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Engineering Research *and* *America's Future:*

Meeting the Challenges of a Global Economy

James Duderstadt
President Emeritus –
University of Michigan

Report is available at:
http://books.nap.edu/catalog/11393.html

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Engineering Research and America's Future

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- PROCESS: To arrive at the findings and recommendations of this report, the National Academy of Engineering has used a process that involves careful selection of a balanced and knowledgeable committee, assembly of relevant information, and peer review of the resultant report. Over time, this process has been proven to produce authoritative and balanced results.

NAE Committee

Assessing the Capacity of the U.S. Engineering Research Enterprise

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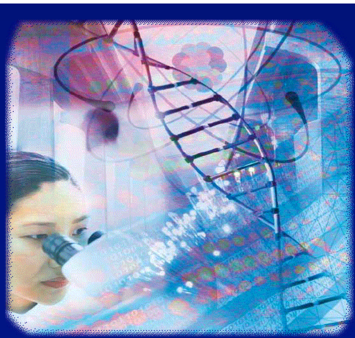
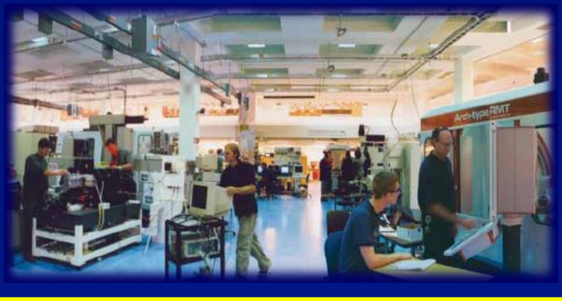


The Context

- Demographics, globalization, technological change
- Global, knowledge-driven economy
- Out-sourcing, off-shoring, inadequate diversity
- Importance of technological innovation to economic competitiveness and national security



The Charge

To conduct a "fast-track" evaluation of

1) the past and potential impact of the U.S. engineering research enterprise on the nation's economy, quality of life, security, and global leadership; and

2) the adequacy of public and private investment to sustain U.S. competitiveness in basic engineering research.

The Consensus Report Process

2004: Hearings and development of preliminary findings and recommendations

December 2004: Report is reviewed by panel of experts.

January 1, 2005: Release of a public (reviewed) draft report for comment from the engineering community.

March 2005: Utilize feedback to re-draft report. Review again.

April 2005: Publication of Final Report

Note: Text in *BLUE* is not part of the normal report process and represents an additional and broader vetting of the recommendations presented.

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Stage 1 Reviewers

- Anonymous peer review in accordance with NAE standards
  - Craig R. Barrett, Intel Corporation
  - G. Wayne Clough, Georgia Institute of Technology
  - Siegfried S. Hecker, Los Alamos National Laboratory
  - C. Dan Mote Jr., University of Maryland
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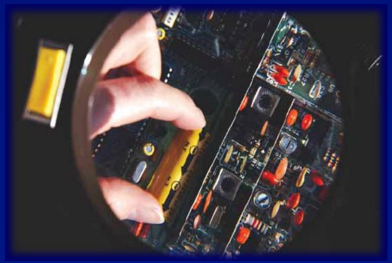

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  - **Robert M. Nerem, Georgia Institute of Technology**
  - **Laurence C. Seifert, AT&T Corporation (ret.)**
  - **Morris Tannenbaum, AT&T Corporation (ret.)**
  - **Vince Vitto, Charles Stark Draper Laboratories**

Premise

- **Leadership in innovation is essential to U.S. prosperity and security.**
- **Continued competitiveness in technological innovation requires leadership in all aspects of engineering: research, education, and practice.**

Note Regarding Innovation

Study after study (including Solow's 1957 Nobel Prize work) have linked over 50% of economic growth in the past 50 years to technological innovation.

Question:
Will flat-lining R&D funding for science and engineering research hinder U.S. innovation?

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Moreover

- The U.S. culture – a diverse population, democratic values, free market practices, a predictable legal system – provides a fertile environment for innovation
- But history has shown that significant public investment is necessary to produce the key ingredients for technological innovation:
  - New knowledge (research)
  - Human capital (education)
  - Infrastructure (physical, cyber)
  - Policies (tax, intellectual property)

"Looking under the hood" – The National Economic Engine

Threats

- Stagnant federal support of phys science & engineering R&D
- Short-term nature of industrial R&D
- Imbalance in federal R&D support
- Budget weakness in states
- Weak domestic student STEM interest
- Weak minority/women presence
- Post 9-11 impact on flow of international STEM students
- Obsolete STEM curricula
- Increasing laboratory expense
- Rapid escalation of cyber-infrastructure needs
- Inadequate federal R&D support in key areas
- Weakened state support

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Elements

New Knowledge (Research)

Human Capital (Education)

Infrastructure (Facilities, IT)

Policies (Tax, IP, R&D)

Technological Innovation

Engineering
...Research
...Education
...Practice

Opportunities

National Priorities
- Economic Growth
- National and Homeland Security
- Public Health and Social Well-being

Global Challenges
- Global Sustainability
- Geopolitical Conflict

Opportunities
- Emerging Technologies
- Interdisciplinary Activities
- Complex, Large-scale Systems

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Looking Ahead

- Dark Clouds on the Horizon?
  – National Academies (COSEPUP)
  – President's Council of Advisors on Science and Technology (PCAST)
  – Dept. of Energy (Vest Committee)
  – National Science Board (NSF)
  – American Association for the Advancement of Science (AAAS)
  – The Media

Funding Trends

- Massive shift of federal R&D toward biomedical sciences and away from physical sciences and engineering.
- Serious distortions are appearing in national R&D enterprise.
- Federal R&D has declined from 70% to 25% of national R&D activity.

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Trends in Federal Research by Discipline

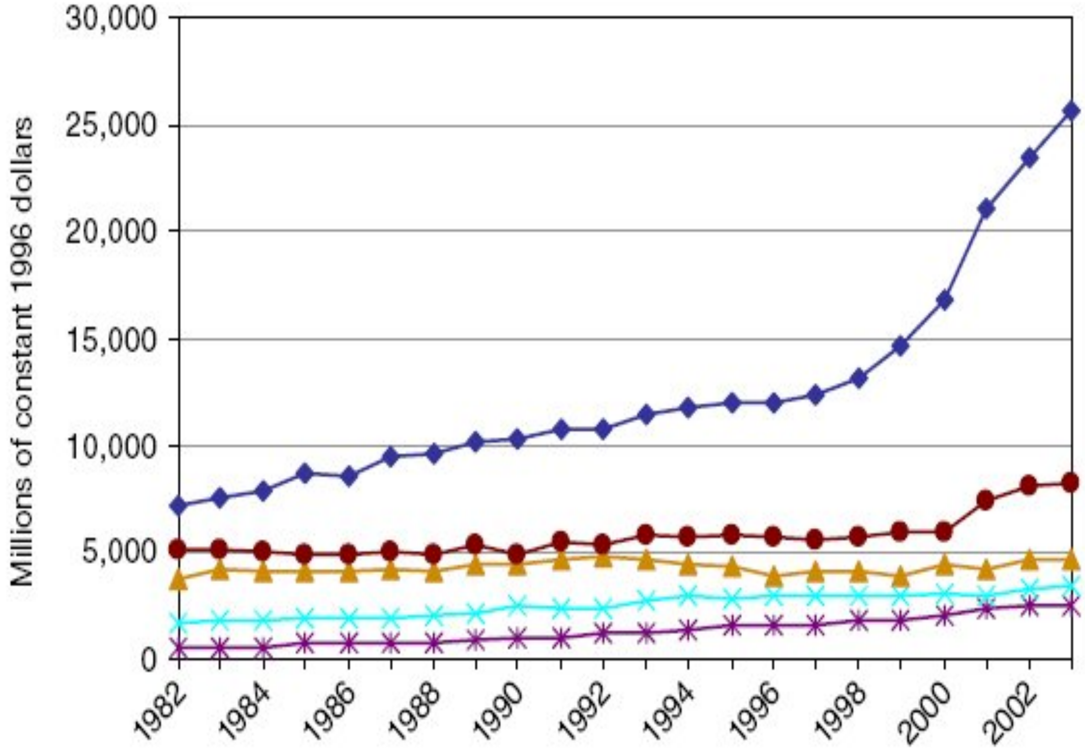

FIGURE 1 Federal funding for basic and applied research in all fields, 1982–2003.

Source: NSF, 2003, 2004a.

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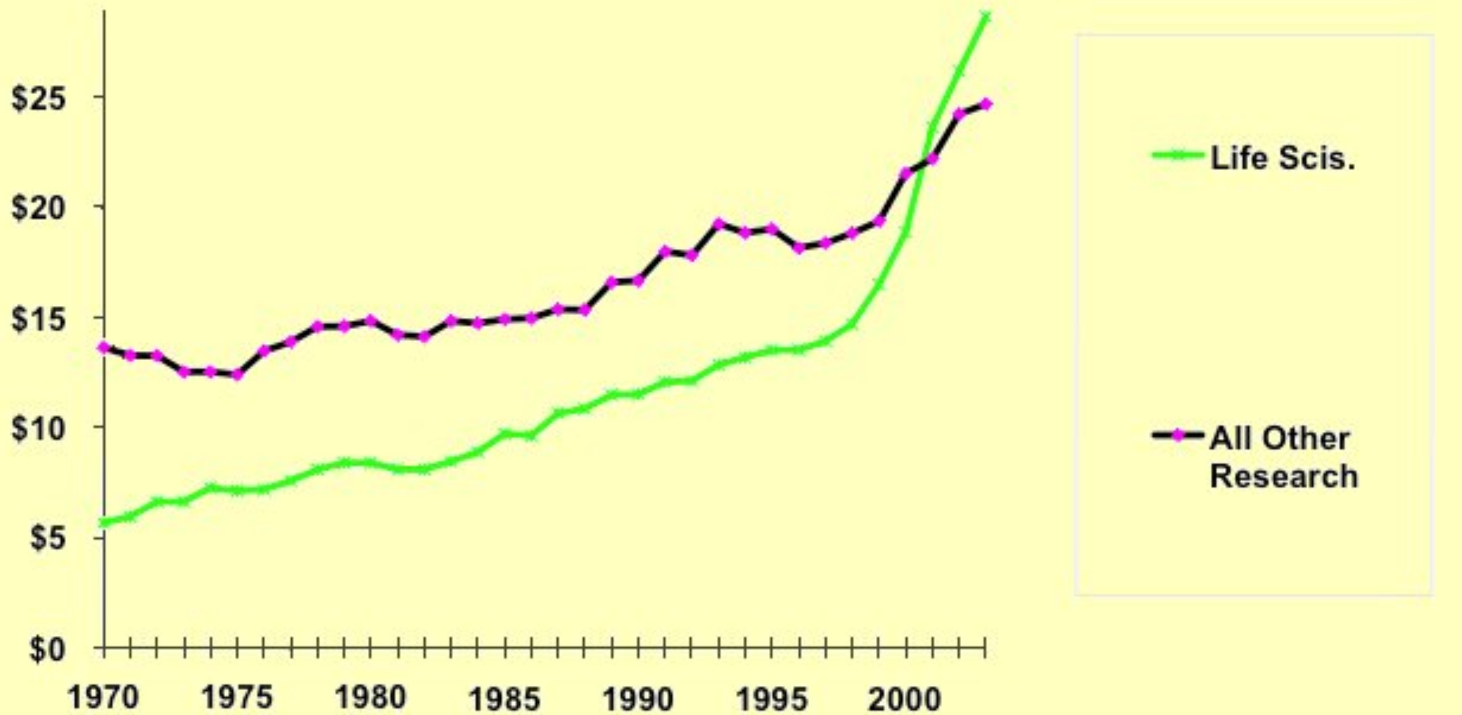
Trends in Federal Research, FY 1970-2003

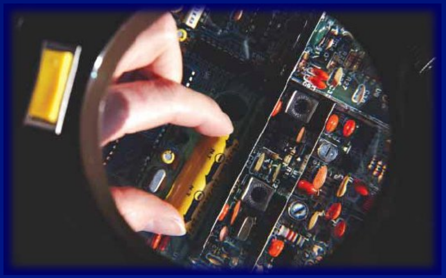
Obligations in Billions of FY 2002 Dollars



Source: National Science Foundation, *Federal Funds for Research and Development FY 2001, 2002, and 2003,* 2003. FY 2002 and 2003 data are preliminary. Constant-dollar conversions based on OMB's GDP deflators. AUGUST '03 © 2003 AAAS

American Association for the Advancement of Science

Funding Trends



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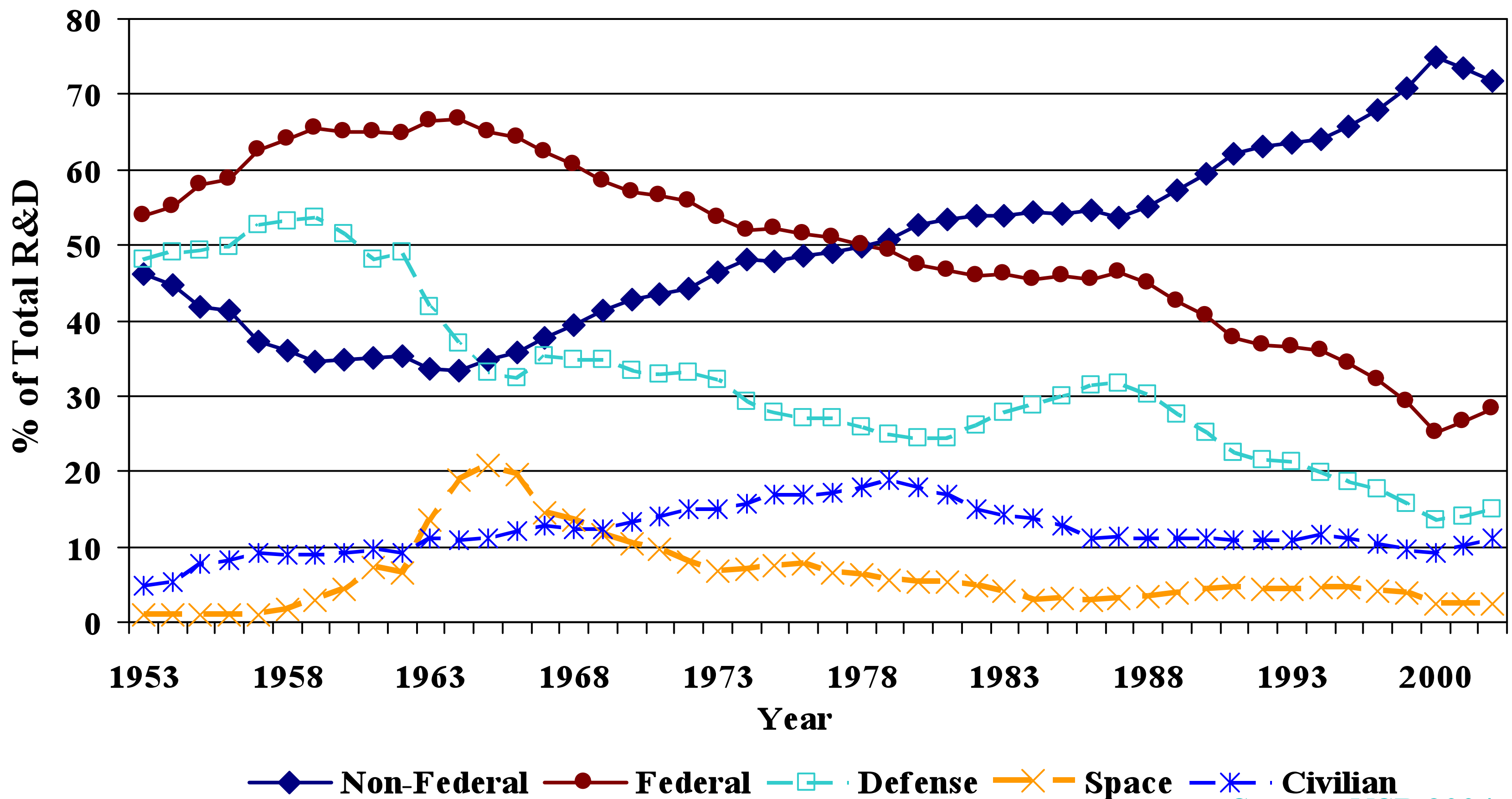
Federal vs. Non-Federal R&D

as a Percent of Total R&D Funding



Source: NSB 2004

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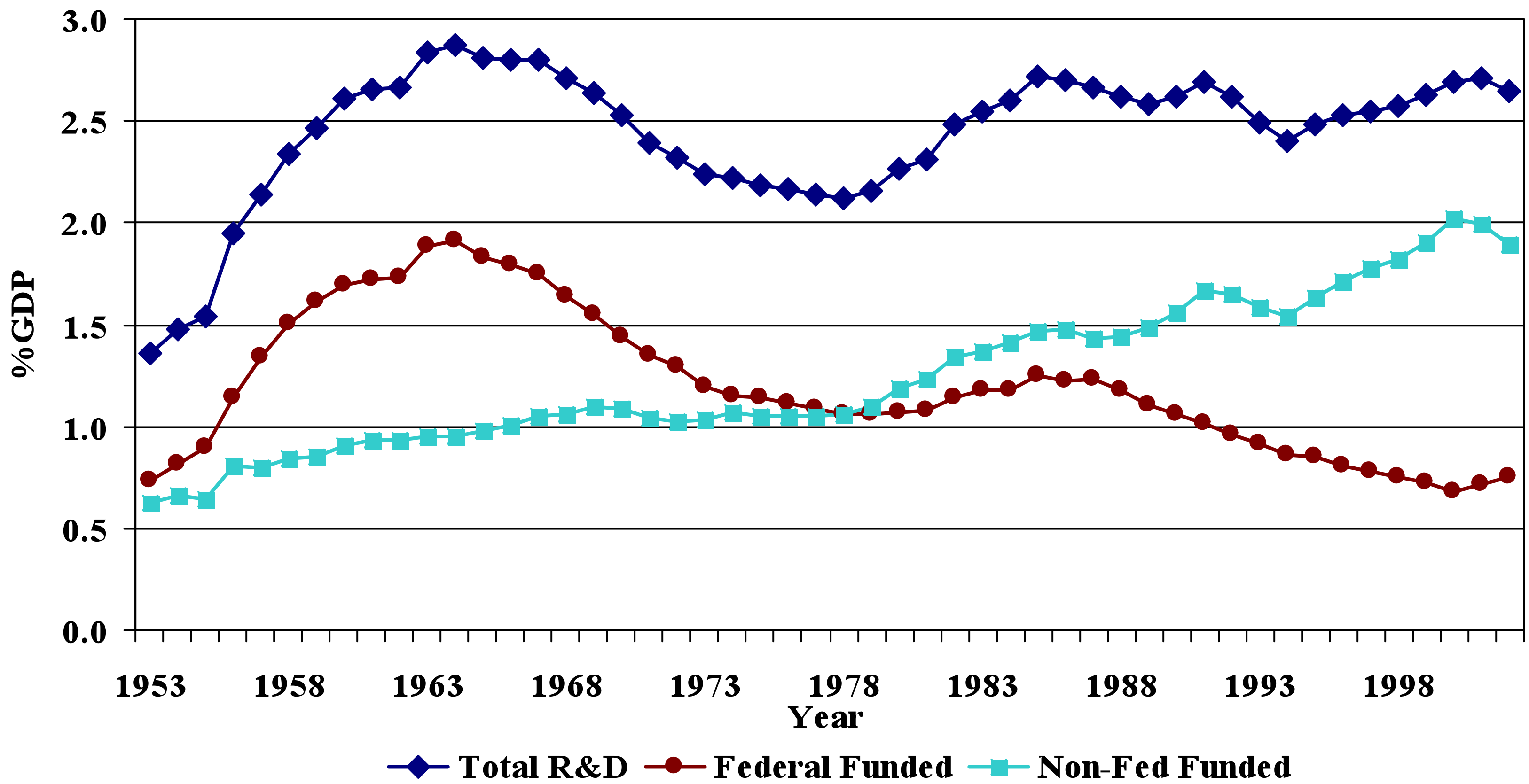
Federal vs. Non-Federal R&D

as a Percent of Gross Domestic Product (GDP)



Note: Non-Federal sources of R&D tracked by NSF include industrial firms, universities and colleges, nonprofit institutions, and state and local governments.

Source: NSB 2004

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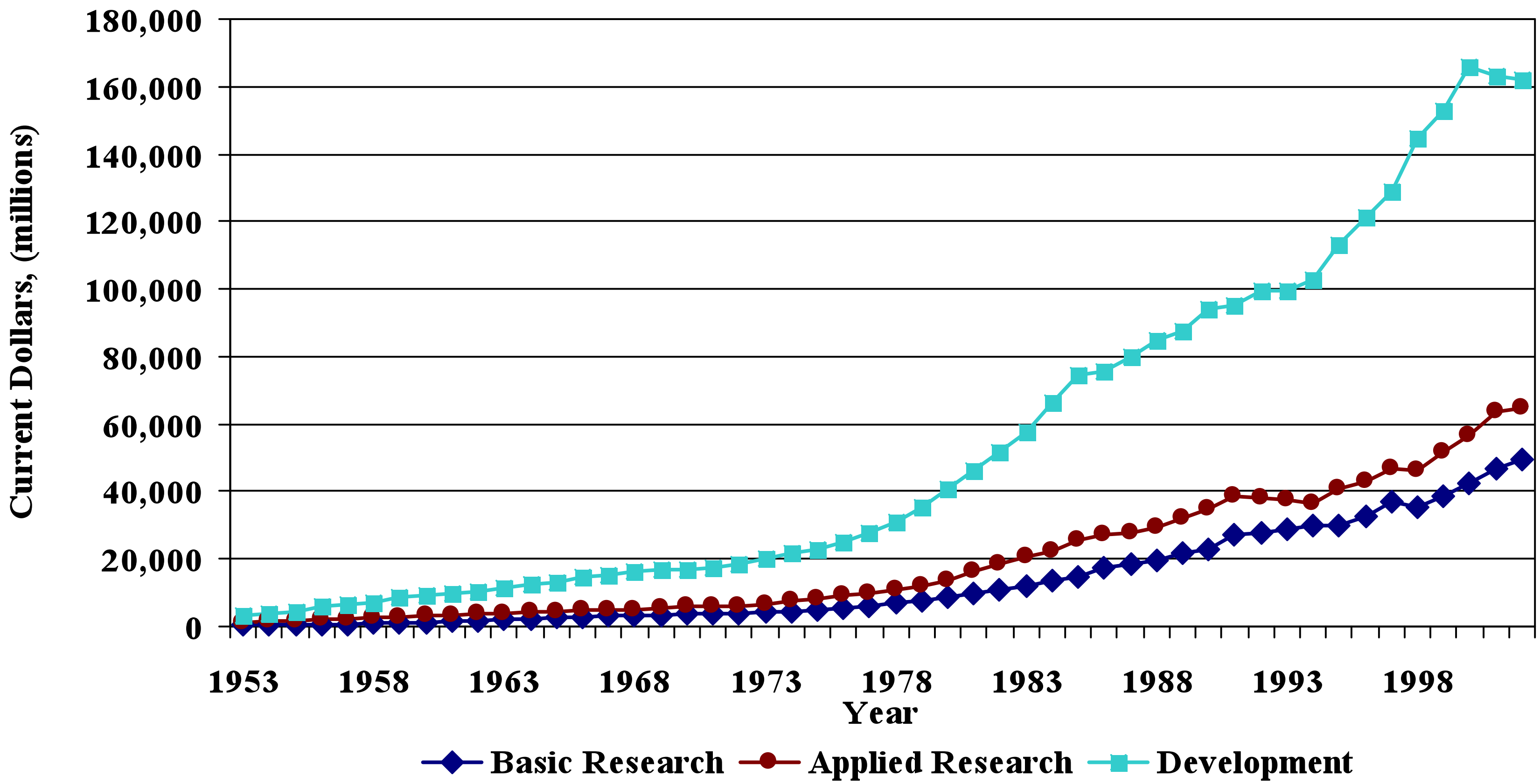
Support for Basic, Applied and Development Research, in current dollars



Source: NSB 2004

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FS&T by Discipline

	% Change
Field	***1982-2003***
Math & computer science	**718.7%**
Life sciences	**504.2%**
Other sciences	**454.7%**
Psychology	**337.4%**
Environmental Sciences	**237.8%**
Social sciences	**172.2%**
Engineering	**170.5%**
Physical Sciences	**108.0%**

President's Council of Advisors on Science and Technology

1. "PCAST's studies have shown that from 1993 to 2000, federal support for the physical sciences and engineering remained relatively flat, and in some instances decreased."

2. "Federal support for science and engineering students enhances economic growth. Yet federal support for graduate students in physical science and engineering has declined significantly over the past two decades."

President's Council of Advisors on Science and Technology

3. R&D "Innovation Ecosystem" critical to U.S. technological advances and economic sectors.

4. Economies around the globe, spurred by investment in R&D and S&E education, are making notable contributions in research and trade in many high technology fields.

PCAST Recommendations

- Increase federal funding for physical sciences and engineering R&D.
- Reinvigorate a next generation “Bell Labs” model.
- Permanent R&D tax credit.
- Improve S&T workforce skills.

Department of Energy
Science Priorities Committee

"During the last 30 years, the federal investment in research in the physical sciences and engineering has been nearly stagnant, having grown less than 25 percent in constant dollars. The corresponding investment in life science research has grown over 300 percent. Specifically, in 1970 physical science, engineering and life science each were funded at an annual level of approximately $5 billion in 2002 dollars. Today, physical science and engineering research are funded at approximately $5 billion and $7.5 billion, respectively. The current funding for life science is about $22 billion."

AAAS

"The record breaking totals for federal investment in R&D in recent years have occurred because of the doubling of the National Institutes of Health coupled with the enormous increases in weapons procurement and creation of new homeland security R&D programs."

AAAS

While the R&D portfolio of $132 billion would be essentially constant, total federal research investment ("FS&T") would drop 1.4% to $55 billion, with cuts to most R&D programs with the exception of modest increases for NASA, DHS, and NSF.

Particularly hard-hit by the proposed 21% cut in DoD and 4.5% cut in DOE research programs would be physical science and engineering research.

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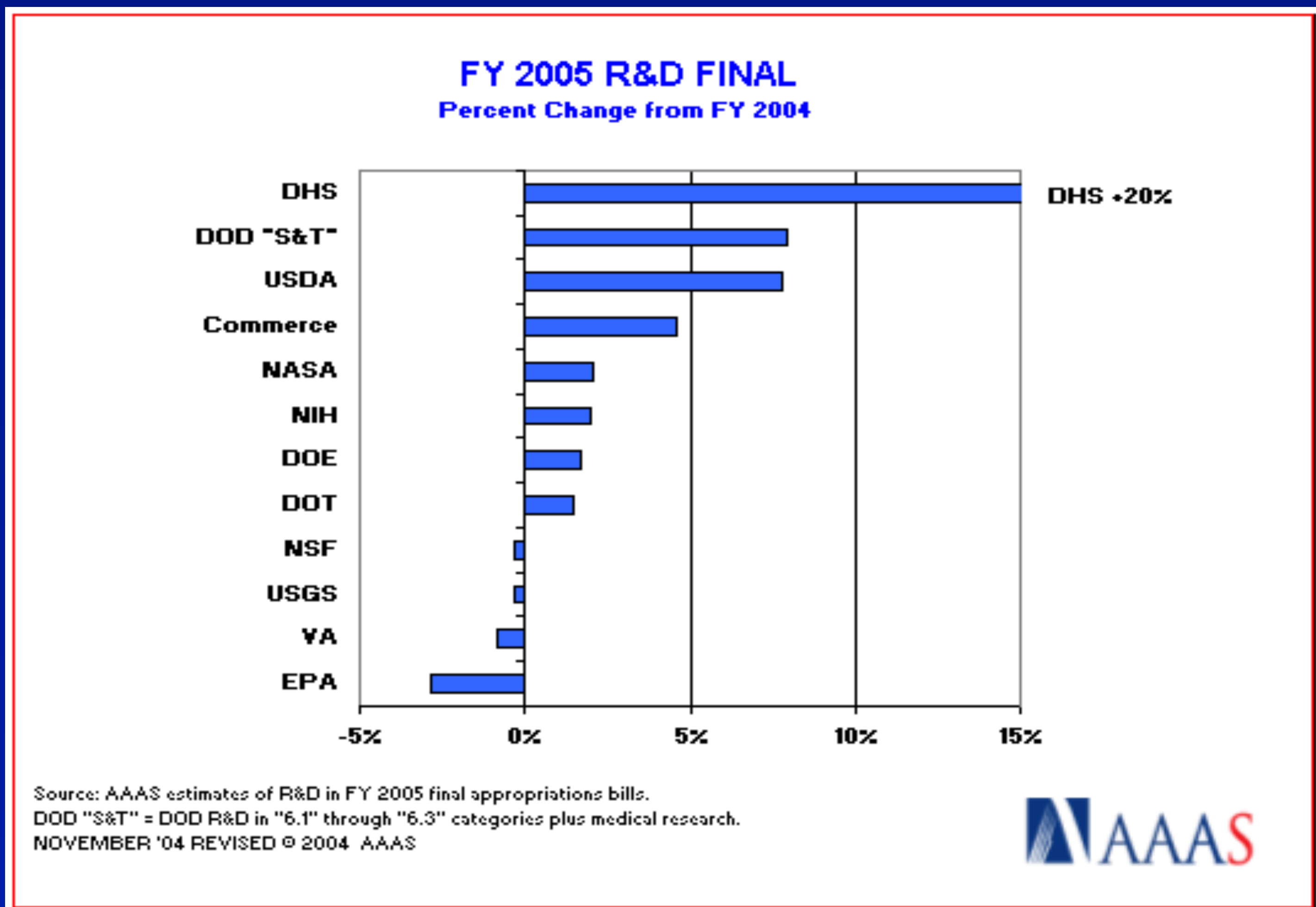
FY 2005 R&D Final
Percent Change from FY 2004



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Media Recognizes the Issue
William Broad (New York Times)

"Europe and Asia are making large investments in physical science and engineering research, while the U.S. has been obsessed with biomedical research to the neglect of other areas of science."

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Media Recognizes the Issue
Tom Friedman (New York Times)

"One of America's greatest assets—its ability to skim the cream off the first-round intellectual draft choices from around the world and bring them to our shores to innovate will be diminished, and that in turn will shrink our talent pool."

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Demographics of Engineering Students at US Institutions

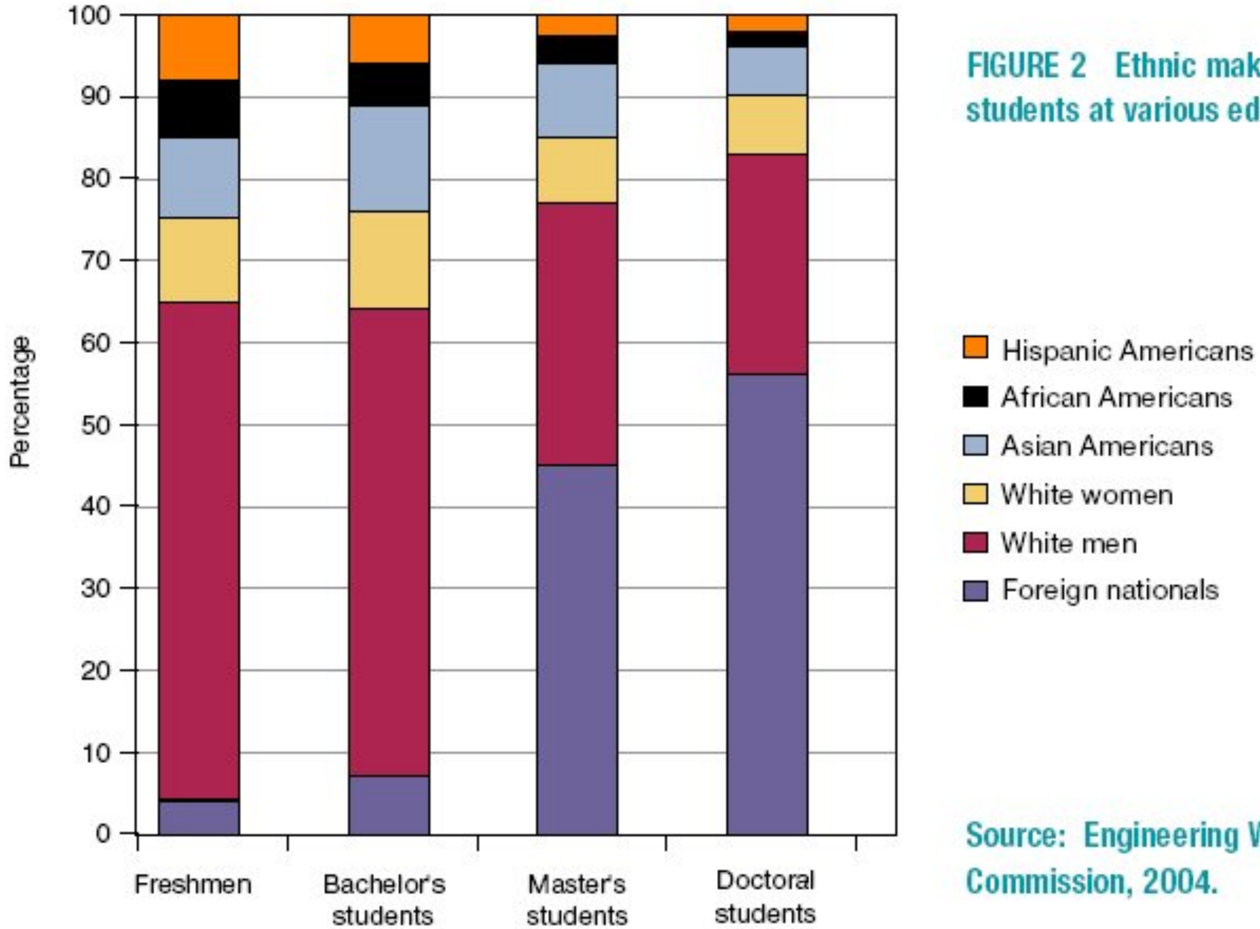

FIGURE 2 Ethnic makeup of engineering students at various educational levels.

Source: Engineering Workforce Commission, 2004.

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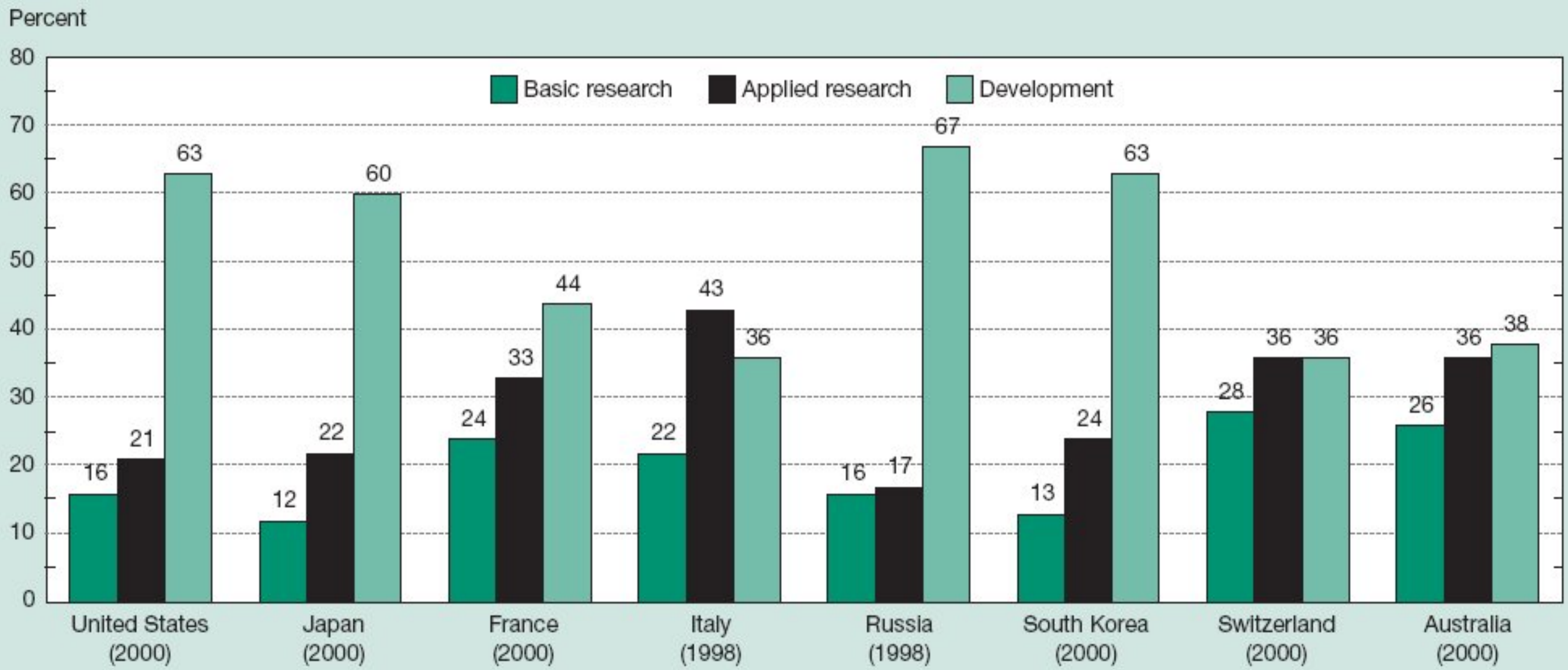
Concerns

- Imbalance between federal investments in R&D in biomedical sciences and in physical sciences and engineering.
- Inadequate investment (both federal and industry) in long-term engineering research.
- Concern about human capital, in view of declining interest in science and engineering careers and increasing constraints on immigration.

Does the US need to rebalance R&D?



NOTES: Character of work for 6 percent of Japan's R&D is unknown. Percents may not sum to 100 because of rounding.

SOURCES: Organisation for Economic Co-operation and Development, *Basic Science and Technology Statistics,* vol. 2002-1 (Paris, 2002); Centre for Science Research and Statistics, *Russian Science and Technology at a Glance 2000*, 2001; and National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, VA, annual series).

Science & Engineering Indicators – 2004

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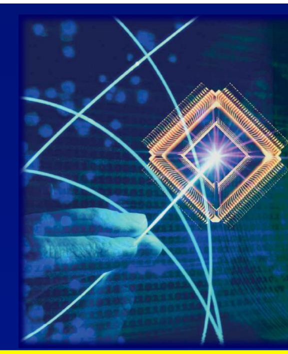
Recommendation 1

The U.S. federal R&D portfolio should be rebalanced by increasing funding for research in engineering and physical science to levels sufficient to support the nation's most urgent priorities, such as national defense, homeland security, health care, energy security, and economic growth. Allocations of federal funds to support these priorities should be based on analysis that recognizes the complementary and interdependent nature of advances in different scientific and engineering disciplines.

Recommendation 2

Long-term basic engineering research should be reestablished as a priority for American industry. Tax and other policies should be crafted to stimulate investments in basic research (e.g., tax credits to support private-sector investment in university-industry collaborative research).



Recommendation 3

Federal and state governments and industry should invest in upgrading and expanding laboratory, equipment, IT and other infrastructure of research universities and schools of engineering to ensure that the national capacity exists to address engineering challenges that lie ahead.

Recommendation 4

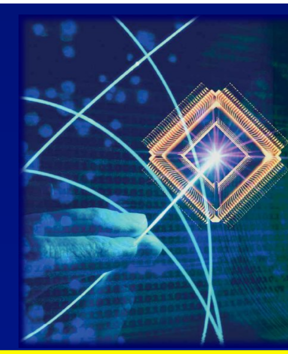
A major effort should be made to increase the participation of American students in engineering. This will require effort on the part of government stakeholders, engineering faculty and administrators, industry, and K12 partners.

Recommendation 5

Participants and stakeholders in the engineering community should place a high priority on encouraging women and underrepresented minorities to pursue careers in engineering. The investment to achieve this outcome, although substantial, is necessary in order to increase the capacity (number, quality and diverse thought) that future challenges and economic prosperity will demand.

Recommendation 6

A major federal fellowship-traineeship program in strategic fields, similar to the program created by National Defense Education Act, should be established to ensure that the supply of next generation scientists and engineers is adequate.



Recommendation 7

Immigration policies and practices should be streamlined (without compromising security) to restore the flow of talented students, engineers and scientists from around the world into American universities and industry.

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Recommendation 8

Links between industry and research universities should be expanded and strengthened. The following actions – funded through tax incentives and grants – should be taken:

- **Support new initiatives that foster multidisciplinary research to address major challenges**
- **Streamline and standardize IP and Tech Transfer policies**
- **Support industry engineers and scientists as visiting "professors of the practice"**
- **Provide incentives for industry R&D labs to host student and faculty researchers**

Final Recommendation: Be Bold!

- At other critical times in the nation's history, bold steps were taken to address national needs:
  - The land-grant acts of the 19th century
  - The G.I. Bill and government-university research partnership following WWII
  - The National Defense Education Act in the 1960s.
- Such a bold step is needed today to sustain a competitive capacity in technological innovation.

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Discovery-Innovation Institutes

CAMPUS LINKAGES
Sciences
Professional Schools

PRIVATE SECTOR LINKAGES
Industry Partnerships
Entrepreneur participation

PUBLIC SECTOR LINKAGES
Federal agencies
National laboratories
States

DISCOVERY-INNOVATION INSTITUTES

Link scientific discovery with societal applications

Educate and train innovators, entrepreneurs, and engineers

Build infrastructure (laboratories, cybersystems, etc.)

Analogous to agriculture experiment stations and academic medical centers

NATIONAL PRIORITIES
Sustainable economic growth
National and homeland security
Public health and social well-being

GLOBAL CHALLENGES
Global sustainability
Geopolitical conflict

OPPORTUNITIES
Emerging technologies
Interdisciplinary activities
Complex large-scale systems

SUPPORT
Core federal support (e.g., Hatch Act)
State participation (physical facilities)
Industry participation
Entrepreneur participation
University participation
- Co-investment
- Policies (e.g., for intellectual property)

Discovery-Innovation Institutes

- Like agricultural experiment stations, they would be responsive to societal priorities.
- Like academic medical centers they would bring together research, education, and practice.
- Like corp R&D laboratories, they would link fundamental discoveries with the engineering research necessary to yield innovative products, services, and systems, but while also educating the next generation technical workforce.

Discovery-Innovation Institutes

- Although primarily centered in engineering schools, DIIs would partner with other professional schools (e.g., business, medicine, law) and academic disciplines.
- To ensure the necessary transformative impact, the DII program should be funded at levels comparable to other major federal initiatives such as biomedicine and manned spaceflight, e.g., building to several billion dollars per year and distributed broadly through an interagency competitive grants program.

DII Summary

- DIIs would be engines of innovation that would transform institutions, policy, and culture and enable our nation to solve critical problems and maintain leadership in a global, knowledge-driven society.
- These are put forward not as a definite prescription but rather to illustrate the bold character and significant funding level we believe necessary to strengthen our national needs for technological innovation.

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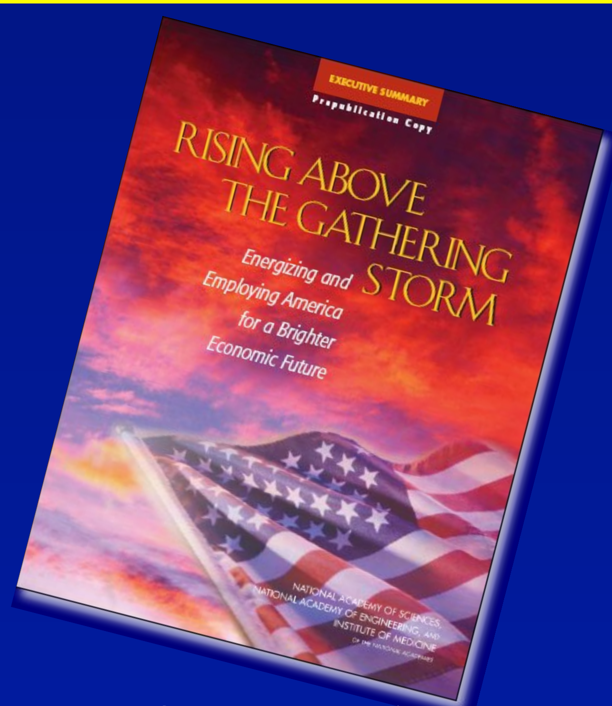
One DII Example

- Institutes linking engineering, business, and public policy programs with biomedical sciences programs to develop drugs, medical procedures, protocols, and policies to address the health care needs and complex societal choices for an aging population.

Allied National Academies Report

- **Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future**
  - **Committee on Science Engineering and Public Policy (CoSEPuP)**



Charge:
What are the top 10 actions, in priority order, that federal policy-makers could take to enhance the science and technology enterprise so that the United States can prosper and be secure in the global community of the 21st Century? What strategy, with several concrete steps, could be used to implement each of those actions?

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Rising Above the Gathering Storm

- Strong agreement with research needs described in Engineering Research and America's Future
  - Double federal support of long-term basic research over next 7 years
  - Create a program to support 200 of the nation's promising young researchers with grants of $500,000 (over 5 years) at a cost of $100 million per year when fully implemented
  - Institute a National Coordination Office for Research Infrastructure to manage a centralized research-infrastructure fund of $500 million per year over the next 5 years
  - Provide federal research agencies with the discretion and resources to catalyze high-risk, high-payoff research
  - Create in the Department of Energy (DOE) an organization like the Defense Advanced Research Projects Agency (DARPA) called the Advanced Research Projects Agency-Energy (ARPA-E)
  - Institute a Presidential Innovation Award to stimulate scientific and engineering advancements.

Rising Above the Gathering Storm

- Goes beyond the research-related recommendations in addressing other national challenges, including:
  - Preparation of K12 Math and Science teachers: 10,000 Teachers, 10 Million Minds
  - Higher Education Policies: Developing the Best and the Brightest
  - Economic Policy: Incentives for Innovation

Gathering Storm Report: Available at http://books.nap.edu/catalog/11463.html

Thank you

for the opportunity to present these findings to Motorola employees worldwide and to use this presentation as a resource on the National Academy of Engineering web pages.