute of Standards and Technology (NIST). The objective of the optical fiber program at NIST is to provide the base of consistent physical measurements and standards required to support the development and commerce of optical fiber telecommunications.

This program has been in operation for about 12 years in close collaboration with the industry through the Electronics Industry Association (EIA), its new subsidiary the Telecommunications Industry Association (TIA), and other standards organizations. It has developed, refined, tested and established 28 standard measurement techniques for characteristics of optical fibers such as: attenuation, bandwidth, refractive index profile, core diameter, numerical aperture,

mode field diameter, cut-off wavelength, birefringence, Verdet constant, OTDR calibration, etc.

The initial emphasis of the program was on the characteristics of the optical fibers themselves because these were the major limitations on telecommunication technology. After much development, single mode fibers evolved to the extent that they now have potential channel capacity that is several orders of magnitude greater than can be used with the comparatively primitive terminal equipment in use today. Now, there are government and private sector efforts worldwide to develop faster transmission, wavelength division multiplexing, optical switching, coherent communication, and other techniques to make full use of the potential channel capacity of optical fibers that are already installed. The program at NIST is expanding to give full support of measurements and standards for these new technologies.

The expanded program includes establishing methods to measure the characteristics of optical waveguides in a variety of substrates. This is a basic technology for many of the new devices under development. A calibration service has been established for optical fiber power meters, using standards already established for laser power meter calibration (improved standards are under development). Two measurement systems are being developed to measure the response of laser diodes, detectors, modulators, and other devices to very fast pulses. A system has been developed to measure the wavelength emitted by laser diodes to support wavelength division multiplexing. Ultimately the means to make consistent and reliable measurements of the engineering characteristics of all components of advanced optical telecommunication systems will be established.

Another application of optical fibers with high commercial potential is to sensors. This requires fibers with certain characteristics that differ from those of telecommunication fibers, particularly with respect to the preservation of polarization and sensitivity to external conditions such as magnetic field, temperature, strain, etc. The optical fiber program at NIST encompasses the

measurement of the special characteristics of these fibers and the development and evaluation of prototype sensors for current, voltage, magnetic field, and other quantities. This work is complementary to that on telecommunication fibers.

3. Superconducting Material

3.1 Low Temperature Superconductors — Introduction to the Technical Issue

3.1.1 Low temperature superconductivity, as represented by conductors for large magnets used in high energy physics, experiments in fusion energy, and magnetic resonance imaging research, is a viable American industry. Superconducting wire and cable are produced by a number of companies in this country and magnets in varying sizes are also made here. However, it is believed that the requirements for sophistication of the wire composite will increase as the demands of new applications increase.

3.1.2 The low temperature superconductor industry developed in the U.S. over the past 20 years. All of the methods now considered as "standard" for the production of these materials were developed slowly as the commerce developed. Such concepts as: a) dividing the superconductor into many fine filaments within a conducting matrix in order to stabilize the magnets against flux motion, b) the wind-and-react technique for the manufacture of magnets from the brittle niobiumtin intermetallic superconductor, or c) the use of thin film superconductor layers on a strong tape, came from the national laboratories and the industrial laboratories working together on problems ranging from basic physics to industrial production. In the final analysis, however, widespread commercialization of these products remains unlikely because they must be operated at or near the temperature of liquid helium. The technology of producing and handling this very cold and expensive liquid is complex.

3.1.3 There are no technical barriers to commercialization of NbTi conductor and there is, in fact, a significant market for these wires and cables. Other, higher field materials such as Nb₃Sn and V₃Ga present some problems although they are available commercially on a limited scale because of the limited number of uses. In both cases, the brittle nature of the superconducting filaments creates problems manufacturing long lengths. There are other superconducting materials known with unique and desirable properties for some applications such as NbN, Nb₃Al and PbMoS which may lead to commercial products.

3.1.4 Superconducting electronic devices have demonstrated outstanding speed, bandwidth, and sensitivity. However, commercial devices are limited to simple magnetic field sensors (SQUIDs) for use in medical and other scientific studies. A high speed sampling system has not sold well. While superconducting microwave mixers are the detector of choice for radioastronomers, the market is very small. More complex devices include a voltage standard developed at NIST and used in 17 laboratories around the world. A very high speed microprocessor developed in Japan offers great promise but is still in laboratory development. Military applications have been under investigation for several decades but none are yet in actual use.

3.1.5 The development of high transition temperature superconductors has produced a renewed interest in low transition temperature superconducting electronics. For many military applications the added cost of cooling with liquid helium is not significant, although added weight of refrigeration remains a problem. Ultra-high-speed microprocessors could be of considerable importance. Just as reduced instruction set computers are making major advances in conventional integrated circuits, the astonishing speed of a superconducting microprocessor could be of significance. The quality of superconducting electronics for scientific applications continues to increase and these should produce a small market.

3.1.6 The technical problems blocking more widespread application include integrated circuit manufacturability and reliability although substantial progress has been made recently. The requirement for cooling with liquid helium inhibits simple applications, but in high value applications such as ultra-high-speed computing, refrigeration is an engineering problem which can be overcome.

3.2 High Temperature Superconductors — Introduction to the Technical Issue

3.2.1 Commercialization of high temperature superconductivity has been the subject of numerous studies and the goal of several major consortia. These materials offer great promise because they bypass the constraints imposed by operation in liquid helium, an expensive substance that is difficult to handle. The possibility of materials that are superconducting in the range of conventional refrigeration methods is real, but not yet achieved. Several problems exist with the high temperature materials that must be resolved before commercialization can be considered on any large scale. They are complex materials that are not well understood. They are brittle ceramics, which makes the production of wires difficult (although Nb₃Sn and other low temperature superconductors are also brittle and have been successfully made into very long lengths). They have widely different superconducting properties depending on direction through the crystal structure which makes large, polycrystalline conductors with good properties very difficult to create. There is no good theory for this type of superconductivity, something which is essential for rapid progress in the development of new materials.

3.2.2 High-transition-temperature superconducting electronics offers potential advantages like those of low temperature superconductors to electronic applications: speed, bandwidth, and sensitivity. Refrigeration should be much simpler with an operating temperature near that of liquid nitrogen. In cases where extreme sensitivity is needed, cooling with liquid helium may continue to be required.

3.2.3 High transition temperature superconductors are difficult to form into integrated circuits. Their sensitivity to precise control of chemical composition makes high quality thin films difficult to fabricate. The heating, which is often used in such processes, can change the composition, damaging superconducting properties. Fabrication of monolithic layered structures such as electrically insulated crossings or tunnel junctions (the superconducting counterpart of the transistor) has never been demonstrated. Other technologies do not offer much guidance to the likelihood of eventual success, although it is clear that a massive amount of educated trial and error will be required.

3.3 Funding Levels for Research and Development in the Area of Superconducting Materials.

The Federal funding for research and development in the area of superconducting materials is summarized in Table 3.

Table 3. Funding of research and development in the area of superconducting materials (dollars in millions) by agency

<u>Agency</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>
Energy	69	138	165
Defense	60	73	72
NSF	20	26	29
NASA	4	6	6
Commerce	3	3	4
Total	\$156	\$246	\$276

The budget data collected for this report was based on a unique set of definitions, a unique process for data collection, and on the budget projections during the 1989 fiscal year. For this reason these numbers do not track with, nor should they be compared to, the budget cross-cuts which have been prepared for subsequent budgets.

The agency programs are summarized in the following sections.

3.4 Department of Energy Superconductivity Program

3.4.1 Low Temperature Superconductivity. This research is conducted primarily because superconducting magnets are required to advance the performance of expensive experimental devices utilized in magnetic fusion energy and high energy and nuclear physics. Such magnets also reduce the substantial electric power cost of these accelerators, detectors, and experimental plasma fusion reactors. In fusion, the emphasis has shifted to development of high-field steady state and pulsed magnets. For accelerators and detection devices, research and development focuses on the development of superconducting wire, materials, and magnets.

3.4.2 High Temperature Superconductors. DoE carries out research and development on high temperature superconductors primarily in support of three program missions: Basic Energy Sciences, Conservation and Renewable Energy, and Defense Programs.

The Basic Energy Sciences research emphasizes synthesis, measurement of properties, determination of properties, theory, characterization, processing, investigation of novel electronic devices, and instrumentation that might benefit from incorporating the unique properties of these new materials. Much of the work is on fundamental questions regarding how materials become superconducting, the parameters of critical temperature, critical magnetic field and current, and synthesis of new materials to expand these parameters.

In Conservation and Renewable Energy, the emphasis is on applications in motors, generators, transmission lines, and other electrical equipment. The goal is to reduce the amount of electricity used by such devices, and the cost of running them. An extensive technology transfer effort includes three pilot centers at DoE laboratories; a series of interlaboratory meetings with university and industry participation telecast over the National Technology University network; a newsletter of world-wide research preprint titles; and database and information centers.

Under Defense Programs, the research is on theory, materials characterization and materials synthesis to gain a scientific understanding of the fundamental properties responsible for superconductivity. There are many possible applications to the Inertial Fusion Program, the Nuclear Weapons Technology Program, and the Strategic Defense Initiative. This includes research on fast-opening switches, levitation bearings, solenoids, and electro-magnetic shielding.

3.5 Department of Defense Superconductivity Program

3.5.1 Low Temperature Superconductivity. Superconductivity technology encompasses both traditional metallic low-temperature superconductors (transition temperature below 23 K) and the new high-temperature superconductors (transition temperature as high as 125 K). Of concern are issues related to their basic properties, their fabrication into usable configurations, and their unique device and systems applications. Potential applications capitalize on the ability of superconductors to support lossless dc currents and low-loss ac currents, to levitate, to shield magnetic and electromagnetic fields, to sense magnetic and electromagnetic fields with unmatched sensitivity, to transmit electronic signals with extremely little distortion, and to fulfill analog and digital electronics functions at speeds 10 to 20 times faster than and at power dissipation 1,000 times less than is possible with semiconductors. Critical to all such applications are efficient and reliable refrigeration systems.

Large-scale, low-temperature superconductivity technology is relatively mature. Literally thousands of supermagnets are in routine use, but there has been only modest exploitation in military systems. Sensors and analog electronic devices are also highly developed, while digital electronics systems are at an earlier stage of development, at least in the United States. This technology promises high utility not only in its own right, but also for pioneering systems to be executed later with higher temperature superconducting materials at such time as that proves

feasible. High temperature materials are in their infancy and are difficult to process. A heavy investment in R&D will be required if their apparent potential is to be realized. The course of development will probably proceed from electronic transmission lines to sensors to analog and digital electronics to a variety of supermagnet applications.

Superconductivity applications, some of which have already been tested in prototype form, include more compact, higher-efficiency, electric drive systems for ships (and possibly land vehicles and aircraft), electric generators, electric energy storage systems for directed energy weapons, superconducting-cavity-particle-accelerator directed energy weapons, electromagnetic sensors from dc through infrared, infrared focal plane arrays, ultra-high-speed, ultra-compact signal processors and computers, high-performance low-noise communications and surveillance systems, superconducting antennas, and superconducting gyroscopes, inertial sensors, and gravimeters. In all cases, the performance advantages of such systems must compensate for the necessary refrigeration penalties. Many of these systems are unique with no normal-conductor counterparts, e.g., superconducting magnetic energy storage systems. In other instances new capabilities can be brought to platforms incapable of supporting conventional semiconductor counterparts, e.g., with superconducting electronic technology it should be feasible to place ultra-high-speed supercomputing capabilities onboard aircraft and space craft, a capability not feasible with semiconductor technology because of its large input power requirements (200 kilowatts) and associated massive cooling system requirements.

DoD programs in low temperature superconductivity research are coordinated through a wide number of intra-service and inter-departmental coordinating mechanisms, including working groups, annual program reviews, and special review panels. The coordinating vehicles help insure against duplication of effort and keep focus on topics of importance.

3.5.2 High Temperature Superconductivity. Future U.S. military electronics will require significant increases in signal processing capability as the number and accuracy of various sensors (infrared, acoustic, radar, etc.) exceeds the ability of existing signal processing hardware to translate this information into usable form. To address this, DoD's first priority in high temperature superconductivity is the development of high temperature superconducting analog-to-digital converters. These devices will be considerably faster than existing converters and will consume far less power. Also of high priority are various analog devices, particularly of the passive microwave type. These will be developed in the near-term and will probably be the first superconducting components utilized in military systems. Gyroscopes, accelerometers, digital devices and meters also have high research priority.

There are critical scientific problems, however, which may inhibit the realization of DoD research goals. These barriers are: (1) imperfect thin film deposition techniques, (2) lack of a superconductive transistor-like (or three-terminal) device, (3) inadequate material capabilities, and (4) incomplete understanding of the mechanism of high temperature superconductivity. DoD is well aware of these technical barriers and its program, by necessity, includes multiple contractors addressing each (particularly in film deposition and materials development).

DoD's program in high temperature superconductivity is focused at the Defense Advanced Research Projects Agency (DARPA). It addresses high temperature superconductors and is a technology-driven program rather than basic research. The program comprises three areas: (1) synthesis, processing and fabrication of materials, (2) pre-commercial manufacturing science issues, and (3) conceptual device development. Since high temperature superconducting materials are brittle ceramics, the first task is fabrication into engineering forms such as wires, coils, and thin films, each with optimized material properties (e.g., mechanical

strength). Manufacturing issues include understanding process control for reproducible quality and quantity of HTSC components, scale-up issues, and cost-effectiveness. Device demonstrations will provide data for checking improvements in system performance while development aspects are oriented toward near-term retrofit of present systems and longer term design of new HTSC devices that may require changes in present systems technology. The DARPA program is designed to develop technology for military systems, however, these technologies may have commercial applications.

3.6 The National Science Foundation Superconductivity Program

3.6.1 Solid State Physics. The National Science Foundation supports research to bring a wide variety of experimental techniques to the study of new high temperature superconductors. Areas of research focus include electronic and crystal structure, and electronic, magnetic, spectroscopic, and thermodynamic properties.

3.6.2 Solid State Chemistry. The NSF supports research to bring experience in chemistry to the synthesis of solid state oxide superconductors.

3.6.3 Low Temperature Physics Research in low temperature physics has long had superconductors as a focus. The NSF currently supports research on bulk properties, thin films, and superconducting devices.

3.6.4 Condensed Matter Theory. The NSF supports solid state theorists to develop models, computer simulations of physical behavior to understand physical limitations of superconductors such as critical temperatures and fields.

3.6.5 Metallurgy. The focus of NSF support in the area of metallurgy includes understanding of metallic and structural behavior of superconductors, and the microscopic behavior of superconducting properties.

3.6.6 Ceramics and Electronic Materials. Current high temperature superconductors

are ceramics. This area of research seeks to expand knowledge of superconductor processing, modification, and synthesis and characterization of superconducting ceramic oxides.

3.6.7 Polymers. Research supported by NSF in this area involves the synthesis of polymeric superconductors.

3.6.8 Superconducting Applications. The NSF supports research leading to applications of both low temperature and high temperature superconductors. Research on high temperature superconductivity includes microwave and strip-line applications. Support is also provided for power applications.

3.7 National Aeronautics and Space Administration Superconducting Materials Program

The Office of Aeronautics and Space Technology (OAST) of the National Aeronautics and Space Administration (NASA) has instituted a program in high temperature superconductivity for applications in space and aeronautics. The program centers around four technology thrust areas:

- I. Communication and Data Systems
- II. Sensor and Cryogenic Systems
- III. Propulsion and Power Systems
- IV. Space Materials Technology

The high-temperature superconductor program includes benefit studies of typical aerospace applications. The research is directed at characterization of new high-temperature superconducting materials for unique aeronautics and space applications including the effects of vacuum and space radiation. Selected thin film and bulk device research will be supported for the most promising aerospace applications identified from the applications studies in data, communications, sensors, cryogenics, propulsion, and power.

3.7.1 Communication and Data Systems. This technology thrust area is complimentary to an on-going base program in OAST in communications and data technology. Space data technology is key to the on-board processing of space generated data, which can exceed a gigabit per second. This massive computational rate is key to future NASA missions, such as the Mars Rover and Sample Return Mission, where some degree of autonomy is a critical mission requirement. In addition, space-based communication is critically important for both geostationary-to-geostationary, geostationary-to-low-earth-orbit and deep-space-to geostationary missions. High speed microwave components and ultrastable oscillators are critical to enable these missions. The following is a partial list of areas of study, research, and development in this area:

- o High speed switches
- o Ultrastable oscillators
- o Microwave components
- o Low noise receivers

3.7.2 Sensor and Cryogenic Systems. This technology thrust area is complimentary to an on-going base program in OAST in Sensor Technology whose main focus is remote sensing of galactic, planetary, and terrestrial phenomena. However, the HTS thrust covers this and in situ sensing applications for both space and aeronautics application areas. Cryogenic technology which revolves around the cooling of focal planes for the various remote observations instruments is key to future NASA missions, such as the Large Deployable Reflector, a 10 to 15 meter reflector for observations from the submillimeter to far infrared portions of the electromagnetic spectrum. The following is a partial list of areas of study, research, and development in this area:

- o Accelerometers for space and aeronautics applications
- o Magnetometers
- o Gyroscopes
- o Mixers
- o Local oscillators
- o Bolometers
- o Magnetic refrigeration

3.7.3 Propulsion and Power Systems. This technology area is complimentary to ongoing base programs in OAST in space power and propulsion technology. Propulsion technology is key to future NASA missions. The proposed manned mission to Mars and the return to the moon for a permanent manned station are just a few areas where this technology is a prerequisite. Space power technology is key to future NASA missions, such as the Mars Rover and Sample Return Mission, where the mission science requirements is heavily dependent on available power and storage. Concepts and technologies in these areas have obvious spinoffs in the aeronautics area. The following is a partial list of areas of study, research, and development in this area:

- o Magnetic bearings
- o Magnetoplasmadynamic thrusters
- o Electromagnetic launchers
- o Energy storage
- o Power transmission

3.7.4 Space Materials Technology. This technology thrust area is directed toward developing materials or processes which will result in high-temperature superconducting materials which are stable in the space environment.

3.7.5 Low Temperature Superconductivity. Low-temperature superconductivity work includes device research utilizing superconducting insulating-superconducting (SIS) junctions for remote sensing applications, superconducting quantum interference devices (SQUIDS) for magnetic sensing and gravity gradiometer instrument applications, superconducting cavities for precise time and frequency determination, and magnets for detector applications.

3.8 Superconductor Research at the Department of Commerce

3.8.1 Introduction. The Department of Commerce carries out its superconductivity research at its National Institute of Standards and Technology (NIST). The technical program may be described in four parts as follows.

3.8.2 Superconductor Properties. Low temperature superconductors are already developed into engineering materials with several technically successful applications, but their characteristics present unique measurement problems that have been the subject of research at NIST for over two decades. These include the measurement of critical current and its variation with magnetic field, temperature, mechanical strain and other test conditions; the measurement of ac loss and other magnetic characteristics; the determination of the limits of stability; and the measurement of basic superconductor characteristics such as the energy gap, the isotope effect, etc. These measurement problems are of equal importance in ceramic and metal superconductors. Standards activities include technical contributions to the development standards adopted by the private sector, a standard reference material for critical current measurements, and international coordination.

3.8.3 Composition and Structure Analysis. Systematic development of ceramic high temperature superconductors must be guided by reliable determination of chemical composition and physical structure of test specimens. NIST has established a wide range of test facilities for this purpose. These include neutron scattering (both elastic and inelastic); x-ray diffraction (including a catalog of diffraction patterns); photoemission spectroscopy; micro-Raman spectroscopy; electron and ion microprobe analysis; neutron activation analysis; isotope dilution mass spectrometry; and ultrasonics. Applying all these techniques to one specimen enables a comprehensive analysis of structure and composition to be made at a wide range of scales.

3.8.4 Process Data. The design of fabrication processes for ceramics depends upon information relating process variables to product materials. Research to establish such data for the high temperature superconductors is in progress in NIST. This includes the establishment of phase equilibrium diagrams; devising and testing process conditions to

promote grain orientation; preparation of starting materials in optimum form; and the establishment of processes to fabricate thin films of high quality.

3.8.5 Superconducting Electronics. There has been a program in superconducting electronics at NIST for over two decades, with the objective of developing the next generation of techniques, instrumentation, and physical standards for a variety of electrical and magnetic measurements. There is a fabrication facility for superconducting microcircuits that has produced SQUID magnetic detectors, an analog-to-digital converter, a fast counter, millimeter wave mixers, and a voltage measurement system that incorporates the basic national standard. All these are based on thin films of low temperature superconductors and Josephson junctions. Present work includes further development of a power standard for infrared and microwave radiation based on a kinetic inductance bolometer. Research to extend the fabrication of microcircuits to high temperature superconductors is in progress. This includes the establishment of processes to fabricate high quality thin films and perform lithography. The greatest challenge is to fabricate reproducible Josephson junctions. Some progress has been made in this area.

4. Advanced Manufacturing Technologies

4.1 Introduction

Flexibility in manufacturing, especially the ability to make incremental improvements to products and process technologies, contributes to competitiveness. Various studies have documented the need for U.S. firms to improve in this area, relative to foreign competitors.

4.2 Introduction to the Technical Issue

Historically, manufacture and measurement have always been two separate processes. A machinist would cut a part on a milling machine and stop periodically to check dimensions with calipers and gauges. As manufacturing techniques became more and more efficient, the measurement part of the operation consumed an

ever-greater percentage of the total work required to produce a part. The development of automated "coordinate-measuring machines" (CMMs) in the 1970s helped somewhat, but measurement still used up about 50 percent of the total time required to produce a precision part.

It would be many times more efficient if the machining process could be made to produce accurate parts without being interrupted by the measuring process. Not only would it take less time, but fewer parts would have to be scrapped for being out-of-tolerance. (Some surveys have shown that in the U.S. one-third of the work force in manufacturing industries is engaged in rework; that is, correcting out-of-tolerance parts made by the other two-thirds.) Research suggests that the problem can be solved by use of today's computer-controlled machine tools, because the position of the cutting edge of the tool is known and controlled at all times, at least in theory, by the computer. The computer can be programmed to compensate for known errors in the machine's movement, using sensors that feed back information on the machine's condition.

This concept of feedback and process control is being broadly applied in advanced manufacturing and affect materials handling, quality control, design, and support as well as fabrication. This trend stimulates the need for a variety of new technologies including robotics, sensors, and advanced control technology. Data handling and communication are also becoming more important in manufacturing.

Even for the largest firms the lack of agreed-upon standards for "interfacing" complex equipment is a difficult — and costly — problem. For close to 90 percent of the discrete parts industry — about 100,000 firms — the problem is worse. These are much smaller companies (fewer than 50 employees) without great financial resources. Discrete parts producers, those who make products in small batches, are responsible for about 75 percent of the total U.S. trade in manufactured goods.

If they choose to automate, the smaller companies frequently prefer to buy automated machinery in stages, one or two machines at a time, and slowly build up to an integrated system. The

effectiveness of this approach would be enhanced by the flexibility to buy from different manufacturers at different times with the assurance that the machines they buy will work together properly without expensive, custom-designed interfaces. This is the same flexibility that one can now find when buying the parts of a home stereo system from several different manufacturers, knowing that they will all plug together. These firms also would benefit from a system flexible enough to switch from the production of one part to another quickly and without expensive reprogramming.

4.3 Funding Levels for Advanced Manufacturing Research and Development

The Federal funding for research and development in advanced manufacturing is summarized in Table 4.

TABLE 4. Funding of advanced manufacturing research and development (dollars in millions) by agency.

<u>Agency</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>
Defense	154	170	173
Commerce	3	3	3
Total	\$157	\$173	\$176

The budget data collected for this report was based on a unique set of definitions, a unique process for data collection, and on the budget projections during the 1989 fiscal year. For this reason these numbers do not track with, nor should they be compared to, the budget crosscuts which have been prepared for subsequent budgets.

The budget numbers shown in this table do not include funding for robotics, and therefore do not show several agencies with which have budgets in that area. The President's FY 91 budget request contains a complete crosscut on robotics funding. A data collection for advanced manufacturing, including robotics, is planned for the President's FY 92 budget.

The agency programs are summarized in the following sections.

4.4 Department of Defense Advanced Manufacturing Program

DoD established the DoD Manufacturing Technology Program (ManTech) in the late 1950's in response to a growing need for advanced production processes. Each military department has a mature ManTech program. The Defense Logistics Agency recently established one. Inter-organizational coordination is accomplished via the Manufacturing Technology Advisory Group (MTAG). It consists of an executive committee and six technical committees which meet at various times throughout the year. Once a year, the MTAG holds a plenary meeting for the entire DoD ManTech community. Attendance has grown to over well over 600 (a high of 1100) during the past several years — two-thirds from the private sector. The meeting includes Service overviews, industry panels, and numerous technical sessions where the results of ManTech projects are discussed.

The ManTech program has produced many success stories. One example involves the development of a laser welder for producing tank engine components. The new welding process is more productive and produces higher quality welds than previous methods. It is estimated that the \$1 million ManTech investment produced a cost avoidance of \$3.5 million. Another project successfully established a more efficient method of producing gallium arsenide integrated circuit substrate material. It has been estimated that the new process paid for the ManTech investment in less than the first month of production. All three Military Departments are benefiting from this project.

ManTech's primary goal is to improve the productivity and responsiveness of the defense industrial base by engaging in initiatives which develop advanced manufacturing technology which will permit DoD and its contractors to produce DoD material more efficiently by using less production resources. While DoD invests in the establishment of advanced technology, DoD contractors normally are expected to invest in the capital equipment necessary to implement that technology.

ManTech program results are distributed via numerous methods. Technical reports are distributed by the sponsoring organization and/or the contractor involved. The reports are also deposited centrally at the Defense Technical Information Center (DTIC) which provides secondary distribution. DTIC's services were augmented in June 1984 by the establishment of a Manufacturing Technology Information Analysis Center (MTIAC). MTIAC serves as a focal point for DoD's manufacturing technology information. It also answers queries on various technology subjects and prepares technical assessment reports such as: 1) higher order languages for robots; 2) artificial intelligence and expert systems applications in manufacturing; 3) evaluation of finite capacity scheduling and simulation systems; and 4) automated inspection systems for flexible machining systems.

The ManTech Program uses other vehicles to distribute program results — one of the most effective means is the end-of-contract briefing. Many (about 100 per year) ManTech contracts require the performing organization to summarize the contract accomplishments for its peers. While attendance is by invitation only, the sponsoring agency will accommodate others if they have a valid reason to send a representative. These briefings give the attendees the opportunity to review the results first hand with the expectation that they will be applied to local problems.

Some ManTech funds are used internally in DoD activities but most of the nominally 200 projects funded each year are awarded to private sector contractors.

The following is a partial list of DoD's planned FY90 ManTech investments.

4.4.1 Department of the Army.

FY 1990:

- o Initiate efforts to improve crystal growth and manufacturing capability for basic integrated circuit materials.
- o Continue to develop alternate process to manufacture access and egress mats and bridge decks with smaller extrusions and

precision welding. Expand effort to enhance current production methods for medium duty landing mats and heavy duty membrane materials.

- o Continue to develop production methods for heat stable enzymes used in detection devices for chemical and biological agents and toxins.
- o Continue investigating gaps in precision gear manufacturing technology.
- o Complete robotized wire harness effort with definition and specification of generic equipment for a variety of wire types and characteristics.
- o Continue machine tool tasks on: improving product quality by computerizing in-process tool wear monitoring and control; computerizing measurement of product's surface finish, straightness, roundness, and cylindricity in order to map defect areas; and computerizing metal finishing bath process control in order to maintain correct chemical balance.
- o Continue work on a variety of ammunition production investments such as: automating stick propellant blending; safely sampling nitroglycerine; mechanizing the assembly of mine clearing line charges; and automated testing of high volume production of infrared transducers for seeker type munitions.
- o Enhance various technologies required to modernize/automate repair and rebuild of tactical vehicle engines.

4.4.2 Department of the Navy.

FY 1990:

- o Utilize the Automated Manufacturing Research Facility (AMRF) to demonstrate the architecture and concepts necessary for the "seamless" processing of part description data through process planning, NC code generation, robot path creation, inspection plan generation, and material handling.

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- o Demonstrate the technology for quality control in the unmanned small batch size environment by developing technology for deterministic metrology.
- o Demonstrate advanced casting technology for 16" and 5" projectiles.
- o Initiate project to develop technology for refurbishment of engine parts (turbine blades/vanes and static components).
- o Demonstrate improved manufacturing process for ausrolling gears.
- o Develop technology for automated tape laying of complex shapes.
- o Develop shape melting technology for fabrication of ship and submarine components.
- o Develop improved manufacturing technology for thermoplastic secondary aircraft structures.

4.4.3 Department of the Air Force.

FY 1990:

- o Complete financial support of the National Center for Manufacturing Sciences.
- o Continue work on producibility of electronic subsystems, flexible micro-electronic manufacturing systems, and advanced radar modules.
- o Continue efforts to implement advanced technologies in repair depots while continuing efforts on flexible repair center and Computer Aided Acquisition and Logistics Support.
- o Continue activities to provide economical manufacturing methods for composite airframe components.
- o Complete development of computer integrated composites manufacturing center.

4.4.4 Defense Logistics Agency (DLA).

FY 1990:

- o Continue work on establishing three apparel manufacturing research centers. Develop in-process quality control systems, computer simulation of apparel manufacturing models, ergonomic research, and real-time data collection.
- o Establish advanced technology for combat rations manufacturing.
- o Establish advanced technology for producing gears by initiating acquisition of equipment for "center for excellence" and begin work on spiral bevel gear cutting machine technology.
- o Establish advanced technology for producing bearings by awarding contract for "center of excellence" for bearing production.
- o Initiate activities to establish DLA's Industrial Modernization Incentives Program through eight investments in bearing and apparel industries. In FY 91 begin application engineering for four factories of the eight factories.

Note: In addition to the ManTech program funding, many other DoD development programs produce advances in manufacturing that are targeted toward specific programs. The results, however, may be used in many other products as the techniques are disseminated through personal contacts, technical contacts, or conferences. There is no reliable way to estimate the manufacturing R&D funding attributable to such programs, but the total could easily exceed that in the ManTech Program.

4.5 Department of Commerce Advanced Manufacturing Program

The core of the Department of Commerce's advanced manufacturing program is the Automated Manufacturing Research Facility (AMRF) at NIST. The AMRF is an engineering laboratory in the Center for Manufacturing Engineering at NIST. The facility provides a basic array of

manufacturing equipment and systems—a “test-bed”—that researchers from NIST, industrial firms, universities, and other government agencies can use to experiment with new standards and to study new methods of measurement and quality control for automated factories.

The AMRF includes several types of modern automated machine tools, such as numerically controlled milling machines and lathes, automated materials-handling equipment (to move parts, tools, and raw materials from one “workstation” to another), and a variety of industrial robots to tend the machine tools. The entire facility operates under computer control using an advanced control approach pioneered at NIST. The AMRF incorporates some of the most advanced, most flexible automated manufacturing techniques in the world.

NIST, as the nation’s primary laboratory for measurement science and engineering, has two principal goals for its automated manufacturing program: to supply American industry with a radically new way of making precisely machined parts—with dimensions that can be referenced to national measurement standards maintained by NIST—and to encourage the modernization of American manufacturing by providing the technical information necessary to develop standardized “interfaces” between various types of equipment. NIST also is using this facility as a testbed for research on the next generation of “knowledge-based” manufacturing systems—automation systems that incorporate artificial intelligence capabilities.

The effective transfer of technical information requires standardization—standard procedures, standard protocols, standard interfaces. The challenge is to develop standards which support current technology and yet still encourage equipment manufacturers to develop new and innovative products. These are problems that NIST is solving in the AMRF.

Three industrial standards have already been developed based on NIST automation research. For example, a standard method for exchanging graphics data between otherwise incompatible computer-aided design (CAD) systems, developed by a government-industry coalition led by

NIST, was adopted by the American National Standards Institute (ANSI), a private voluntary standards organization. The standard now is supported by all U.S. CAD vendors which have at least a 1% market share.

NIST has recently established the National PDES Test Bed at the AMRF to support industry and government projects in developing and testing the Product Definition Exchange Specification (PDES), the next generation of data interchange standards for automated manufacturing. Recent demands for solid modeling, configuration control, fully computer-interpretable data, and interactive access by cooperating users have led to the need for PDES, one of the most ambitious standards ever attempted.

Implementing the new standard currently under development by voluntary standards organizations, industry, and government still requires serious technical effort. Implementations must be tested as they are built to uncover problems and inconsistencies in the various definitions.

Experienced researchers working in a testbed environment such as the AMRF can identify potential problems and suggest clarifications and interpretations of the standard. Work in the AMRF on manufacturing data preparation has already developed a product part model which is consistent with the expected PDES standard. AMRF researchers are testing to determine the effectiveness of this part model as the information needed by the manufacturing applications in the facility. As PDES is developed, this effort will be expanded.

AMRF research also led to standards for the characterization of computerized coordinate measurement machines, and for a method of surface texture measurement. Seven other potential standards are now being considered by various industrial standards groups.

The AMRF is a unique government facility for many reasons, including:

- o Its location at the National Institute of Standards and Technology. As an open federal laboratory with no commercial interests, NIST can make this facility ac-

cessible to private firms interested in automation research—firms that individually could not afford such a complex research facility. NIST has a long history of working with private firms and organizations to develop standards and measurement and test methods that benefit the entire industry.

- o The active participation in the AMRF by industry, universities, and other government agencies. The AMRF has become a focal point for interactions among all American researchers in automated manufacturing.
- o The use of a wide variety of commercially available machine tools and robots. This is a direct result of the NIST decision to study the most practical, incremental route to automation for the small- to medium-sized firm; it is an approach that has never been used before.
- o The flexibility of the system. One of the goals of the AMRF is to create a facility that is, in the jargon of the researchers, "data driven"—the actions of the various machines and robots should be determined primarily, or solely, by a computerized description of the part to be manufactured. This stands in contrast to modern "flexible manufacturing" cells which are truly flexible only for a limited "family" of parts for which the machine tools are programmed.
- o Sensory interaction. The AMRF makes use of an unusually versatile robot control system in which sensory information from, for example, the NIST robot vision system is fed back to the controller to provide a basis for its decisions. This is important because it enables the system to react to its environment, eliminating the need for a lot of rigid programming.
- o The scope of the facility. Research at the AMRF covers everything from the preparation of data on a new part to final automated inspection.

The AMRF is not a prototype of the "factory of the future." It is extremely unlikely that any actual factory would resemble the AMRF, at least physically. The AMRF is a laboratory for studying factory automation. Further, the AMRF is not a demonstration project. Although it does demonstrate several new and potentially important techniques for machine control and the integration of diverse systems, the AMRF is not a museum piece but rather a working research facility.

In addition to NIST funding, the Navy's Manufacturing Technology Program is a major source of support. Private firms and universities also contribute to AMRF research through the donation or loan of equipment or by providing personnel through the NIST Research Associate Program.

The Research Associate Program is also one of the ways that NIST research results are transferred out of the AMRF. Another approach to transferring this technology is through the establishment of the Manufacturing Technology Centers Program at NIST. The objective of this program is to accelerate the transfer of advanced manufacturing technology to small- and medium-sized U.S. businesses to assist these firms in improving their manufacturing and process capabilities and market competitiveness. Each center will apply advanced manufacturing techniques to the needs of manufacturers located within its region. The advanced technologies transferred will emphasize those developed at the AMRF. Each center is expected to communicate its experience to all interested parties.

While research is the focus of the AMRF, the transfer of advanced manufacturing technology is the primary task of the Manufacturing Centers Program. Activities of each center are expected to include: 1) informing and educating the industrial firms in its region about ad-

vanced manufacturing techniques; 2) demonstrating the applicability of advanced technology to these firms; 3) actively assisting firms in evaluating their requirements; 4) assisting with the implementation of desired applications; 5) supporting work-force training and retraining; and 6) communicating technology transfer experiences to a wide national audience.

One aspect of this new program is that it represents the first time the federal government explicitly attempted to establish an intermediary between the federal laboratories that perform research and development in new technological areas and the small- and medium-sized manufacturing firms that hope to benefit from the availability of this technology.

NIST's successes in transferring technology have generally been a result of cooperative research agreements in which private sector personnel spend up to a year working side-by-side with NIST staff solving some problem of mutual interest. Some of these agreements also entail a donation of some piece of equipment to the AMRF. In these cases, the research program will typically involve incorporating the equipment into the AMRF. At the end of these cooperative research programs, the visiting staff return to their organizations, taking with them the knowledge of advanced manufacturing techniques developed in the AMRF.

This technology transfer process has worked well for NIST over the years. Unfortunately it only works well for large firms, with a large enough staff that they can afford to send one or two staff members to NIST for an extended period of time. Obviously, this is not the case for most of the small- and medium-sized manufacturing firms in this country. This is the motivation for the establishment of regional centers—to serve the needs of the manufacturing firms in their region by working closely with them to identify

technological improvements that can help these firms improve productivity. These centers must serve as more than just brokers, however. It is also their responsibility to help increase the flow of technology out of federal laboratories by identifying technologies that can benefit industry, and where necessary, extracting that technology, refining it, packaging it, fine tuning it, and otherwise making it available and useable to the general public. This step is important because it is not the mission of the federal laboratories, including NIST, to engage in product development. This manufacturing Technology Centers Program at NIST is unique. It builds on the resources of NIST and other laboratories while establishing a mechanism to combine the push of new technology development with the pull of manufacturing competition for marketshare.

Three organizations have been selected to become the first NIST Regional Manufacturing Technology Centers: The Manufacturing Technology Center at the Cleveland Advanced Manufacturing Program in Cleveland, Ohio; The Northeast Manufacturing Technology Center at Rensselaer Polytechnic Institute in Troy, New York; and The South Carolina Technology Transfer Cooperative based at the University of South Carolina in Columbia, South Carolina. NIST has established cooperative working arrangements with each of these organizations.

DRAFT

F. G. SGT

[March 26, 1991]

U.S. INDUSTRY ACCESS TO JAPANESE SCIENCE AND TECHNOLOGY

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Executive Office of the President

**Conference on U.S. Industry Access
to Japanese Science and Technology**

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It is a pleasure to be here to open this conference on "U.S. Industry Access to Japanese Science and Technology." International cooperation and competition in science and technology are issues of vital importance to this country, and that importance is only going to grow as markets and technology transfer become increasingly global.

In part, the increasing globalization of economies is a reflection of the widening influence of science and technology in our lives. Science and technology have always been among the most international of all human activities. It is frequently the case that scientists and technologists are on more intimate terms with colleagues on the other side of the globe than they are with those at the other end of the hall. What happens in Japan or Germany in biology is often of more interest to a biologist than what happens across the campus.

At an even more fundamental level, the globalization of markets reflects a deeper transition from predominantly resource-driven economies to information-driven economies. As Walter Massey, the new Director of the National Science Foundation, has

said, "The resources that are most critical to progress today are no longer mined from the Earth but are created in the mind."

Francis Bacon said much the same thing four centuries ago in his Religious Meditation. He wrote, "Nam et ipsa scientia potestas est," which translates as "knowledge itself is power." I might add, by the way, that since coming to Washington I've heard that when Senator Everett Dirksen first heard this quotation, he immediately replied, "particularly if you know it about the right people."

This morning I would like to begin by discussing the United States' general policies toward science and technology. I shall then turn specifically to international science and technology, which Bob White and Reggie Bartholomew (or John Boright) will examine in more detail.

Importance of Science and Technology in Government Policy

Today, science and technology are integral elements of both domestic and international policy in the United States. One place where this can clearly be seen is in the budgets that President Bush has sent to Congress for the past two years. In both of those

budgets, science and technology were among the very first items featured, second only to increasing the national savings rate (in the FY 1991 budget) and education and prevention (in the FY 1992 budget).

In general, the Bush Administration views science and technology as key investments in the future economic prosperity and national security of this country. The past investments we have made in science and technology have paid great returns in economic growth and an improved quality of life. These returns are going to continue, most likely at an accelerating pace, in the years ahead.

In the Fiscal Year 1992 budget, the President proposed a record \$75.6 billion for research and development, a 13 percent increase over the amount Congress appropriated for FY 1991. In a year when real growth in the domestic discretionary budget is essentially limited to the rate of inflation, this increase for R&D -- one of the largest in the federal budget this year -- marks a major commitment to science and technology.

One area of emphasis in this year's budget is basic research. To take advantage of the countless scientific opportunities available to researchers at our nation's colleges and universities, the budget

proposes an 18 percent increase in funding for the National Science Foundation and a 9 percent increase in funding for research project grants awarded to individual investigators at the National Institutes of Health. By focusing on these two agencies, the Administration is seeking to strengthen the individual investigator and small group research that remains the heart and backbone of American science and technology.

Yet basic research clearly cannot be the only component of a nation's R&D enterprise. Other nations such as Japan have R&D enterprises that bring great benefits to society yet include very little basic research. The difference is that these systems are able to very efficiently and effectively exploit the results of basic research, no matter where it is done. This is the stage of the innovation process -- the stage between the generation of knowledge and its application in the marketplace -- that poses the greatest challenges to the United States.

To help strengthen the latter stages of the innovation process, the budget includes funding for many areas of applied research and technology development, including high performance computing and communications, energy technologies, biotechnology, advanced manufacturing and materials, and aeronautics. To take just one

example, the budget includes a special Presidential initiative on high performance computing and communications, which is designed to sustain and extend America's preeminence in this critically important area of technology. This program, which was put together by an interagency committee organized through my office, focuses on the hardware, software, networks, and human resources that will be necessary to increase computing and communications capabilities by several orders of magnitude. In my view, these new capabilities could have the kind of catalytic effect on society, businesses, and universities that the telephone system has had during the twentieth century.

The budget emphasizes a number of areas of applied research and development. In fact, it goes so far as to state that it is providing increased funding "for all major civilian applied R&D areas." This is an important measure of the Administration's intentions.

In a speech to the recipients of the National Medals of Science and National Medals of Technology last fall, the President said, "Today, our government must help carry [basic] research forward and contribute to the development of generic technologies that build on basic discoveries. If America is to maintain and strengthen our

competitive position, we must continue not only to create new technologies, but learn to more effectively translate those technologies into commercial products. In this way, we can help leverage the R&D of the private sector, helping whole industries advance in an increasingly competitive global market." As part of this commitment from the highest levels of government, applied research and technology development are going to be increasingly important federal emphases.

Science and Technology Policy in the Executive Branch

Let me describe for a moment the institutional structure within the Executive Branch that shapes science and technology policy, because it is important both in developing the budget numbers I have been describing and in considering international science and technology. As science advisor to President Bush, I wear several different hats. First, I am an assistant to the President and therefore part of the White House staff. In my role as assistant, the President has made me a member of the Economic Policy Council, the Domestic Policy Council, and the National Space Council, which

are three of the senior policy-making bodies within the White House.

I am also the Director of the Office of Science and Technology Policy, which is an office of about 40 people situated within the Executive Office of the President. This office, which was created in 1976, serves several functions. It helps me in the preparation of the information, analysis, and advice that I provide to the President in science and technology policy. It works closely with the Office of Management and Budget in reviewing and shaping R&D budgets within the federal government. And in general it monitors and acts as a source of information for the President and the rest of the Executive Branch on what might be termed policy for science and technology -- the influence of federal actions on the science and technology enterprise -- and science and technology for policy -- the influence of scientific and technological considerations on broader issues of national and international importance.

The same legislation that created OSTP also created an entity called the Federal Coordinating Council for Science, Engineering, and Technology, which goes by the rather unfortunate acronym of FCCSET. FCCSET is a Cabinet-level entity that was established to review and coordinate activities in science and technology that cut across the missions of more than one federal agencies. The

members of FCCSET now consist of the Secretaries and Administrators of the agencies and independent agencies involved with science and technology, together with the Assistant Secretaries of the agencies involved with science and technology less directly. With this level of representation, FCCSET is having a major impact on science and technology activities throughout the federal government.

Following its reorganization last year, FCCSET formed seven umbrella committees in science and technology. One of these is the Committee on International Science, Engineering, and Technology, which is chaired by Reggie Bartholomew, with Fred Bernthal of the National Science Foundation and Philip Schambra of the National Institutes of Health as Vice-Chairmen. That committee has initiated a number of activities in such areas as the intellectual property protection annexes in science and technology agreements and international cooperation on megaprojects in the basic sciences.

It is important to keep in mind when considering FCCSET, however, that all of its members, by law, must be government employees. Obtaining the private sector's input on matters of science and technology was one of the reasons why the President established his Council of Advisors on Science and Technology

(PCAST). This is a group of twelve distinguished representatives of industry and academia that meets monthly with the President and with other high members of the White House staff to discuss a broad range of issues in science and technology. Furthermore, PCAST has been setting up panels in specific areas of science and technology, many of which parallel the FCCSET committee structure so that the private sector's views can be used to calibrate the activities of the federal government.

International Science and Technology

Having described the institutional structure that will be shaping science and technology policy, I want to spend some time addressing the question of international research and development -- and particularly the concern of this conference, access to Japanese science and technology.

I believe very strongly in international access to basic science and basic technology, and particularly in the free flow of researchers and ideas. Unlike some other forms of international exchange, science and technology are positive sum games where international

cooperation benefits all participants. The question is not whether a country gains or loses from such cooperation. The only question is the magnitude of the gains. To quote my friend and predecessor William Graham, "Science is the rising tide that raises all ships."

There is no question that other countries are building on our basic research. But we unquestionably gain much more by maintaining an open system than we could by trying to build barriers. As you know in your own countries, the markets for technology and ideas are global, and anyone who's really interested can gain access to them.

We gain not by restricting access to our technology but by developing capabilities greater than our competitors. Thus there is a very strong link between our domestic activities in science and technology and our international efforts. By further developing our own science and technology enterprise, we will inevitably strengthen our international standing in the marketplace.

Some individuals, recognizing the link between our national science and technology and international competitiveness, have called for restricting international access to U.S. science and technology. For basic research and the development of precompetitive technologies, I believe these calls to be misguided.

After all, in the early years of our development, the U.S. technical community relied heavily on access to European science and technology.

But we do need to do a better job of monitoring and drawing on technologies from abroad, including Japan. The Commerce Department has mounted some ambitious, if still underused, programs in this area, and I know you will be discussing them later today and tomorrow. These and similar programs will continue to grow in importance as other countries become even more competitive in science and technology.

We must also work to ensure that individual researchers and private sector firms are able to participate in R&D endeavors in the other country's territory to the same extent that domestic researchers in that country can do. Although there may be projects for which these rules do not apply, we should strive to achieve a level playing field for all parties.

The Protection of Applied Technology

At some point in the continuum between basic research and the development of commercial products, R&D moves from being precompetitive to competitive. Because this point is not always well defined, some countries tend to be overcautious in defining R&D as competitive.

I am convinced, however, that the line between competition and cooperation can be sharply drawn. The results of fundamental research are, by their very nature, public knowledge. What can and, in some cases, must be protected are the details of a particular application of the results of this fundamental research. This know-how, in the final analysis, is our only edge in an increasingly competitive world.

What this country needs to do is be much more focused on those aspects of technology that we want to protect. Rather than trying to protect a broad range of technologies, we have to focus on the particular technologies -- and particularly on the systems integration inherent in technologies -- and protect those things as firmly as we can.

As part of this effort, we have to be much more vigorous in enforcing intellectual property rights than we have been in the past. Of the three sectors of American industry that have remained most successful internationally during the 1980s -- the pharmaceutical industry, the chemical industry, and the aeronautics industry -- two of those have the strongest IPR protection of virtually any American industry. The protection of intellectual property has been a key element in their success.

We are reviewing our international science and technology agreements to ensure that research pursued in cooperation with foreign countries is subject to strong IPR protection. As many of you may know, IPR protection is also a major element of the Administration's objectives in the multilateral trade talks convened under the GATT.

We also have to identify much earlier than we have in the past exactly what we want to get in return for our technology. All too frequently in the past we have sent representatives to international negotiations without clear instructions on what we wanted to get and what we were prepared to give, and not surprisingly we have sometimes come out of those negotiations without the results that we might have wished. I will be doing my best to make sure that

such lopsided negotiations do not happen in the future.

Future International Cooperation in Science and Technology

In general, I see international cooperation becoming an even greater feature of science and technology policy in the future. For example, we are about to design a program to determine future cooperation with the Japanese and others on Intelligent Manufacturing Systems, and the Japanese have proposed another program on advanced computing. In these efforts, we are taking a number of steps to ensure that openness and international cooperation strengthen the competitiveness of our economy and our nation's science and technology capabilities.

The reciprocal benefits of science and technology are the main reason for my being here today, and for OSTP being a cosponsor of this conference. Access to science and technology in Japan and in other countries is going to be vitally important to the continued vitality of American science and technology. If our own science and technology enterprise is to remain health, we must ensure that we know and appreciate what is going on internationally.

For many years the United States has had the strongest science and technology enterprise that the world has ever known, but the world situation is now changing. Our overall preeminence is not being challenged. But in specific areas, other countries, by focusing their efforts into particular areas, have moved up to equal, and in some cases surpass, the scientific and technical achievements of this country.

We have nothing to fear from these international achievements. Rather, we should view them as opportunities. Still, to take advantage of these opportunities, we must have and take advantage of access to foreign science and technology. Those of you in this room -- as well as scientists, engineers, and managers throughout this country -- must make a concerted effort to look beyond our own borders to the renewed scientific and technological expertise of the world.

The development of this expertise should not surprise us. As I said at the beginning of my remarks, science and technology are inherently international activities, and other countries were bound to recognize and emulate the successes that American science and technology has brought to this country. But the great benefit of science and technology is that they can make the world better for

everyone. As Louis Pasteur once said, "Science knows no country because knowledge belongs to humanity and is the torch which illuminates the world."

