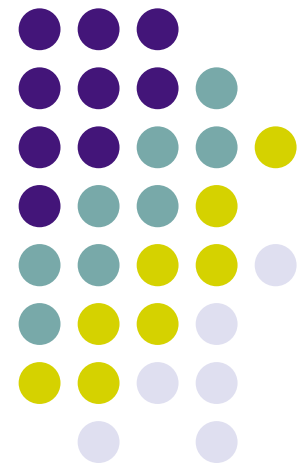
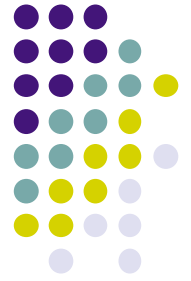


# Engineering for a Changing World

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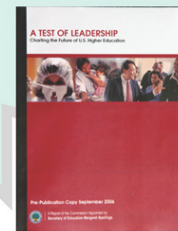
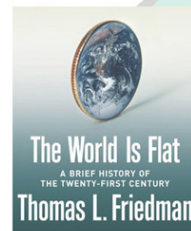
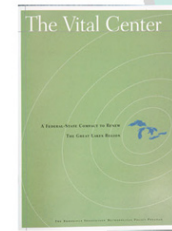
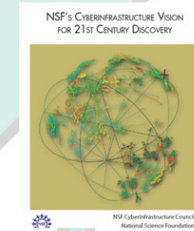
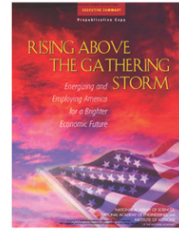
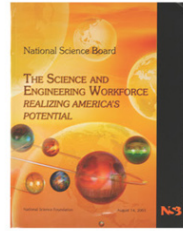
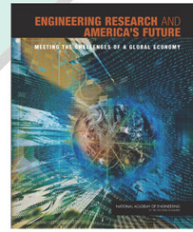
The Future of  
Engineering Practice,  
Research, and Education





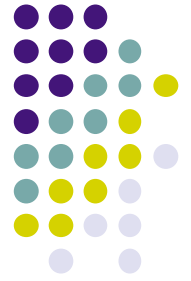
# The Challenge of Change

- The changing workforce and technology needs of a **global knowledge economy** are changing engineering practice and demanding far broader skills.
- Importance of **technological innovation** to economic competitiveness and national security is driving a new priority for application-driven basic engineering research.
- Challenges such as **out sourcing and off shoring**, the **decline of student interest** in STEM careers, inadequate social **diversity**, and **immigration** constraints are raising serious questions about the adequacy of our current national approach to engineering.





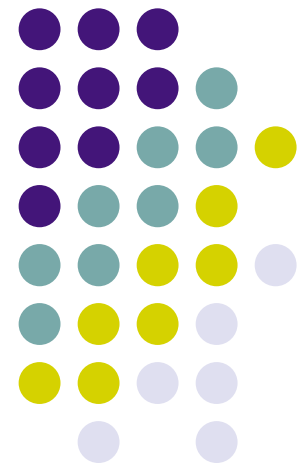
# Questions



- What should our nations seek from engineering?
- What is engineering? A **discipline**? An **occupation**? A **career**? A **profession**?
- Whom should engineering serve? Industry? Government? The nation? The world? Students? The profession itself?
- Granted that engineering education should not be monolithic, but how can we achieve adequate intellectual depth, breadth, and rigor across a highly diverse engineering enterprise demanded by our changing needs as a society and as a nation?

# **An Interesting Comparison: Medicine ...at the turn of the last century**

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## Dr. Howard's Office

Alonson Howard attended two medical schools – including the one at the University of Michigan – but did not graduate from either school. He simply returned home and became a doctor.

Doctors' offices of the mid-1800s were very different from those today.

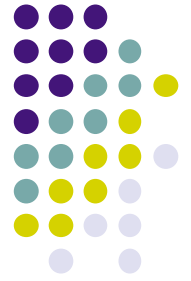
Alonson Howard ran this office around the time of the Civil War. He often made house calls to rural Michigan towns, traveling by horse or train. Many times he stayed overnight at patients' homes to watch them. He made his own syrups and pills from herbs, roots and barks.

Built about 1840 in Tekonsha, Michigan.



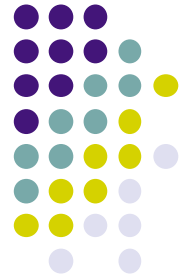


# The Medical Profession



- During the 19th century medical education had evolved from a practice-based apprenticeship to an entirely didactic (lecture-based) education.
- To become a doctor, one needed only a high school education, a year of lectures, and a few dollars for a license to begin practice as a physician.
- The changing health care needs of society, coupled with the changing knowledge base of medical practice, would drive a very rapid transformation of the medical profession, along with medical education, licensure, and practice.

# The Flexner Report



- The **Carnegie Foundation** commissioned noted educator Abraham Flexner to survey 155 medical schools and draft a report on the changing nature of the profession and the implications for medical education.
- The key to his study was to promote educational reform as a public health obligation: **“If the sick are to reap the full benefit of recent progress in medicine, a more uniformly and expensive medical education is demanded.”**

**MEDICAL EDUCATION  
IN THE  
UNITED STATES AND CANADA**

**A REPORT TO  
THE CARNEGIE FOUNDATION  
FOR THE ADVANCEMENT OF TEACHING**

**BY  
ABRAHAM FLEXNER**

**WITH AN INTRODUCTION BY  
HENRY S. PRITCHETT  
PRESIDENT OF THE FOUNDATION**

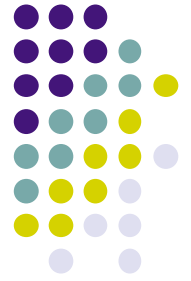
**BULLETIN NUMBER FOUR (1910)**

*(Reproduced in 1960)*

*(Reproduced in 1972)*

**437 MADISON AVENUE  
NEW YORK CITY 10022**

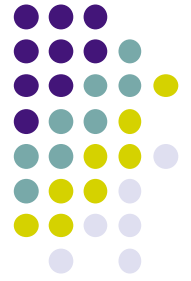
# Flexner's Impact



- The **Flexner Report of 1910** transformed medical education and practice into the **20th century paradigm of scientific (laboratory-based) medicine and clinical training in teaching hospitals.**
- Flexner held up Johns Hopkins University medical school as the model (the existence proof) of the **new approach, requiring a baccalaureate degree for entry, a teaching hospital for training, and a strong scientific foundation.**
- Over the next two decades, two-thirds of all medical schools were closed, and those that remained were associated with major universities!

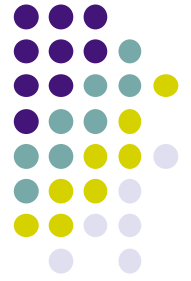


# Oh, and by the way...



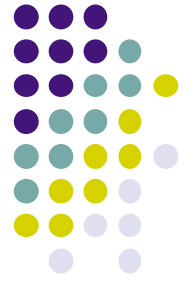
- Although he was primarily focused on medicine, Flexner raised very similar concerns about engineering education even at this early period.
- “The minimum basis upon which a good school of engineering accepts students is, once more, an actual high school education, and the movement toward elongating the technical course to five years confesses the urgent need of something more.”

# A Flexner Report for Engineering?



- Mann Report (1918)
- Wilkenden Report (1923)
- ASEE Grinter Report (1955)
- ASEE Green Report (1994)
- NRC BEED Report and ABET EC2000
- NAE Engineering of 2020 (2004)
- **Carnegie Foundation Study (2007)**
- Bill Schowalter: “Appearance every decade of a definite report on the future of engineering education is as predictable as the sighting of the first crocuses in spring.” (2003)

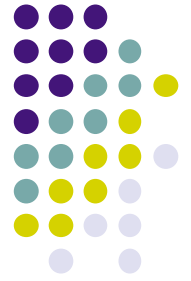




# Yet, despite these efforts

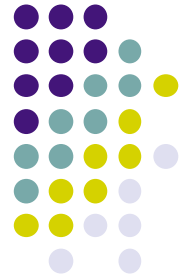
- Although engineering is one of the professions most responsible for profound changes in our society, its characteristics of **practice, research, and education have been remarkably constant**—some might suggest even stagnant—relative to other professions.
- **Engineers are still used as commodities** by industry, and engineering services are increasingly off shored.
- **Engineering research is still misunderstood and inadequately supported** by industry and government.
- **“Most of our universities are attempting to produce 21st century engineers with a 20th century curriculum in 19th century institutions.”** (JJD)

# The stakes are very high!!!



- An extrapolation of current trends such as the off shoring of engineering jobs and services, inadequate investment in long-term engineering research, inadequate innovation in engineering education, declining interest on the part of students in STEM careers, and immigration constraints raises very serious concerns.
- **Without concerted action, we face the very real prospect of losing its engineering competence in an era in which technological innovation is the key to economic competitiveness, national security, and social well-being.**
- Bold and concerted actions are necessary to sustain and enhance the profession of engineering in America—its practice, research, and education!

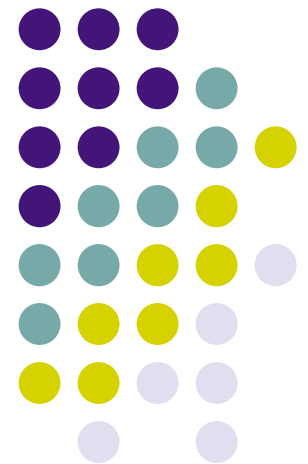
# The Approach: Roadmapping



- Engineering Today (“Where we are...”)
- Engineering Tomorrow (“Where we need to be ...”)
- Gap Analysis (“How far we have to go...”)
- The Roadmap (“How to get there...”)

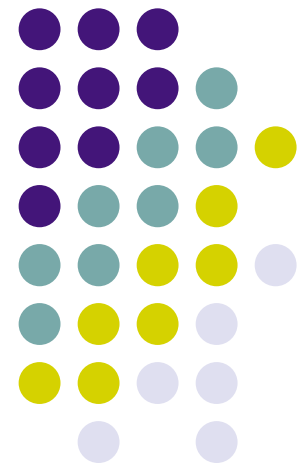
# Today's Challenges

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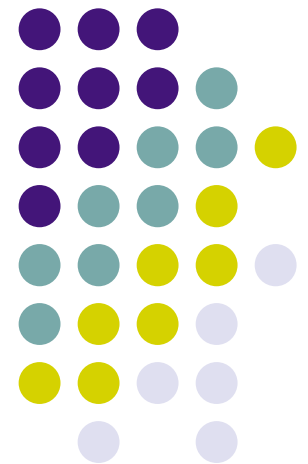
# Engineering Practice

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# The Way the World Works Today

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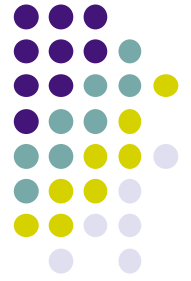


# The World Is Flat

A BRIEF HISTORY OF  
THE TWENTY-FIRST CENTURY

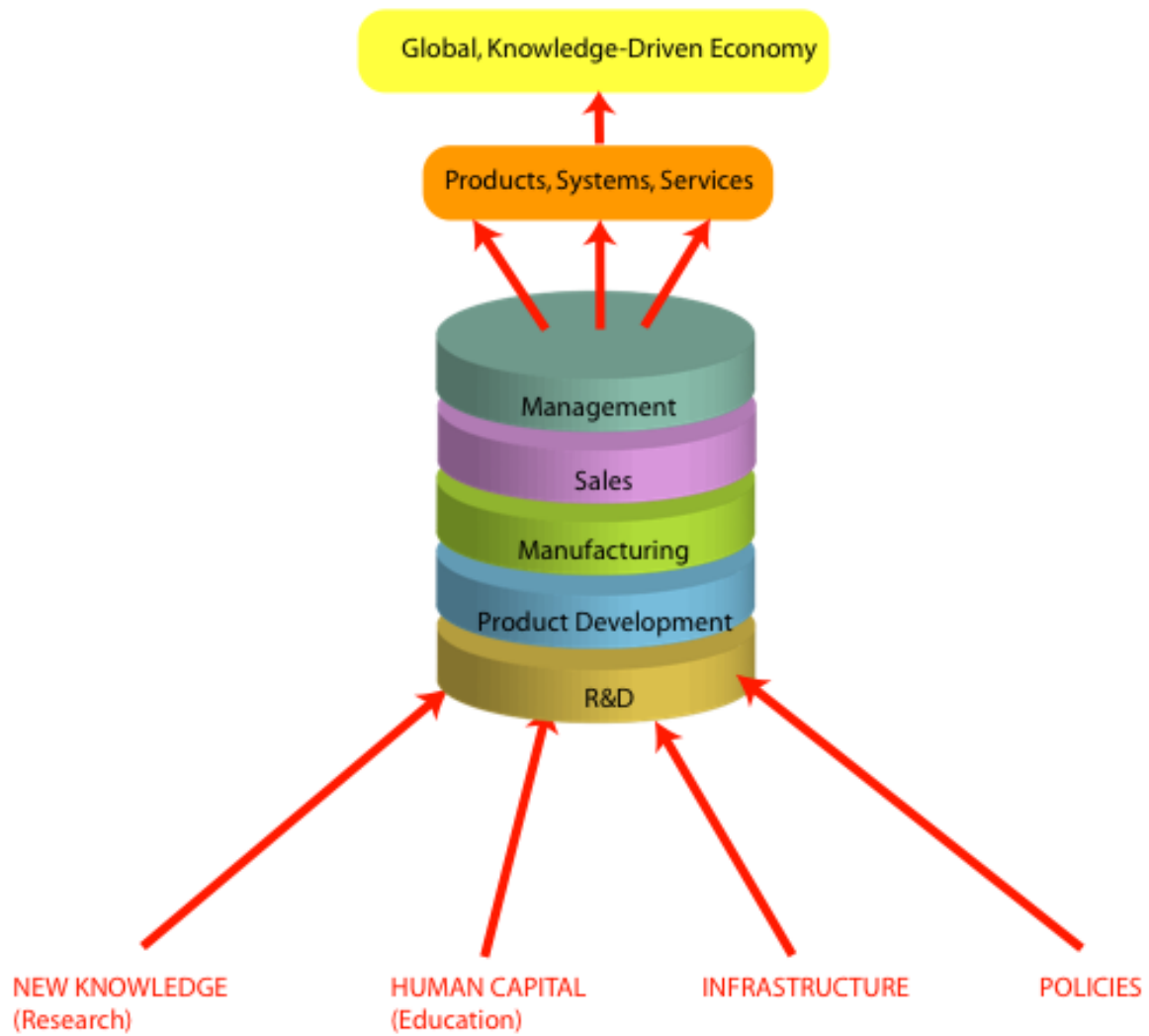
Thomas L. Friedman

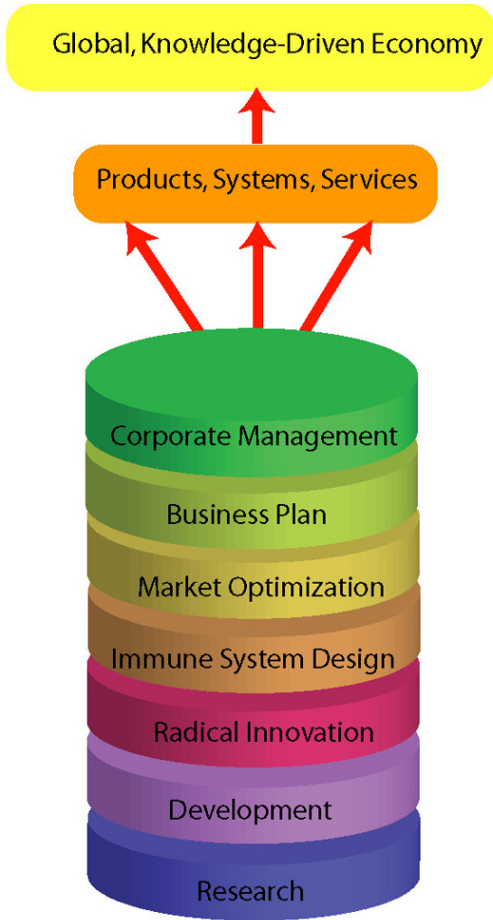
# Innovation and Globalization

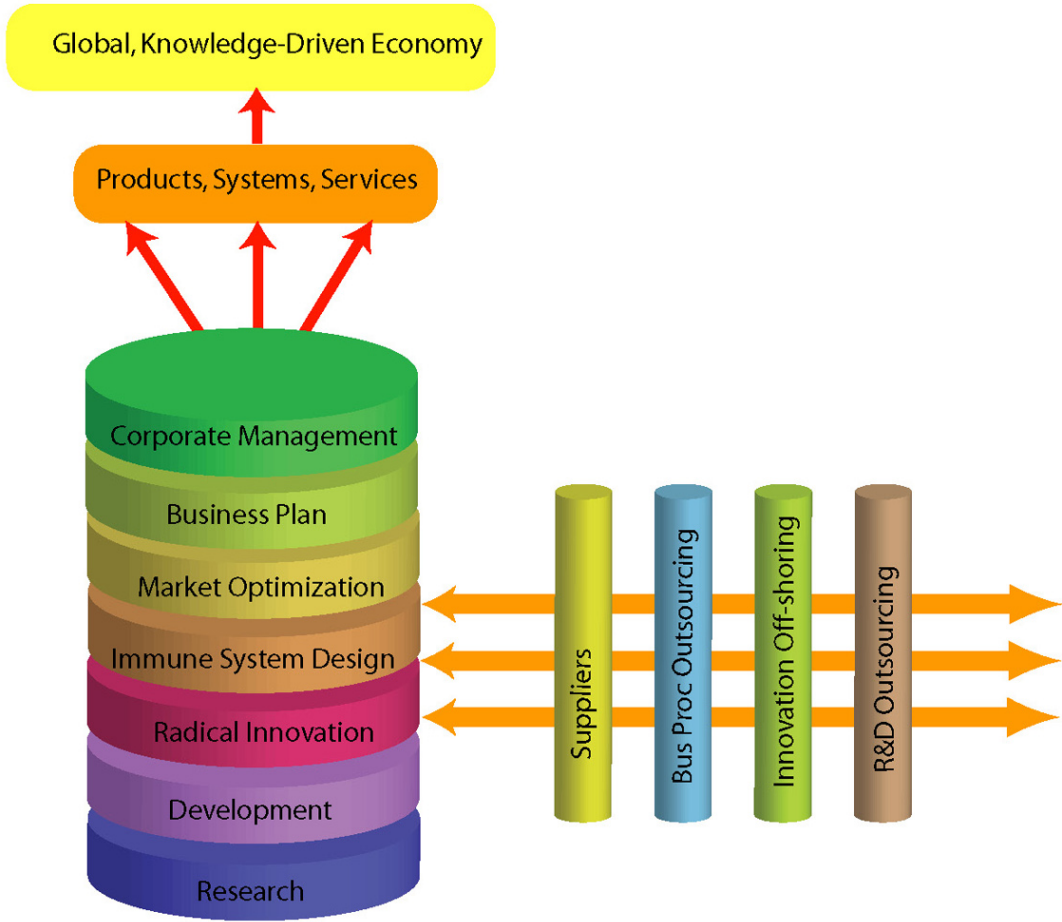


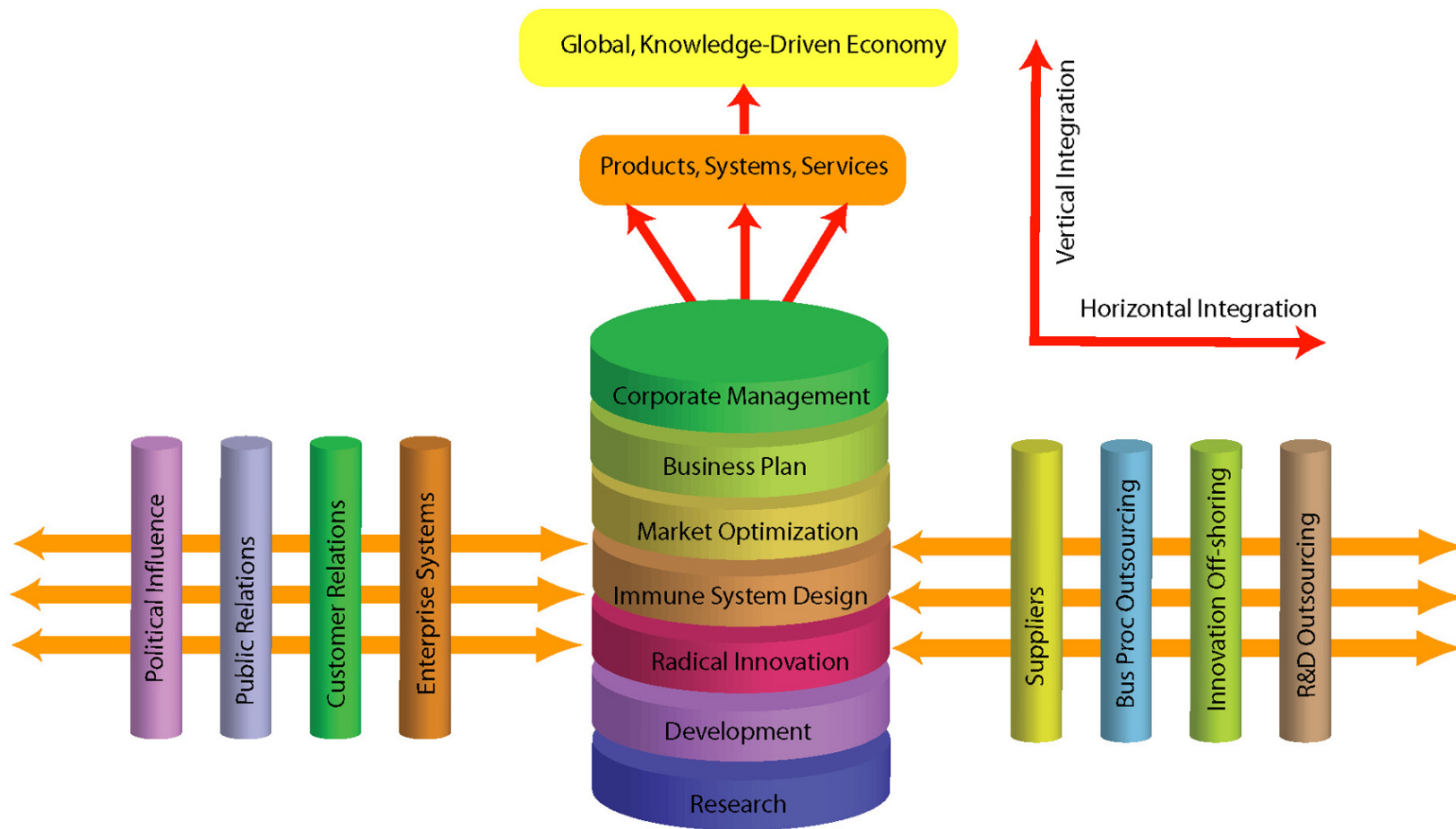
- A **radically new system for creating wealth** has emerged that depends upon the creation and application of new knowledge and hence upon educated people and their ideas.
- “**Intellectual work and capital can be delivered from anywhere**—disaggregated, delivered, distributed, produced, and put back together again...” (Friedman)
- “Some three billion people who were excluded by the pre-Internet economy have now walked out onto a level playing field, from **China, India, Russia, and Eastern Europe**, regions with rich educational heritages.”

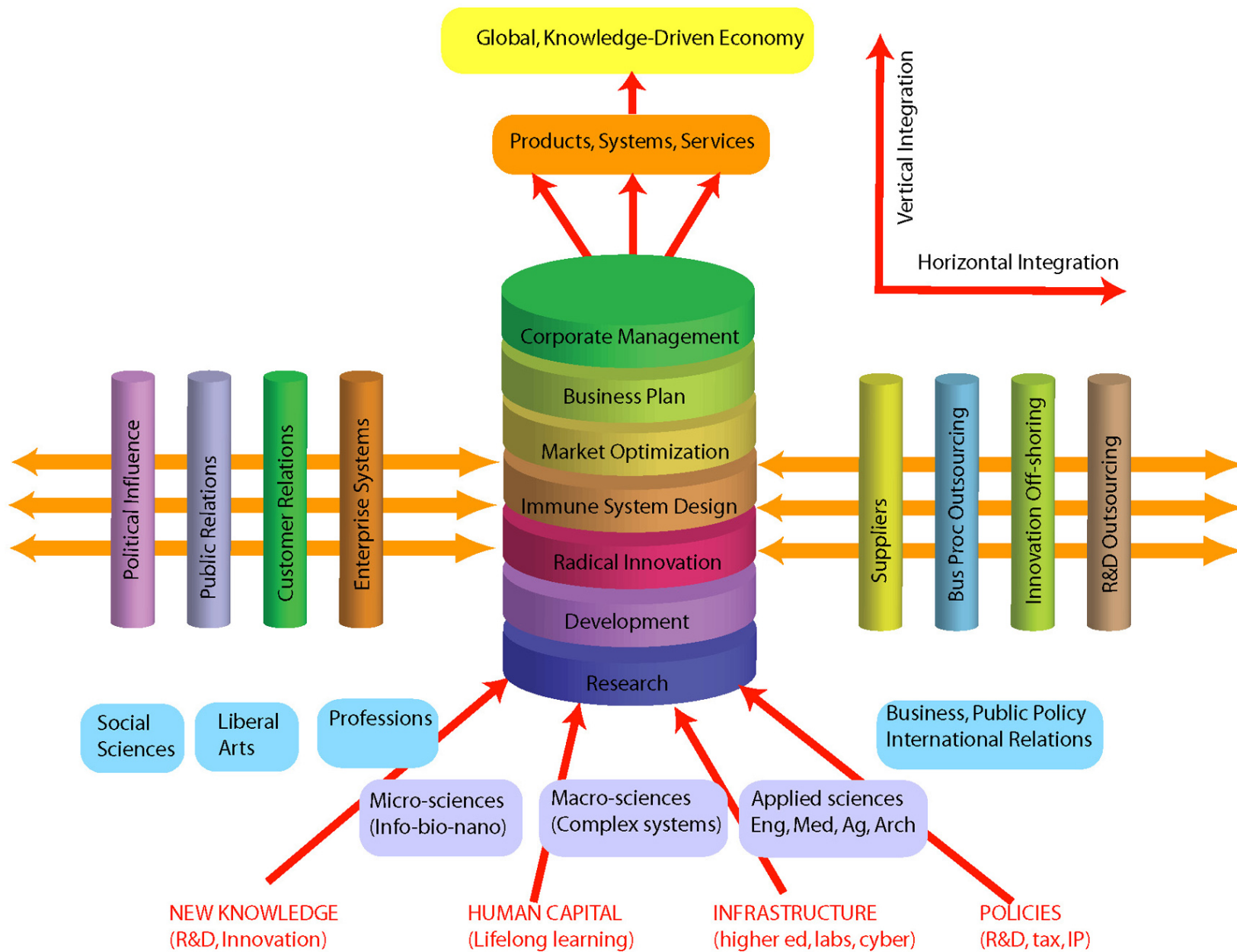




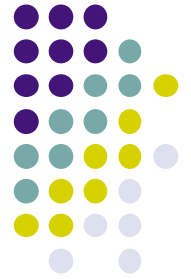






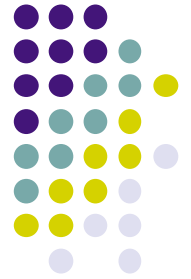


# The Global Economy



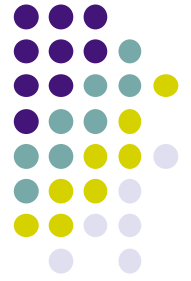
- Today's global corporations manage their technology activities to take advantage of the **most capable, creative, and cost-effective engineering talent, wherever they find it.**
- The rapid evolution of high quality engineering services in developing economies with low labor costs raises a serious question about the **viability of the American engineers.**
- This is a moving target as **global sourcing** moves up the value chain to product design, development, and innovation.

# The Challenge of Globalization



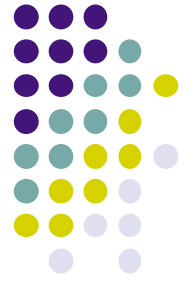
- Engineers must develop the capacity of working in **global markets characterized by great cultural diversity**.
- This requires a **much faster pace of innovation**, shorter product cycles, lower prices, and higher quality than ever before.
- Global innovation requires a shift from traditional problem solving and design skills to more innovative solutions imbedded in an **array of social, environmental, cultural, and ethical issues**.
- American engineers **must achieve several times the value-added** of engineers in other parts of the world to sustain their competitiveness relative to global sourcing.

# Prestige and Influence?



- In the U.S. the engineering profession still tends to be held in relatively **low public esteem** compared to other learned professions such as law and medicine.
- American **industry utilizes engineers as consumable commodities**, subject to layoffs or off shoring when their skills become obsolete or replaceable by cheaper engineering services from abroad.
- Students sense this, as evidenced by **declining interest in engineering** relative to business, law, and medicine.



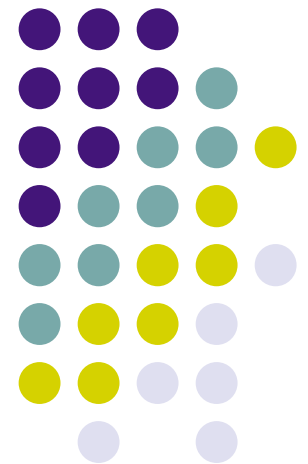


# The Gathering Storm

- “The U.S. is not graduating the volume of engineers and scientists, we do not have a lock on the infrastructure, and we are either flat-lining or cutting back our investments in physical science and engineering.” (Craig Barrett)
- “We need to get going immediately. It take 15 years to train a good engineer, because this really is rocket science!” (Tom Friedman)

# Engineering Research

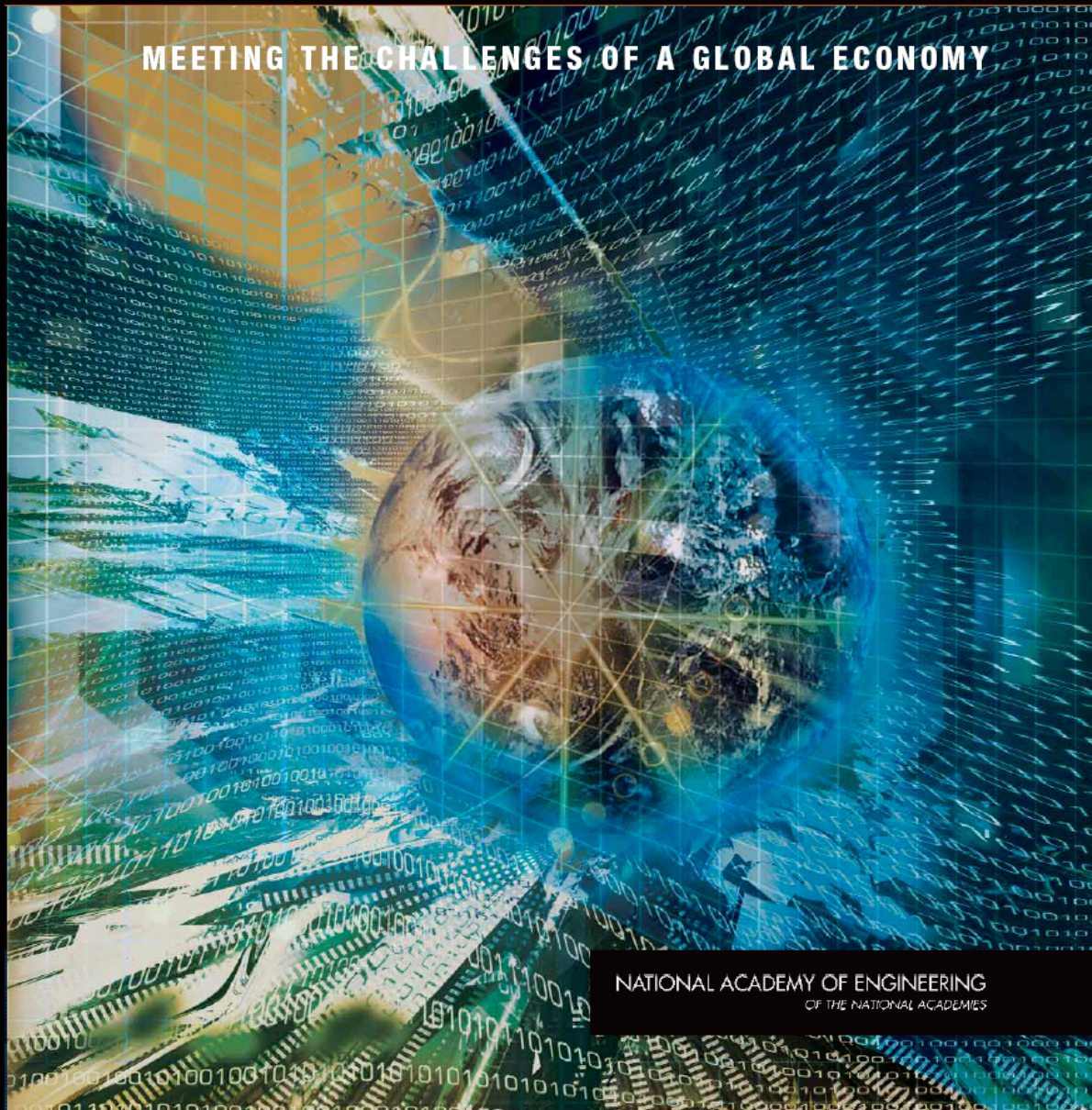
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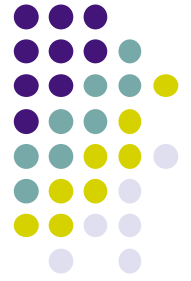
# ENGINEERING RESEARCH AND AMERICA'S FUTURE

MEETING THE CHALLENGES OF A GLOBAL ECONOMY

NATIONAL ACADEMY OF ENGINEERING  
OF THE NATIONAL ACADEMIES

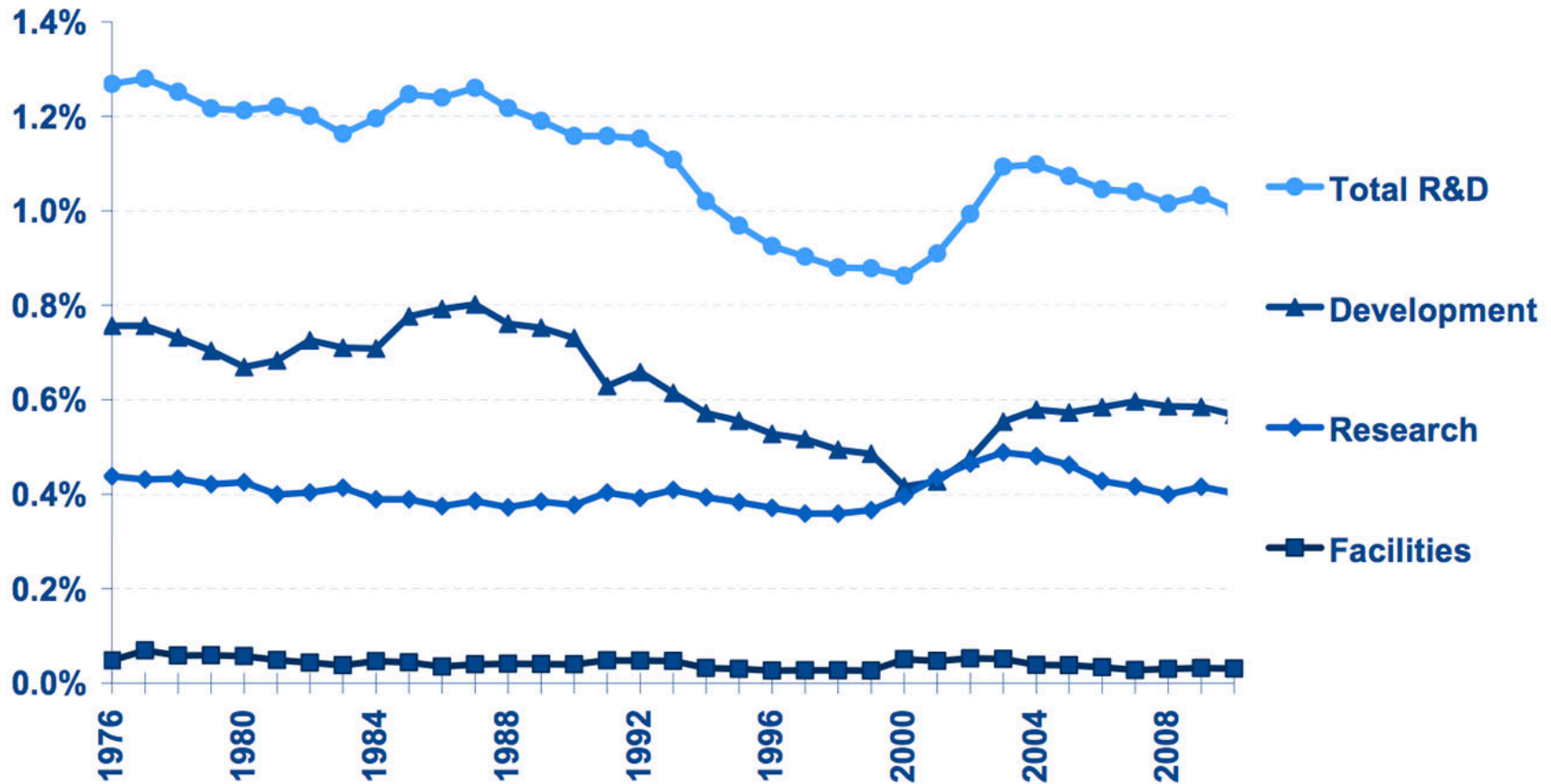


# Concerns



- Large and growing imbalance in federal R&D funding (e.g., NIH = \$30 B, NSF = \$6 B)
- Federal R&D has declined from 70% of national R&D in 1970s to less than 30% today.
- Increased emphasis on short-term R&D in industry and government-funded R&D
- Deterioration of engineering research infrastructure
- Declining interest of U.S. students in STEM careers
- Eroding ability of U.S. to attract STEM students, scientists, and engineers from abroad.

## Trends in Federal R&D as Percent of GDP, FY 1976-2010

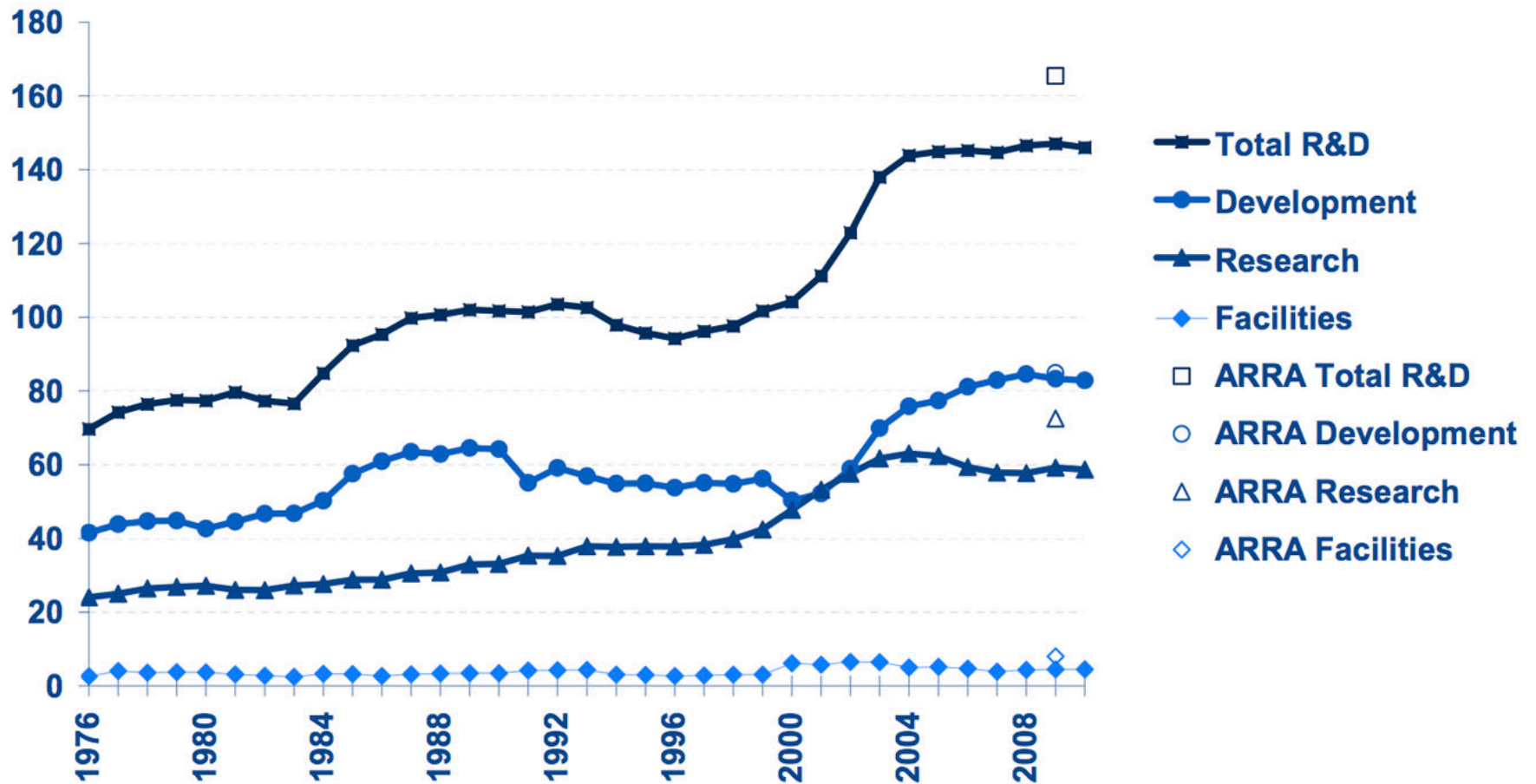


Source: AAAS Report: Research and Development series.  
 FY 2010 figures are latest AAAS estimates of the FY 2010 request.  
 R&D includes conduct of R&D and R&D facilities.  
 Data to 1984 are obligations from the NSF Federal Funds survey.  
 GDP figures are from OMB, *Budget of the U.S. Government FY 2010*.  
 © 2009 AAAS



# Trends in Federal R&D, FY 1976-2010

in billions of constant FY 2009 dollars



Source: AAAS analyses of R&D in annual AAAS R&D reports.

\* FY 2010 figures are latest AAAS estimates of FY 2010 request.

R&D includes conduct of R&D and R&D facilities.

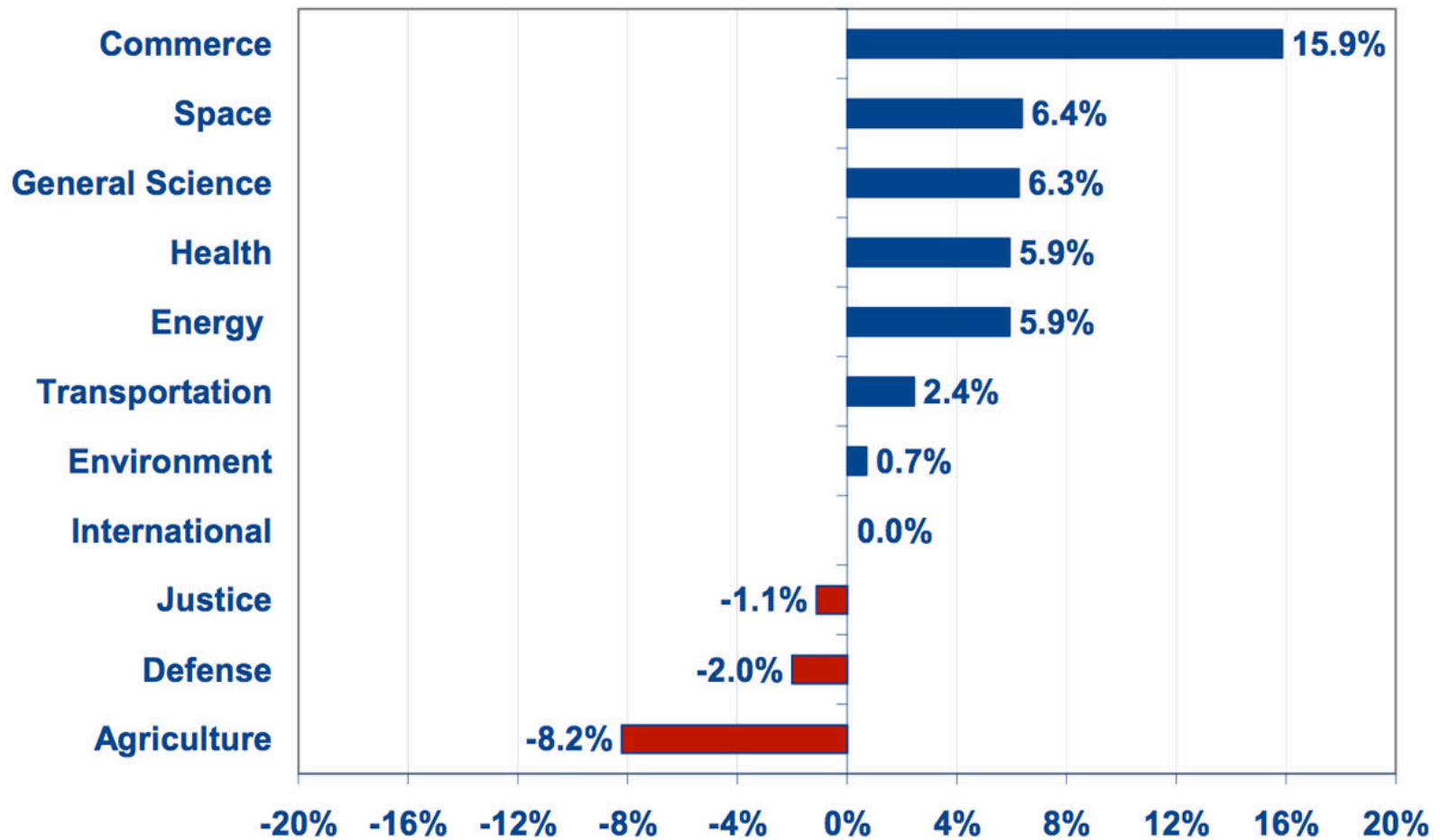
1976-1994 figures are NSF data on obligations in the Federal Funds survey.

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# FY 2010 R&D Budget Request by Function

percent change from FY 2009

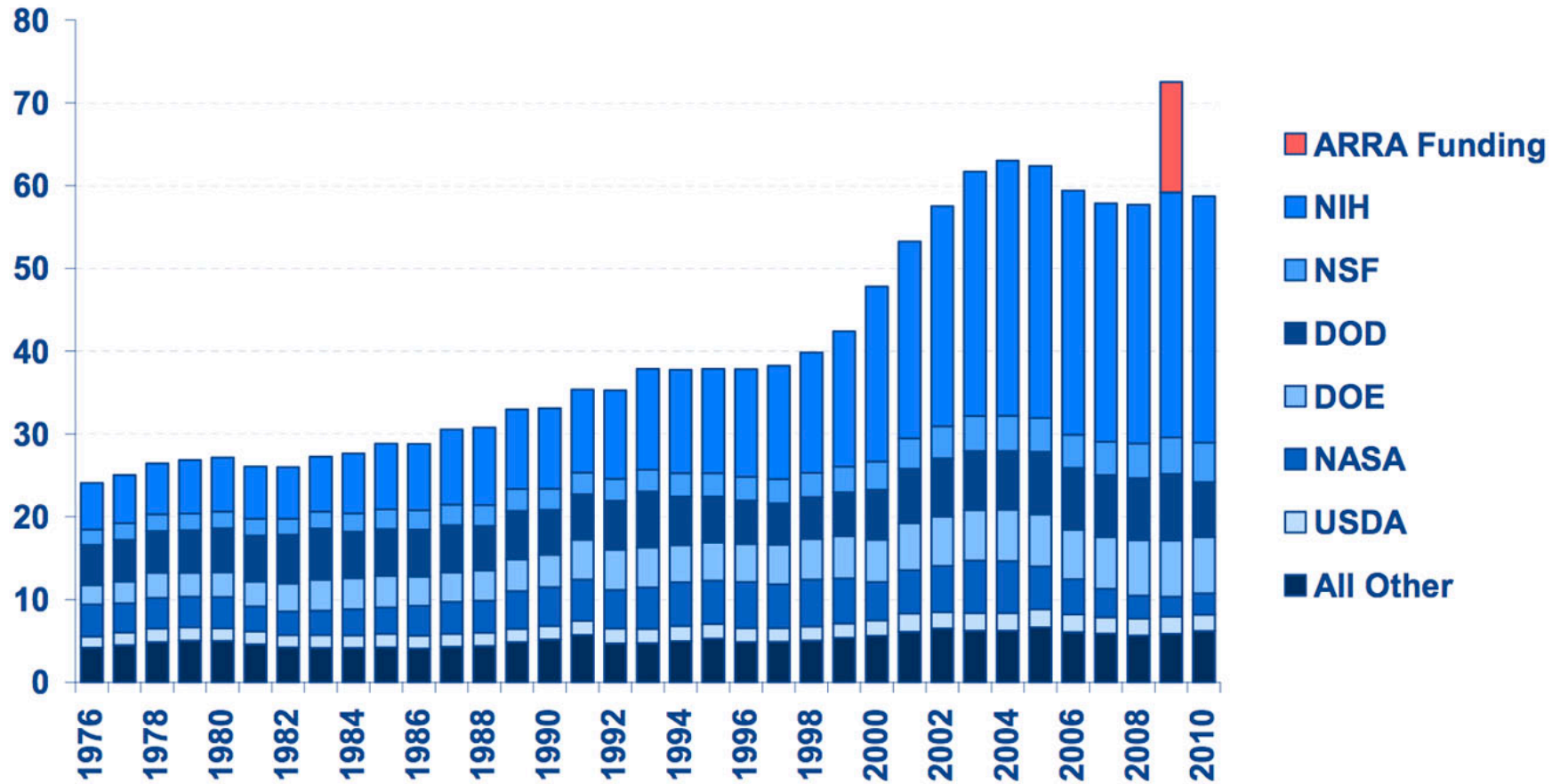


Source: OMB and agency budget data.  
Environment includes natural resources R&D  
© 2009 AAAS



# Trends in Research by Agency, FY 1976-2010

in billions of constant FY 2009 dollars



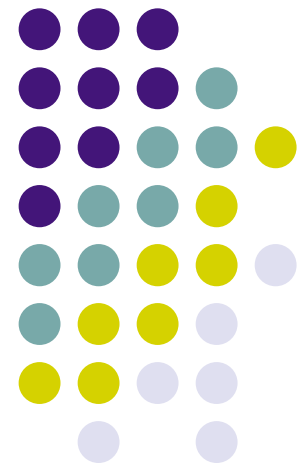
Source: AAAS Report: Research & Development series.  
 FY 2009 and FY 2010 figures are latest estimates.  
 Research includes basic research and applied research.  
 1976-1994 figures are NSF data on obligations in the Federal Funds survey.  
 © 2009 AAAS



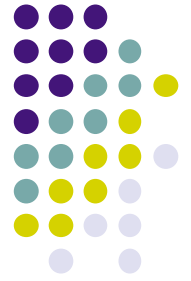


# Engineering Education

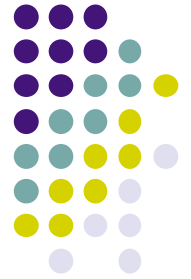
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# Engineering Workforce Concerns



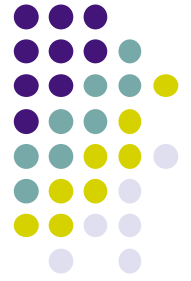
- **Student interest in science and engineering careers is at a low ebb**—and likely to go much lower as the implications of global sourcing become more apparent!
- **Cumbersome immigration policies** in the wake of 9-11 along with negative international reaction to U.S. foreign policy is threatening the pipeline of talented foreign science and engineering students.
- It is increasingly clear that a far bolder and more effective strategy is necessary if we are to tap the talents of all segments of our **increasingly diverse society** (particularly women and underrepresented minorities).



# International Comparisons

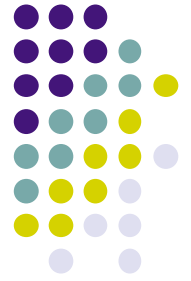
- While a comparison of the production of U.S. engineers (85,000/y) with China (350,000/y) and India (170,000/y) is complex, **of far more importance is the trend**, e.g. with China on a five-year doubling pace.
- Similarly, PhD comparisons of U.S. (17,000/y) and China (8,000/y) is misleading; China is doubling every 5 years.
- Today the **U.S. currently produces less than 4% of world's engineers**, and this is dropping fast.
- **Clearly the U.S. cannot achieve engineering leadership through the number of engineering graduates. It must focus instead on quality and value-added** through new educational paradigms for a rapidly changing, global, knowledge-driven economy.

# Yet, same old...same old...



- Curriculum **still stresses analytical skills** to solve well-defined problems **rather than engineering design**, innovation, and systems integration.
- **Continue to pretend that an undergraduate education is sufficient**, despite fact that curriculum has become bloated and overloaded, pushing aside liberal education.
- **Fail to take a more formal approach to lifelong learning** like other professions (medicine, law).
- **Need to broaden education** to include topics such as innovation, entrepreneurial skills, globalization, knowledge integration.
- And **make it all exciting and attractive** to young people!

# We need new paradigms...

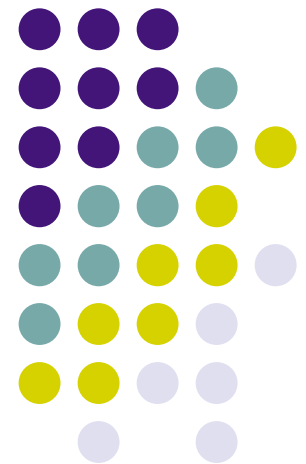


- To respond to the **incredible pace of intellectual change** (e.g., from reductionism to complexity, analysis to synthesis, disciplinary to multidisciplinary)
- To accommodate a far **more holistic approach** to addressing social needs and priorities, linking economic, environmental, legal, and political considerations with technological design and innovation.
- To reflect in **diversity, quality, and rigor** the characteristics necessary to serve a 21st C world.
- To infuse in our students a **new spirit of adventure**, in which risk-taking and innovation are seen as an integral part of engineering practice.



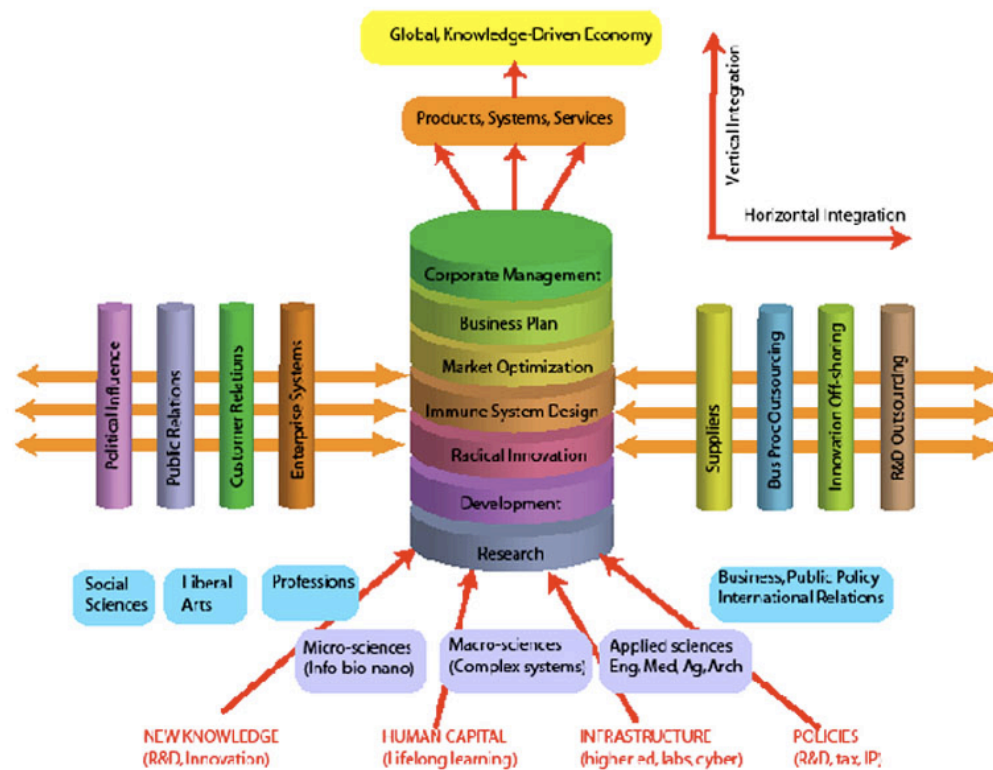
# A Roadmap to 21st Century Engineering

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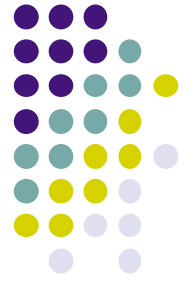
# Engineering for a Changing World

## A Roadmap to the Future of Engineering Practice, Research, and Education



The Millennium Project  
The University of Michigan

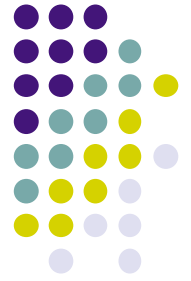




# Conclusion 1

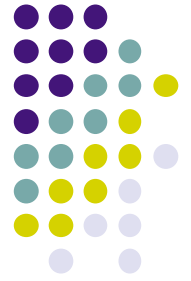
In a global, knowledge-driven economy, technological innovation—the transformation of knowledge into products, processes, and services—is critical to competitiveness, long-term productivity growth, and the generation of wealth. Preeminence in technological innovation requires leadership in all aspects of engineering: engineering research to bridge scientific discovery and practical applications; engineering education to give engineers and technologists the skills to create and exploit knowledge and technological innovation; and the engineering profession and practice to translate knowledge into innovative, competitive products and services.

# Conclusion 2



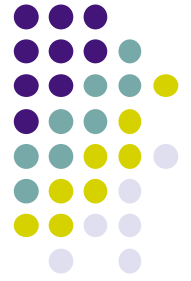
To **compete** with talented engineers in other nations in far greater numbers and with far lower wage structures, **American engineers must be able to add significantly more value than their counterparts abroad** through their greater intellectual span, their capacity to innovate, their entrepreneurial zeal, and their ability to address the grand challenges facing our world.

# Conclusion 3



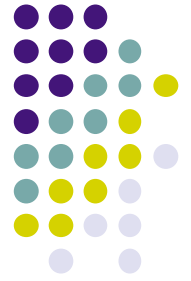
It is similarly **essential to elevate the status of the engineering profession, providing it with the prestige and influence to play the role it must** in an increasingly technology-driven world while creating sufficiently flexible and satisfying career paths to attract outstanding students. Of particular importance is greatly enhancing the role of engineers both in **influencing public policy** and popular perceptions and as participants in **leadership roles in government and business**.

# Conclusion 4



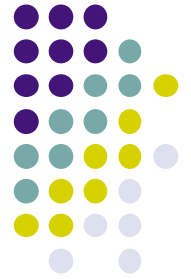
From this perspective **the key to producing such world-class engineers** is to take advantage of the fact that the comprehensive nature of our universities provide the opportunity for **significantly broadening the educational experience of engineering students**. Essentially **all other learned professions have long ago moved in this direction** (law, medicine, business, architecture), **requiring a broad liberal arts baccalaureate education as a prerequisite for professional education at the graduate level**.

# Engineering Practice



Goal: To establish engineering practice as **a true learned profession**, similar in rigor, intellectual breadth, stature, and influence to law and medicine, with extensive post-graduate education and a culture more characteristic of **professional guilds** than corporate employees.

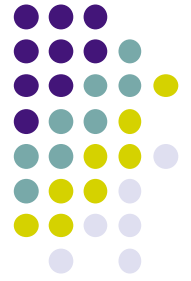
# Proposed Action



Proposed Action: Engineering professional and disciplinary societies working with engineering leadership groups should strive to create a guild culture in the engineering professional similar to those characterizing other learned professions such as medicine and law.

In such a guild culture engineers would identify more with their profession than their employer, taking pride in being a part of a true profession whose services are highly valued by clients and society.

# A Guild Culture



Note the transition:

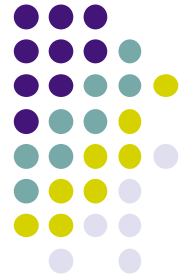
Engineers: from **employees** to **professionals**

Market: from **employers** to **clients** or **customers**

Society: from **occupation** to **profession**

The Challenge: The great diversity among engineering professional and disciplinary societies and engineering roles that inhibits working together to develop sufficient influence at the state and federal level to elevate the status of the profession.

# Engineering Research



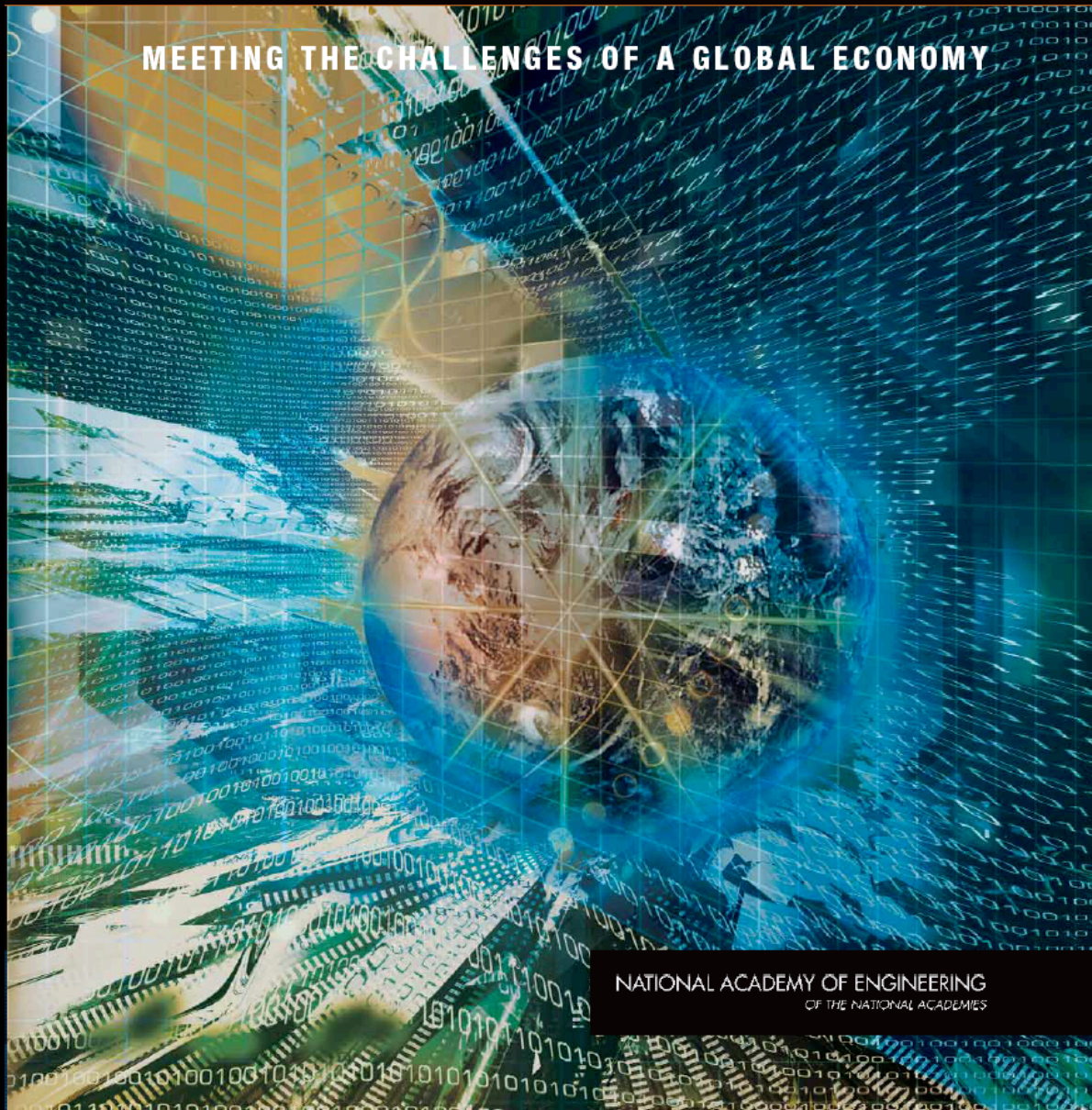
Goal: To redefine the nature of basic and applied engineering research, developing **new research paradigms** that better address compelling social priorities than those characterizing scientific research.



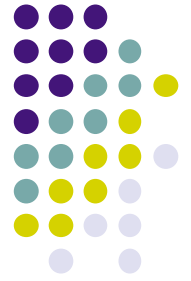
# ENGINEERING RESEARCH AND AMERICA'S FUTURE

MEETING THE CHALLENGES OF A GLOBAL ECONOMY

NATIONAL ACADEMY OF ENGINEERING  
OF THE NATIONAL ACADEMIES



# Recommendations



- Balancing Federal R&D Portfolio
- Re-establishing Basic Engineering Research As A Priority of Industry
- Strengthening Linkages Between Industry and Research Universities
- Human Capital
- Discovery-Innovation Institutes

EXECUTIVE SUMMARY

Prepublication Copy

# RISING ABOVE THE GATHERING STORM

*Energizing and  
Employing America  
for a Brighter  
Economic Future*

NATIONAL ACADEMY OF SCIENCES,  
NATIONAL ACADEMY OF ENGINEERING, AND  
INSTITUTE OF MEDICINE

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OF THE NATIONAL ACADEMIES

# Committee on Science and Technology

U.S. HOUSE OF REPRESENTATIVES



BART GORDON, CHAIRMAN



About  
Us

Subcommittees

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Our Events &  
Investigations

Tracking  
R&D Funding

Press  
Room

Hearings &  
Publications

For Members  
& Citizens

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## **Find Our Legislation**

- NEW Highlight
- All Highlights
- Legislative Reports (110th Congress)
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- Legislative Reports (107th Congress)
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- Legislative Reports (105th Congress)
- Legislative Reports (104th Congress)
- Legislative Reports (103rd Congress)
- Legislative Reports (102nd Congress)

..... Search the Web site .....

**Legislative Highlights** :: *July 31, 2007*

## **The America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (COMPETES)**

**H.R. 2272**

**Bill Summary and Status**

**H.R. 2272 Legislative Text**

**Amendments Adopted in Conference**

**Academic, Research and Business Groups Endorsing the Conference Report**

***Conference Completed, July 31, 2007***

***Signed Into Law by the President, August 9, 2007***

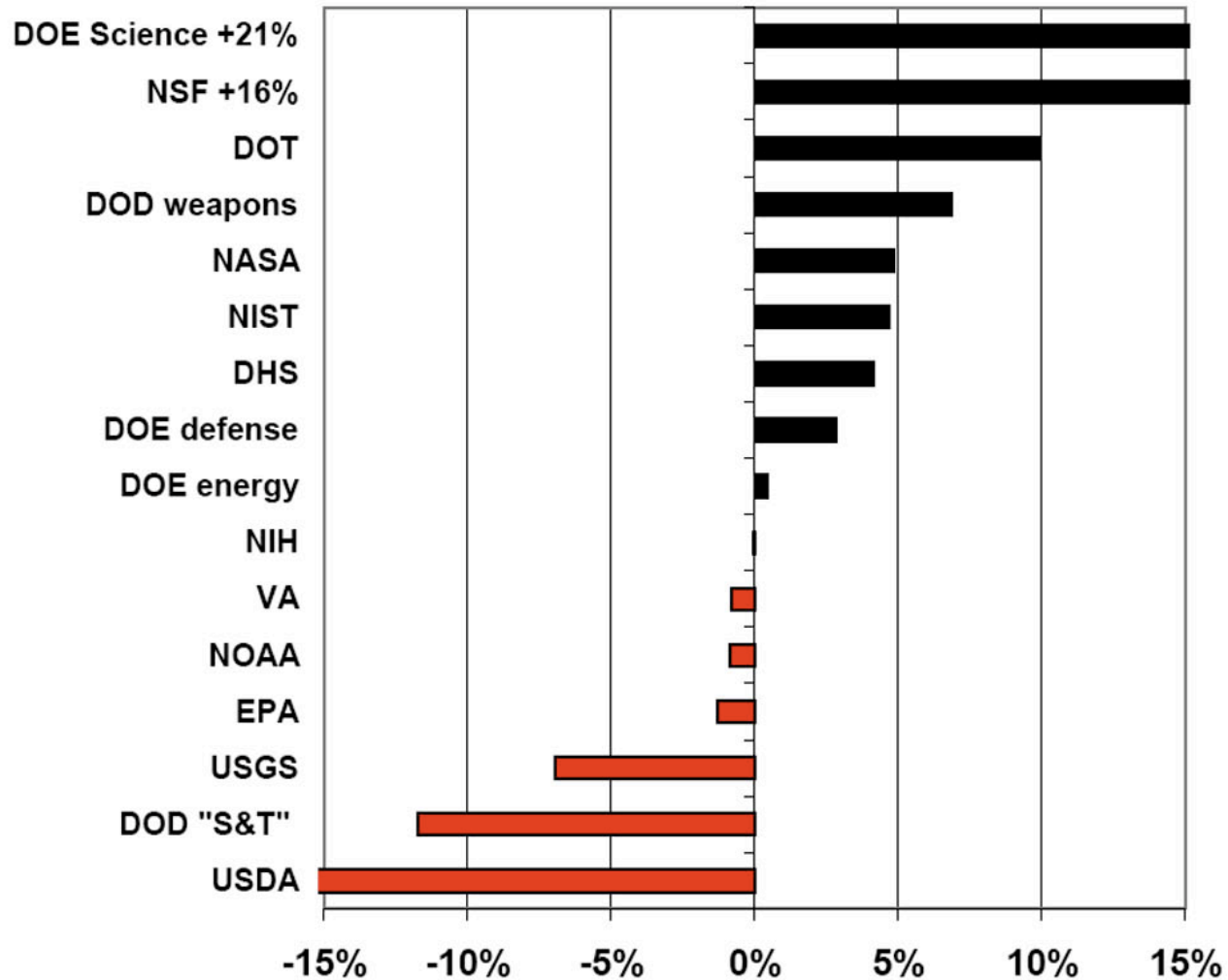
### **SUMMARY**

Earlier this year, both the U.S. House and Senate passed comprehensive legislation (H.R. 2272, S. 761) to ensure our nation's competitive position in the world through improvements to math and science education and a strong commitment to research.





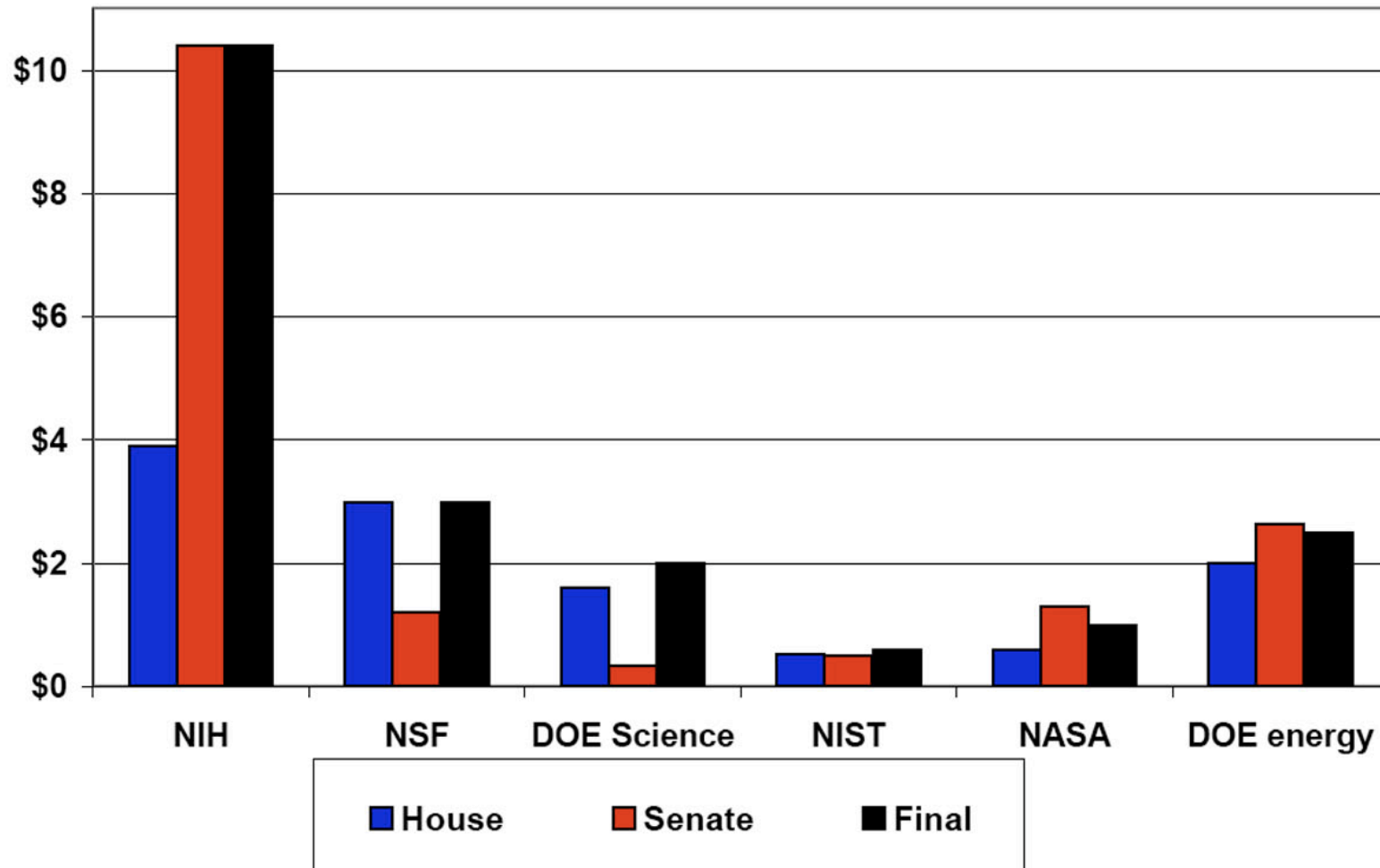
## FY 2009 R&D Request Percent Change from FY 2008



Source: AAAS, based on OMB R&D data and agency estimates for FY 2009.  
 DOD "S&T" = DOD R&D in "6.1" through "6.3" categories plus medical research.  
 DOD weapons = DOD R&D in "6.4" and higher categories.  
 MARCH '08 REVISED © 2008 AAAS



## 2009 Supplemental Recovery Funding for R&D (House, Senate, and Final bills) (budget authority in billions of dollars)



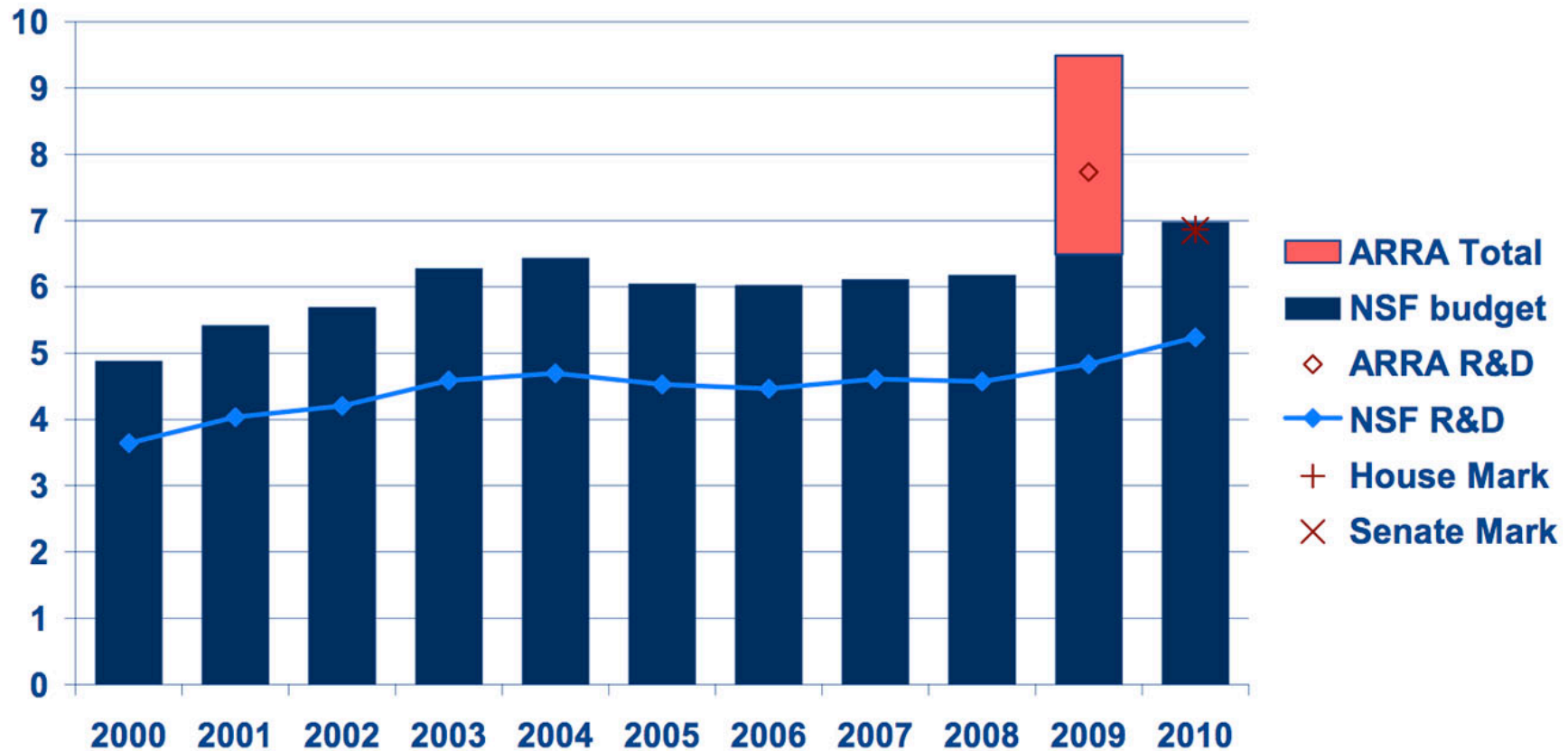
Source: AAAS analysis of R&D in House, Senate, and Final stimulus appropriations bills (HR 1).  
FEB. '09 © 2009 AAAS





# National Science Foundation Budget, FY 2000-2010

budget authority in billions of constant FY 2009 dollars



Source: AAAS Report: Research & Development series.  
 FY 2009 and FY 2010 figures are latest estimates.  
 R&D includes conduct of R&D and R&D facilities.  
 © 2009 AAAS

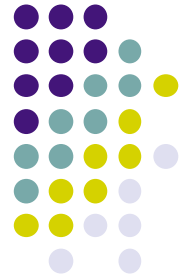


# Leadership in Innovation will Require Changes



- In the way research is prioritized, funded, and conducted.
- In the education of engineers and scientists.
- In policies and legal structures such as intellectual property.
- In strategies to maximize contributions from institutions (universities, corporate R&D, federal agencies, national laboratories)

# Discovery Innovation Institutes



“To address the challenge of maintaining the nation’s leadership in technological innovation, the committee is convinced that a bold, transformative initiative is required. To this end, **we recommend the establishment of multidisciplinary Discovery-Innovation Institutes on university campuses** designed to perform the engineering research that links fundamental scientific discovery with the technological innovation to create the products, processes, and services needed by society.”

National Academy of Engineering Study (2005)



Corporate R&D Laboratory (Pfizer)



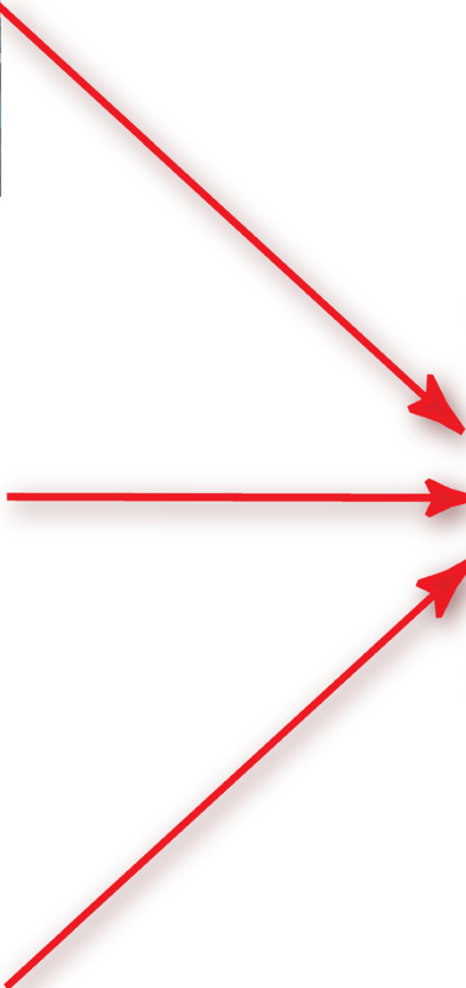
Agricultural Extension (Michigan State)



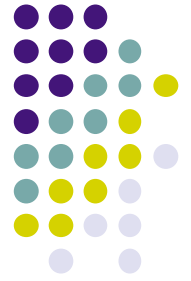
Academic Medical Center (Michigan)



Discovery Innovation Institute???

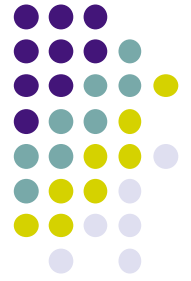


# Discovery-Innovation Institutes



- Although **primarily associated with 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.

# Engineering Education

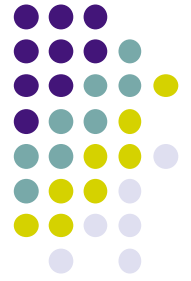


Goal 1: To adopt a **systemic approach to the reform of engineering education**, recognizing the importance of diverse approaches—albeit characterized by quality and rigor—to serve the highly diverse technology needs of our society.

Goal 2: To establish **engineering as a true liberal arts discipline**, similar to the natural science, social sciences, and humanities by imbedding it in the general education requirements of a college graduate for an increasingly technology-driven and dependent society of the century ahead.

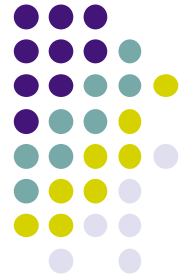
Goal 3: To **achieve far greater diversity** among the participants in engineering, the roles and types of engineers needed by our nation, and the programs engaged in preparing them for professional practice.

# A Significant Advantage



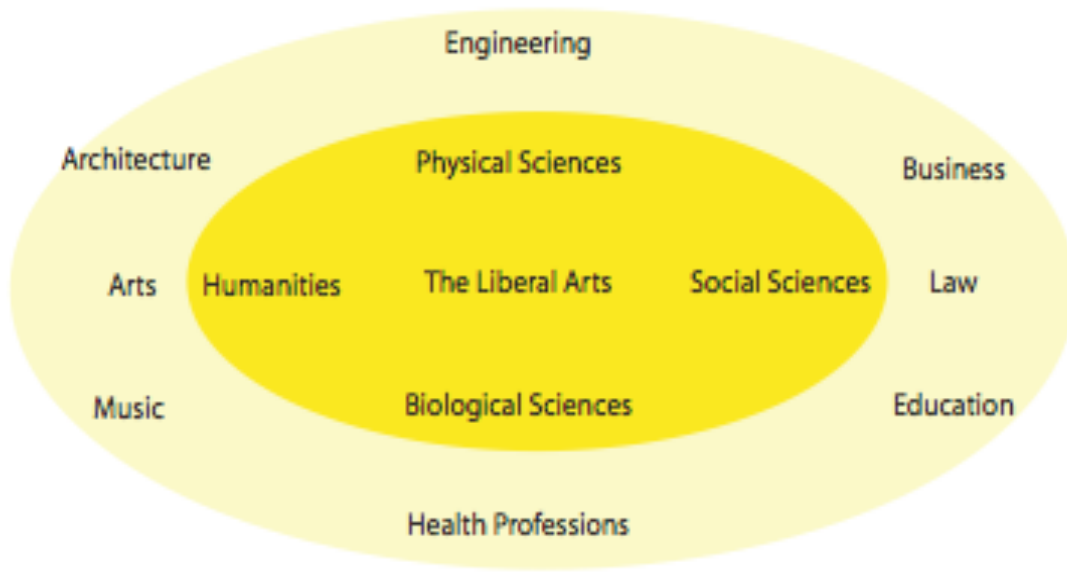
- The comprehensive nature of universities in which most engineering education occurs, spanning the range of academic disciplines and professions, from liberal arts to law, medicine, and other learned professions.
- Comprehensive universities have the **capacity to augment STEM education with the broader exposure to humanities, arts, and social sciences**, critical to building both the creative skills and cultural awareness necessary to compete in a globally integrated society.
- Their **integration of education, research, and service** provides a formidable environment for educating 21st century engineers.

# A new paradigm

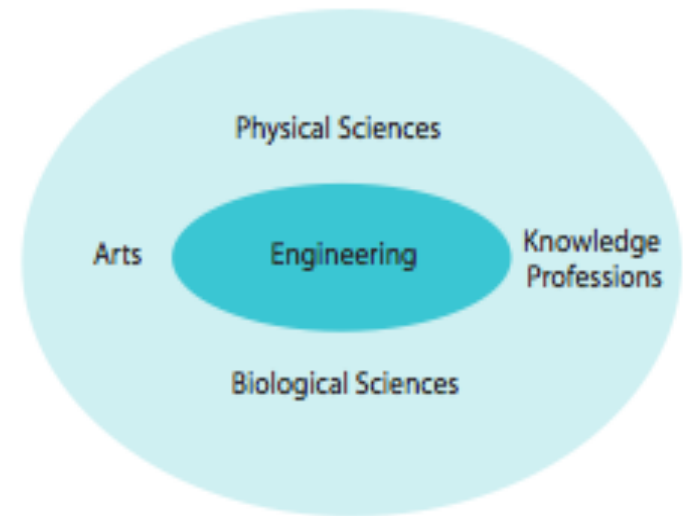


- U.S. universities have the **unique capacity to develop a new paradigm for engineering education that takes full advantage of their comprehensive nature** to create a new breed of engineer, capability of adding much higher value in a global, knowledge economy.
- But this will require a **separation** of engineering as an **academic discipline** from engineering as a **learned profession!**



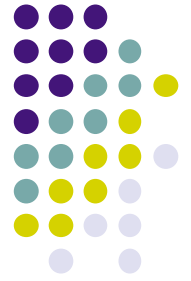


Engineering as a Profession



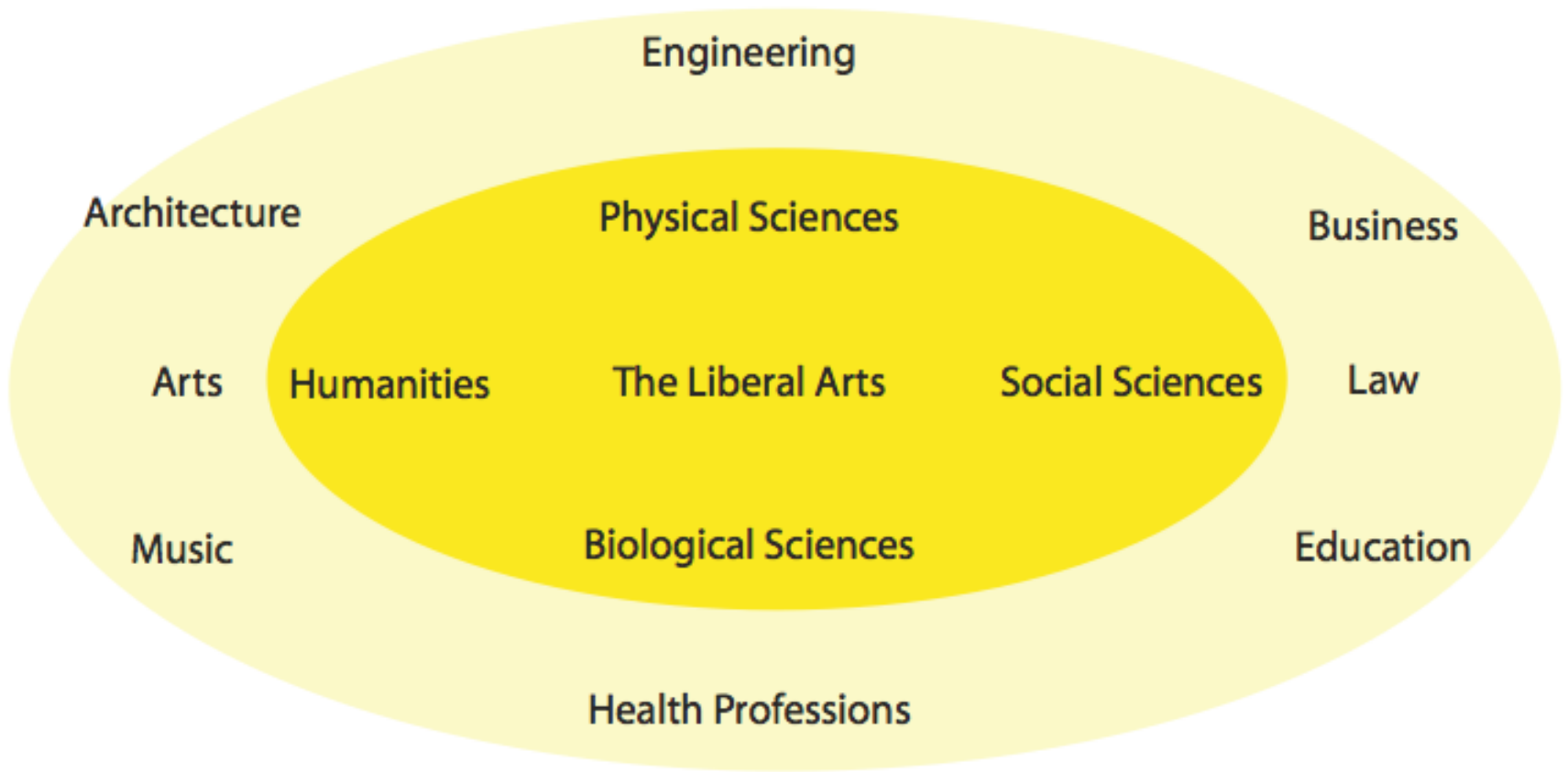
Engineering as a Liberal Arts Discipline

# Proposed Actions



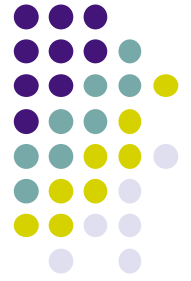
Action 1: Working closely with industry and professional societies, higher education should establish *graduate professional schools of engineering* that would offer practice-based degrees at the post-baccalaureate level as the entry degree into the engineering profession.

The most effective way to raise the value, prestige, and influence of the engineering profession is to create true post-baccalaureate professional schools, with practice-experienced faculty, which provide clinical practice experience for students, similar to medicine and law.



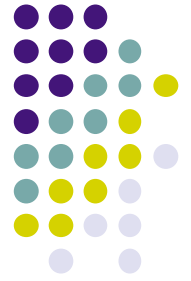
Engineering as a Profession

# Professional Schools

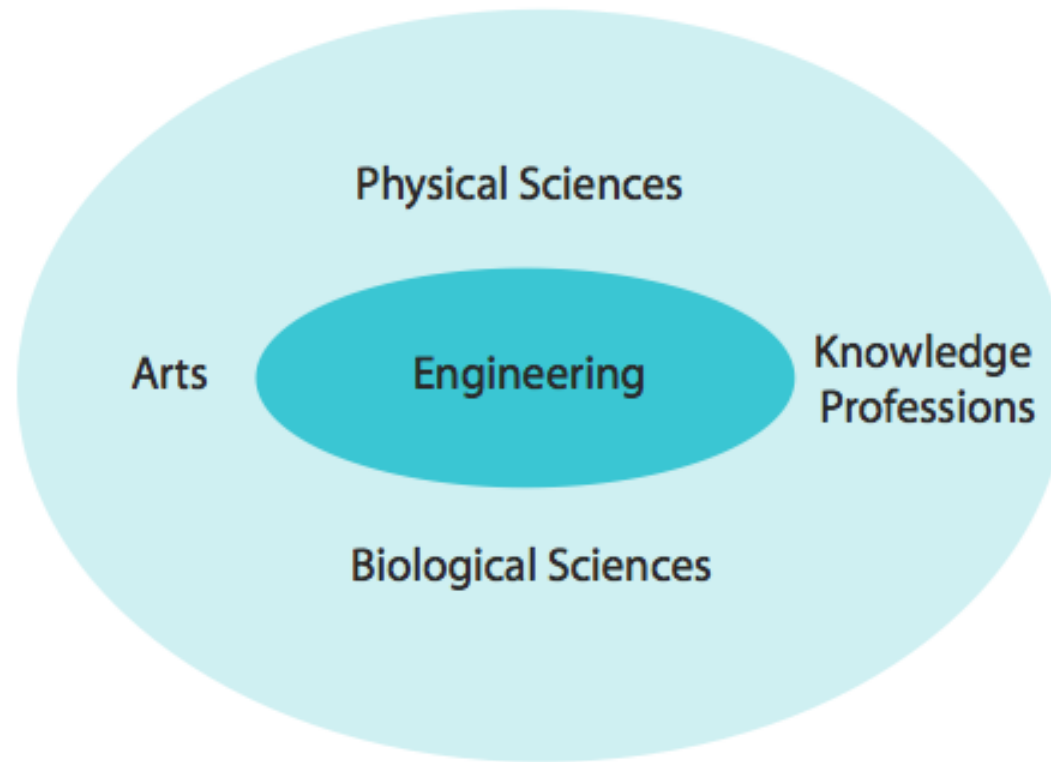


- Shifting the professional education and training of engineers to **two- or three-year practice-focused degree programs**.
- Staffed by **faculty** with strong backgrounds **in practice** and **scholarly interests** in areas such as design, innovation, entrepreneurial activities, and global systems.
- Students drawn from a **broader array of undergraduate programs**.
- Augmented by either **internships or affiliated organizations** (e.g., discovery-innovation institutes, engineering services companies).

# Proposed Actions (cont.)

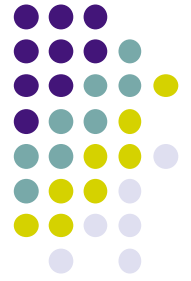


*Action 2: Undergraduate engineering should be reconfigured as an academic discipline, similar to other liberal arts disciplines in the sciences, arts, and humanities, thereby providing students with more flexibility to benefit from the broader educational opportunities offered by a comprehensive university with the goal of preparing them for a lifetime of further learning rather than professional practice.*



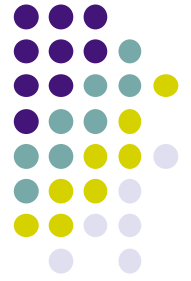
Engineering as a Liberal Arts Discipline

# Opportunities



- **Removing burdens of professional accreditation** would allow UG engineering to be reconfigured as other academic disciplines, thereby providing students with more flexibility to benefit from the broader educational opportunities offered by the comprehensive university.
- This would **reverse the trend toward ever more narrow specialization** among engineering majors currently driven by the reductionist approach of science rather than the highly integrative character of engineering synthesis.
- **Reframing UG engineering as an academic discipline** rather than a pre-professional program would allow students to benefit from a truly liberal education.

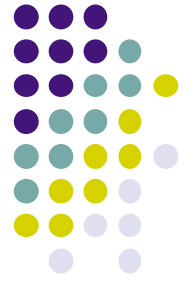
# Proposed Actions (cont.)



Action 3: Working together with disciplinary and professional societies, industry, and government, engineering educators should develop a structured approach to providing lifelong educational opportunities for practicing engineers similar to those in medicine and law.

Note: This will require not only a significant commitment by educators and employers and likely as well additional licensing requirements developed by professional societies and regulatory bodies.



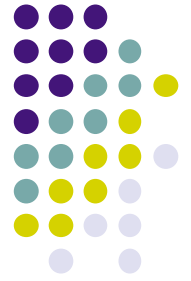


# Proposed Action (cont.)

Action 4: The academic discipline of engineering (or, perhaps more broadly technology) should be *included in the liberal arts canon* undergirding a 21<sup>st</sup> undergraduate education for all students.

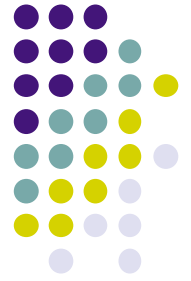
In a world increasingly dependent upon technology, it seems appropriate that the engineering discipline be added to the liberal arts core of a general education, much as the natural sciences were added a century ago to the classical liberal arts (the *trivium* and *quadrivium*)

# Proposed Action (cont.)



Action 5: All participants and stakeholders in the engineering community (industry, government, higher education, professional societies) should commit the resources, programs, and leadership necessary to enable participation in engineering to achieve a racial, ethnic, and gender diversity consistent with changing nature of the American population.

# The Future of Engineering Schools



- What would the separation of engineering as a profession and a discipline portend for existing **engineering schools**?
- Would they evolve into **science-like disciplines** with extensive service teaching obligations?
- Where would **professional engineering schools** (and faculties) reside in the university?

***Academic  
Medical  
Center***

***Education***

Biomedical Sciences  
Physician Training  
Residencies

Degrees  
...M.D., Ph.D.

***Research***

Basic Research  
Clinical Research  
Clinical Trials

Publications  
Patents

***Organizations***

Teaching Hospitals  
Research Centers

Clinical Care  
Spinoff Companies



**Academic  
Medical  
Center**

**Education**

Biomedical Sciences  
Physician Training  
Residencies

Degrees  
...M.D., Ph.D.

**Research**

Basic Research  
Clinical Research  
Clinical Trials

Publications  
Patents

**Organizations**

Teaching Hospitals  
Research Centers

Clinical Care  
Spinoff Companies

**Engineering  
School**

**Education**

Undergraduate  
Graduate  
Professional

Degrees  
...B.S., B.A.  
...M.S., Ph.D.  
...M.Eng., D. Eng..

**Research**

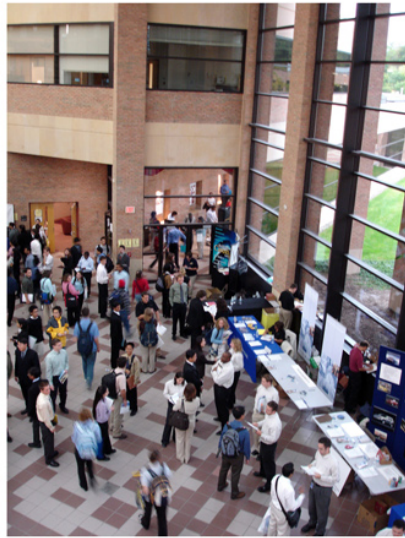
Basic Research  
Applied Research  
Systems Development

Publications  
Patents  
Systems, Products

**Organizations**

Discovery-Innovation Centers  
Captive Consulting Companies  
Practice Schools

Engineering Services  
Systems, Products  
Spinoff Companies





# Wm Wulf, NAE President

In his 2003 address to the National Academy of Engineering, **Bill Wulf** pleaded: “We have studied engineering reform to death. While there are differences among the reports, the differences are not great. Let’s get on with it! It is urgent that we do!”

He then went on to observe: “I honestly don’t know the answer, but I have a hypothesis—namely, that most do not believe change is necessary. They are following the time-tested adage---“**if it ain’t broke, don’t fix it.**”



# JJD's View



"Well, **American engineering IS broke**, at least when measured against the emerging technology capabilities of the rest of the world. **Otherwise it would not be outsourced and off-shored!** We can no longer afford simply chipping away at the edges of fundamental transformation of the engineering profession and its preparation."

**"Radical transformation will require radical actions!"**

The Flaws of Engineering Today

Profession  
Narrow skills  
Employed as a commodity  
Globalization  
Risk of obsolescence & off-shoring  
Supply concerns  
Low prestige

Knowledge Base  
Exponential growth of knowledge  
Disruptive technologies  
Obsolescence of disciplines  
Analysis to innovation  
Reductionist to information-rich  
Out-sourcing/off-shoring of R&D

Education  
20th C UG curriculum  
High attrition rate  
Limited exposure to practice  
Unattractive to students

The Needs of Engineering Tomorrow

Knowledge Economy  
Globalization  
Demographics

Technological Change  
Market Forces

Grand Challenges

Profession  
High value-added  
Global  
Diverse  
Innovative  
Integrator  
Communicator  
Leader

Knowledge Base  
Multi-disciplinary  
Use-driven  
Emergent  
Recursive  
Exponential

Education  
Liberal education  
Intellectual breadth  
Professionally trained  
Value driven  
Life-long learner

The Destination

A New Profession  
A learned profession  
Practitioner-trained  
World-class value added  
Guild-based rather than employed  
High prestige

New R&D Paradigms  
Integrated sci-tech  
Cyberinfrastructure enabled  
Stress on creativity/innovation  
Discovery-Innovation Institutes

A New Approach to Education  
Post-graduate professional school  
Practitioner-trained/intern experience  
Liberal education pre-engineering  
Structured lifelong learning  
Engineering as liberal art discipline  
Renewed commitment to diversity

Professional Societies

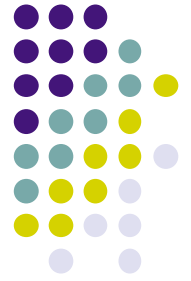
National Academy

ABET

NSF

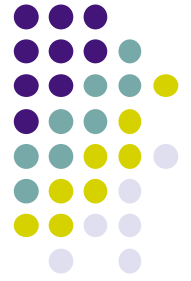
Higher Education

# What's Next?

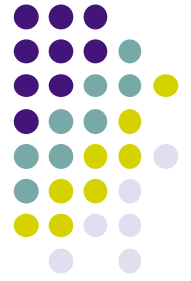


- **Option 1: Benign Neglect:** Simply continue the status quo, accepting the current global market realities, and reacting as best one can to new requirements such as the need for global engineers...and wait until conditions deteriorate sufficiently to stimulate bolder action.
- **Option 2: Evolution (Education and Persuasion):** Launch a major outreach and education campaign aimed at industry, government and the public of the importance of sustaining and enhancing domestic engineering capacity through additional investments in engineering education and research to raise the value-added of American engineers.

# “2x4” Efforts



- National Organizations
  - NSF, NSB
  - NAE
- Professional
  - ABET
  - Professional Societies
- Education
  - Deans and provosts
  - US and Canadian Deans Meetings
  - CASE, ASEE, APLU, AAU,...

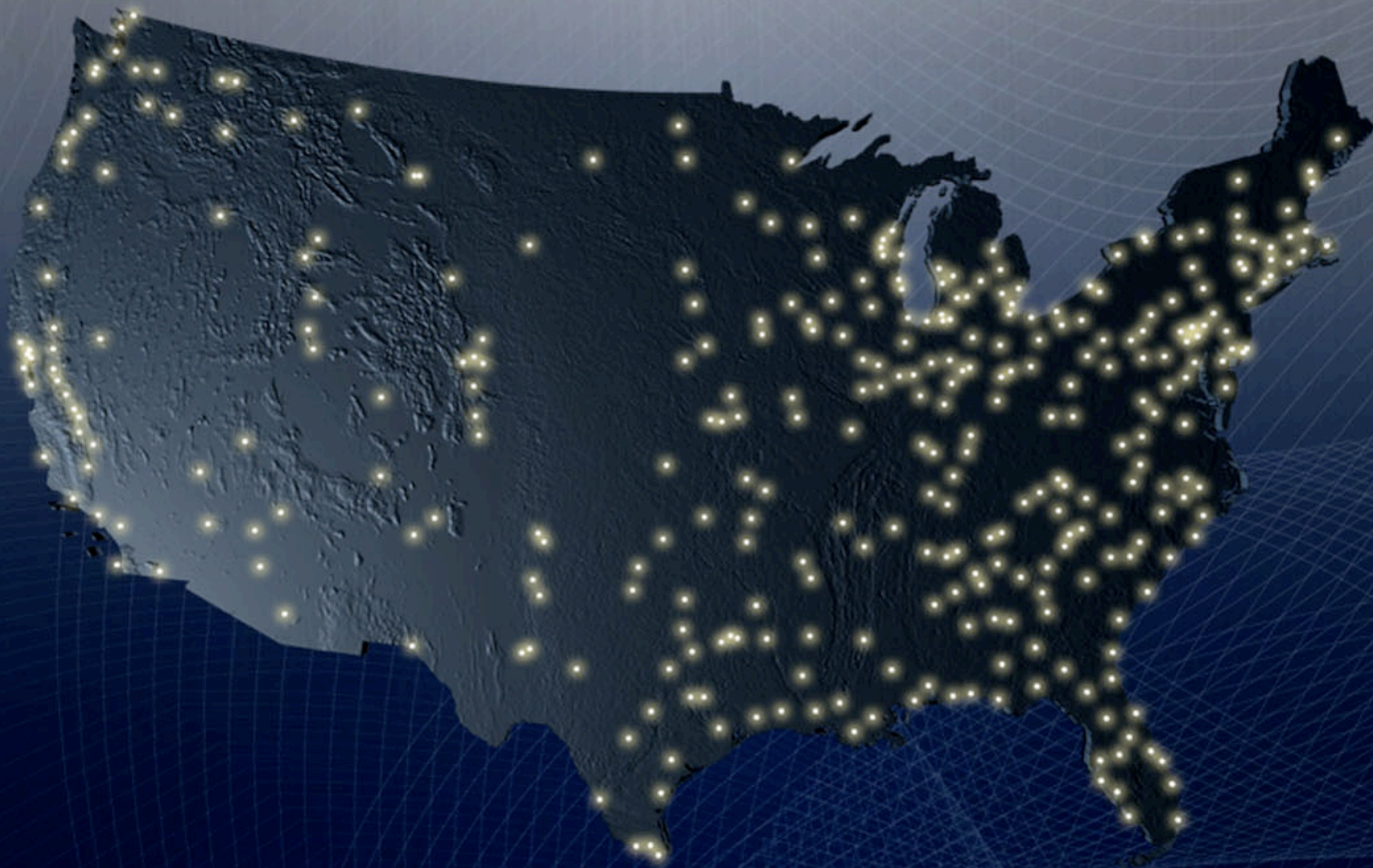


# “2x4” Efforts (cont)

- International
  - Glion Conferences (world university leaders)
  - EU (European rectors)
- University visits (US, Canada, Europe)
  - MIT, Caltech, UM, UG, UI, CWRU, ...
  - ASU, Dartmouth, Olin, McGill, Vienna,...
- Follow-on
  - UC Berkeley Conference (Spring)
  - ASU Conference (April)

# Blueprint for American Prosperity

Unleashing the Potential of a Metropolitan Nation



Metropolitan Policy Program  
at BROOKINGS

February 9, 2009  
Washington D.C.

**Paradigm: The federal government should direct a portion of the increased energy R&D funding toward a new research paradigm—  
Energy discovery-innovation institutes**

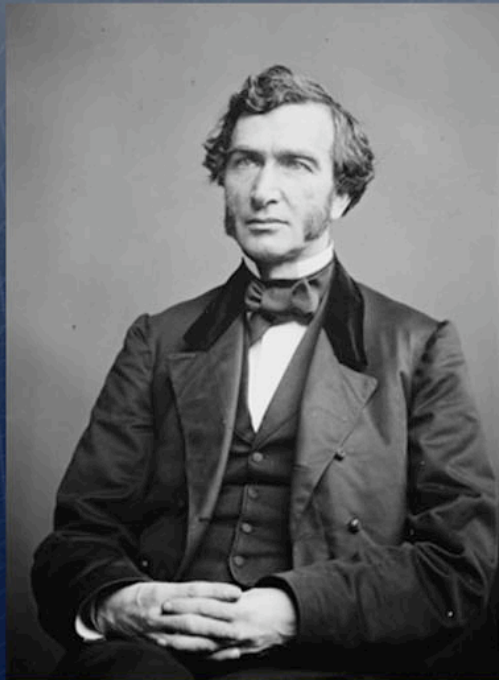
*e-DIIs*

The DII concept—  
developed by the  
National Academy of  
Engineering—aims to  
link scientific  
discoveries with  
technological  
innovation to create  
products, processes,  
and services needed  
by society

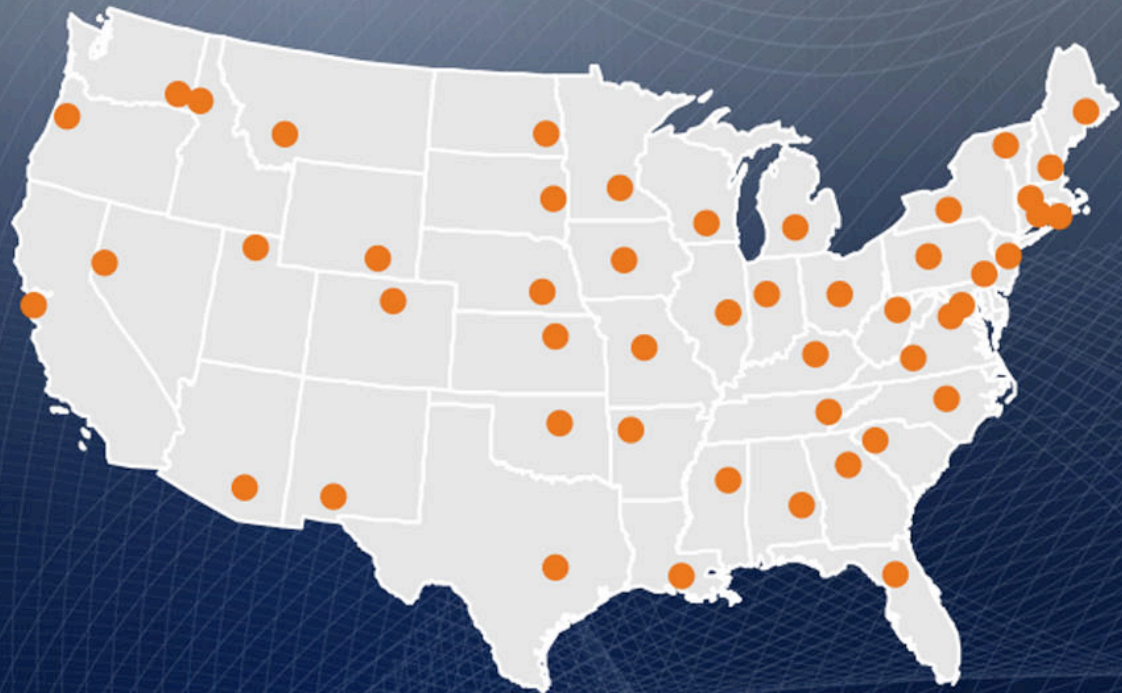




The DII concept is a contemporary adaptation of a successful research paradigm created over a century ago through the Morrill Land-Grant Act



*Justin Smith Morrill*



*The original Land-Grant colleges and universities (1862)*

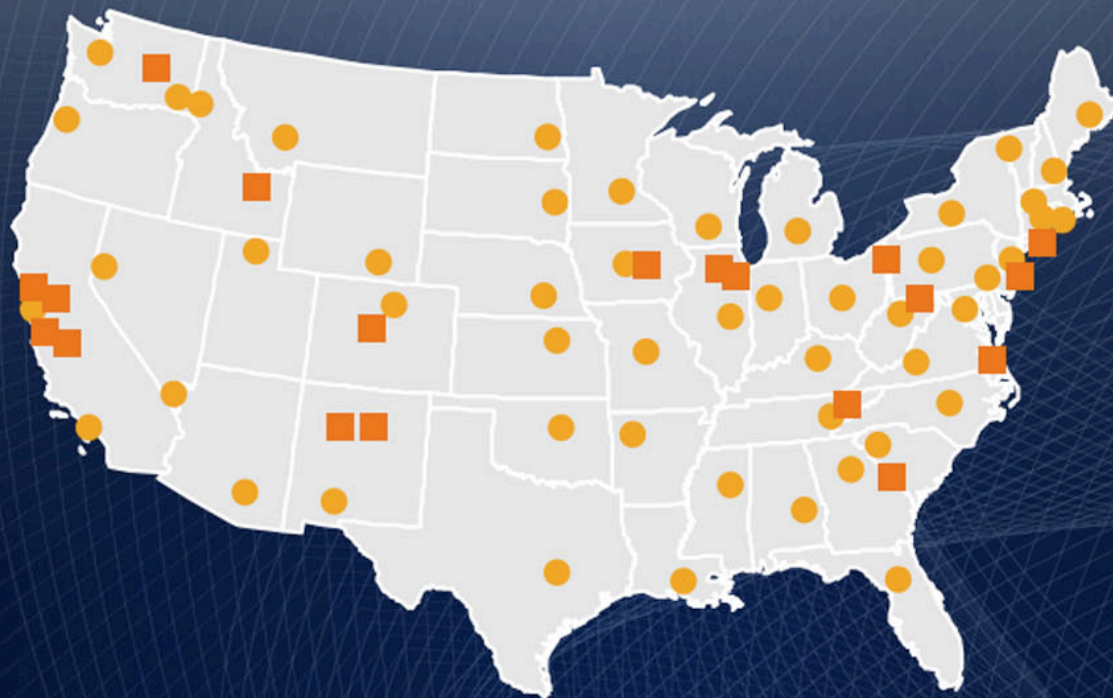
## The energy DIIs should be distributed competitively among the nation's universities and federal laboratories

Several types of institutes would anchor the national network:

- University-based e-DIIs
- Federal lab-based e-DIIs
- Federal lab—university partnerships
- Satellite energy research centers

**Core federal support would range from \$10s of millions per year for small institutes to \$200 million per year for larger university or laboratory consortia and partnerships**

Total federal commitments would approach \$6 billion per year—about 25 percent of the total recommended energy R&D funding goal of \$20 to \$30 billion annually



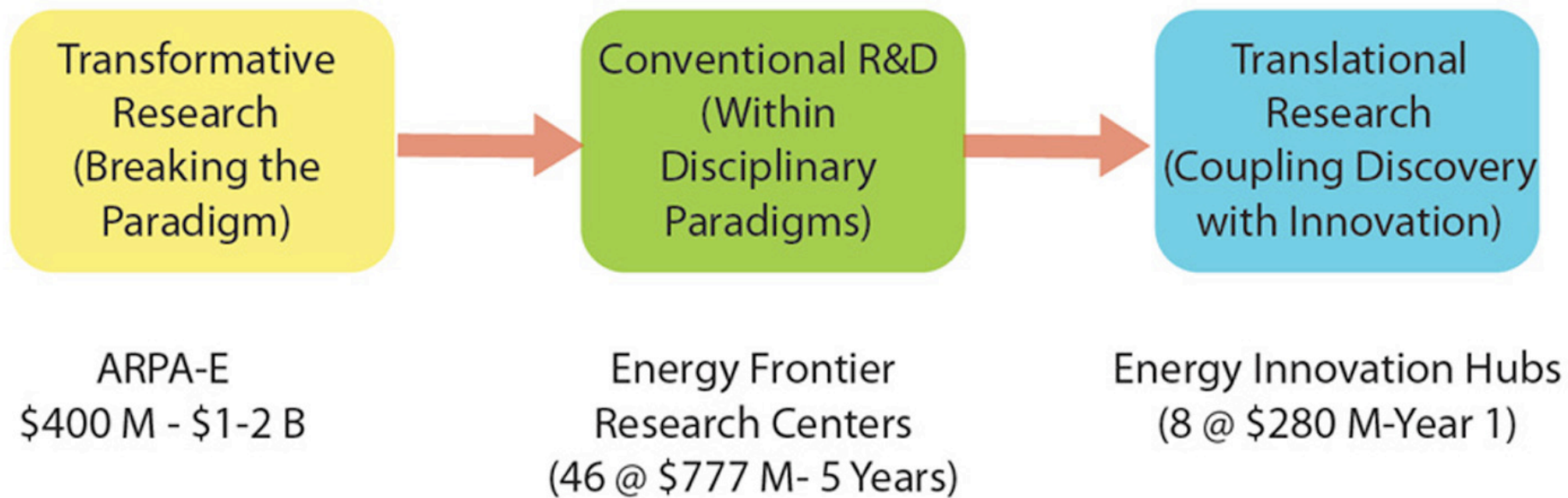


U.S. DEPARTMENT OF  
**ENERGY**

**Department of Energy  
FY 2010 Budget**

**Transforming the Energy Economy  
through Science and Innovation**

May 7, 2009



**FY 2010 budget  
funds  
breakthrough  
science**

**Eight Energy  
Innovation Hubs –  
\$280 million**

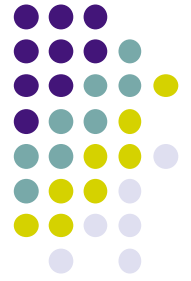
**Encourage collaboration and  
team science**

**Connect research lab to  
industrial world**

Builds on success of DOE's Bioenergy Research Centers:



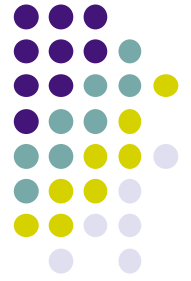
# 5xME Workshop Recommendations



- In today's global knowledge economy, mechanical engineers educated in the USA must be **able to add significantly more value** than their counterparts abroad, through the breadth of their intellectual capacity, their ability to innovate, and their leadership in addressing major societal challenges.
- The **bachelors degree should introduce engineering as a discipline**, and should be viewed as an extension of the traditional liberal arts degree where education in natural sciences, social sciences and humanities is supplemented by education in the discipline of engineering for an increasingly technological world.

# 5xME Workshop

## Recommendations (cont)



- This **bachelors degree** in the *discipline* of engineering can be viewed as the **foundational stem** upon which several extensions can be grafted: (1) continued professional depth through a professional masters degree in engineering, and (2) transition to non-engineering career paths such as medicine, law, and business administration.
- The **masters degree should introduce engineering as a *profession*, and become the requirement for professional practice**. This is where educational institutions and professional societies can build an awareness of the profession, as opposed to producing graduates who view themselves merely as employees.

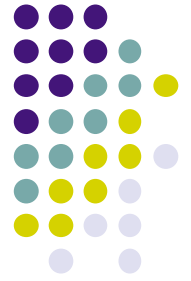


# 5xME Workshop

## Recommendations (cont)



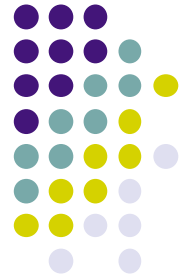
- Doctoral education in engineering is essential to national prosperity, and global competition is rapidly increasing. The **doctoral degree** in engineering, while indisputably the best in the world, **needs to be enhanced and strengthened with an emphasis on breadth as well as depth**, linking **discovery** and **innovation**, and improved **leadership** and **teaching** skills.
- **Lifelong learning** programs in engineering, including executive education, need to be developed and delivered to engineers at all stages in their professional development.



# What's Next? (cont.)

- **Option 3: Revolution (Politics and Cartels):** Engineering professional societies would emulate the efforts of the medical and law professions to seek legislation at the state and federal level to create a regulatory environment sufficient to empower the engineering profession.
- **Option 4: Punctuated Evolution and Spontaneous Emergence:** Search for tipping points that would drive rapid and fundamental change in engineering practice, research, and education (e.g., cyberinfrastructure, open education resources, new business paradigms).

# Take Heart...



“Perhaps the sentiments contained in the following pages, are not sufficiently fashionable to procure them general favour; a long habit of not thinking a thing wrong, gives it a superficial appearance of being right, and raises at first a formidable outcry in defense of custom. But the tumult soon subsides. **Time makes more converts than reason.**” (Paine, *Common Sense*, 1776)

