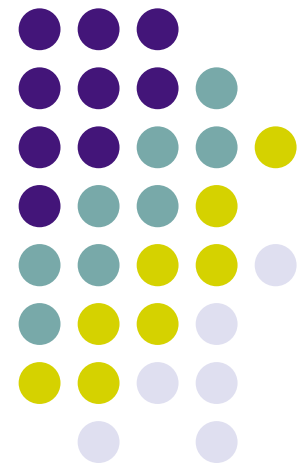
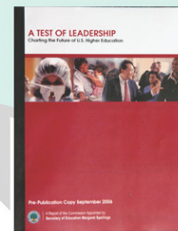
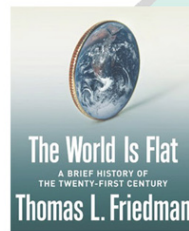
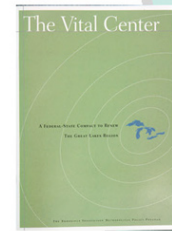
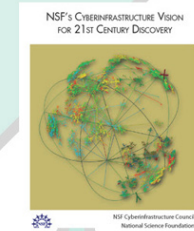
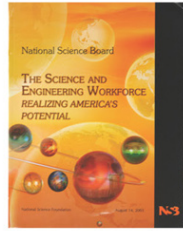
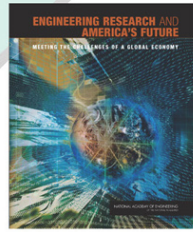


Engineering for a Changing World

The Future of
Engineering Practice,
Research, and Education



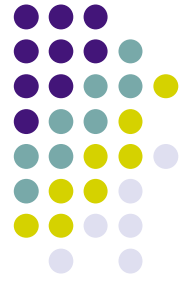




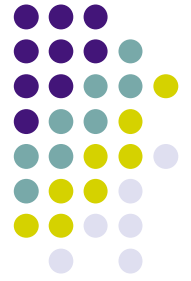
The Challenge of Change

- 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.

Perspectives of engineering



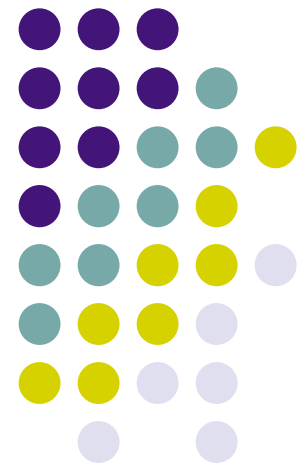
- As a **discipline** (similar to physics or mathematics), possibly taking its place among the “liberal arts” characterizing a 21st C technology-driven society.
- As a **profession**, addressing both the urgent needs and grand challenges facing our society.
- As a **knowledge base** supporting innovation, entrepreneurship, and value creation in a knowledge economy.
- As a diverse **educational system** characterized by the quality, rigor, and diversity necessary to produce the engineers and engineering research critical to prosperity, security, and social well being.



Questions

- What should our nation 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





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.



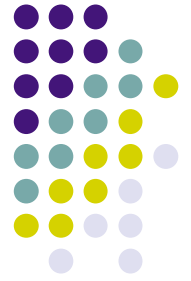




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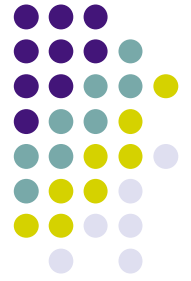
**EXTRACT
OF
BUCK-EYE**
useful for treatment
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The Medical Profession

- 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 diploma, 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!





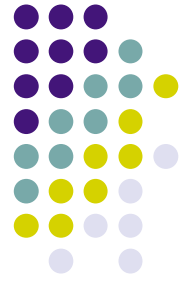
Oh, and by the way...

- 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?

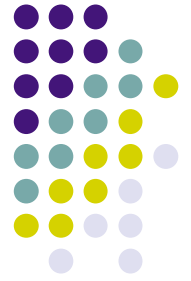


- Mann Report (1918)
- Wilkenden Report (1923)
- ASEE Grinter Report (1955)
- ASEE Green Report (1994)
- NRC BEED Report and ABET EC2000
- NAE Engineering of 2020 (2004)
- Carnegie Foundation Study (2006)
- Bill Schowalter: “Appearance every decade of a definite report on the future of engineering education 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!!!

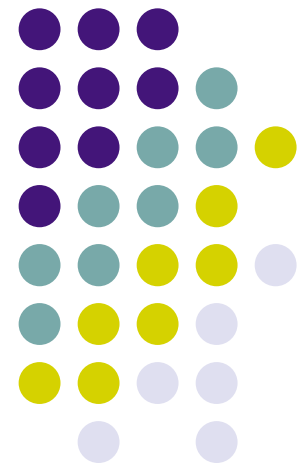
- An extrapolation of current trends such as the off shoring of engineering jobs and services, inadequate investment in long-term engineering research, inadequate innovation in engineering education, declining interest on the part of students in STEM careers, and immigration constraints raises very serious concerns.
- Without concerted action, America faces 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

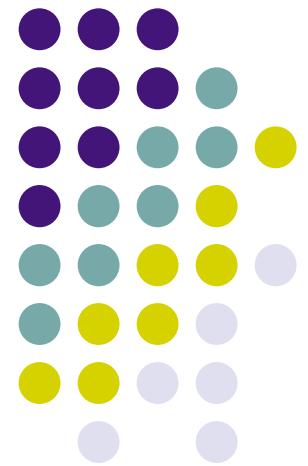


- Engineering Today (“Where we are...”)
- Engineering Tomorrow (“Where we need to be ...”)
- Gap Analysis (“How far we have to go...”)
- The Roadmap (“How to get there...”)

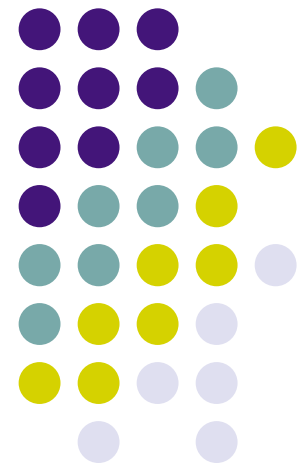
Today's Challenges



Engineering Practice



The Way the World Works Today





The World Is Flat

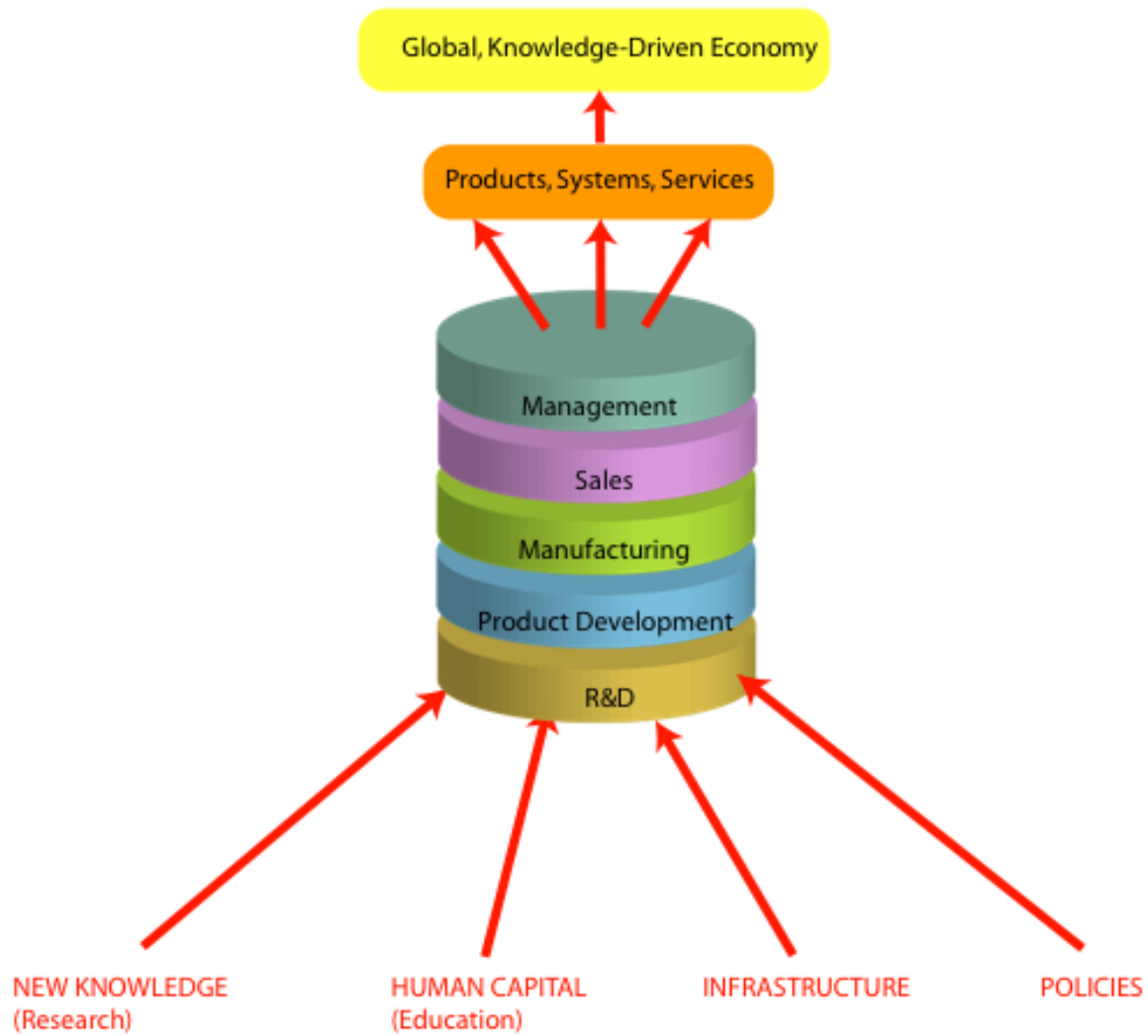
A BRIEF HISTORY OF
THE TWENTY-FIRST CENTURY

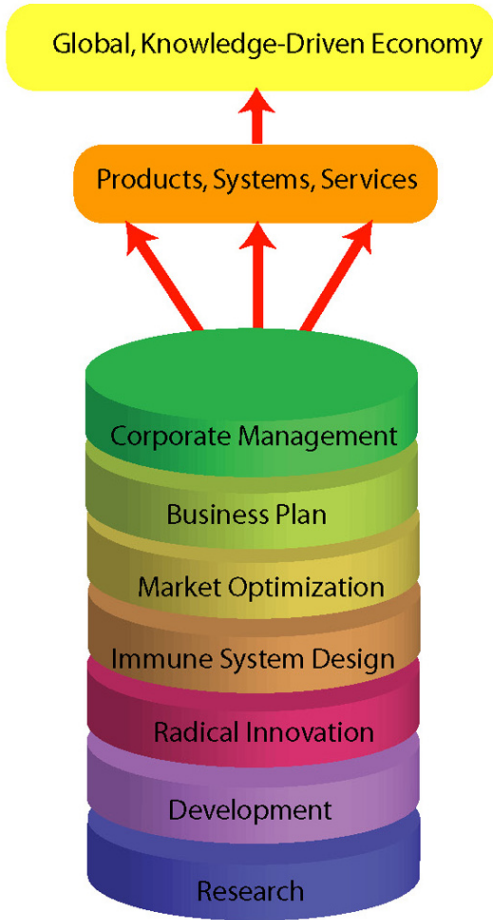
Thomas L. Friedman

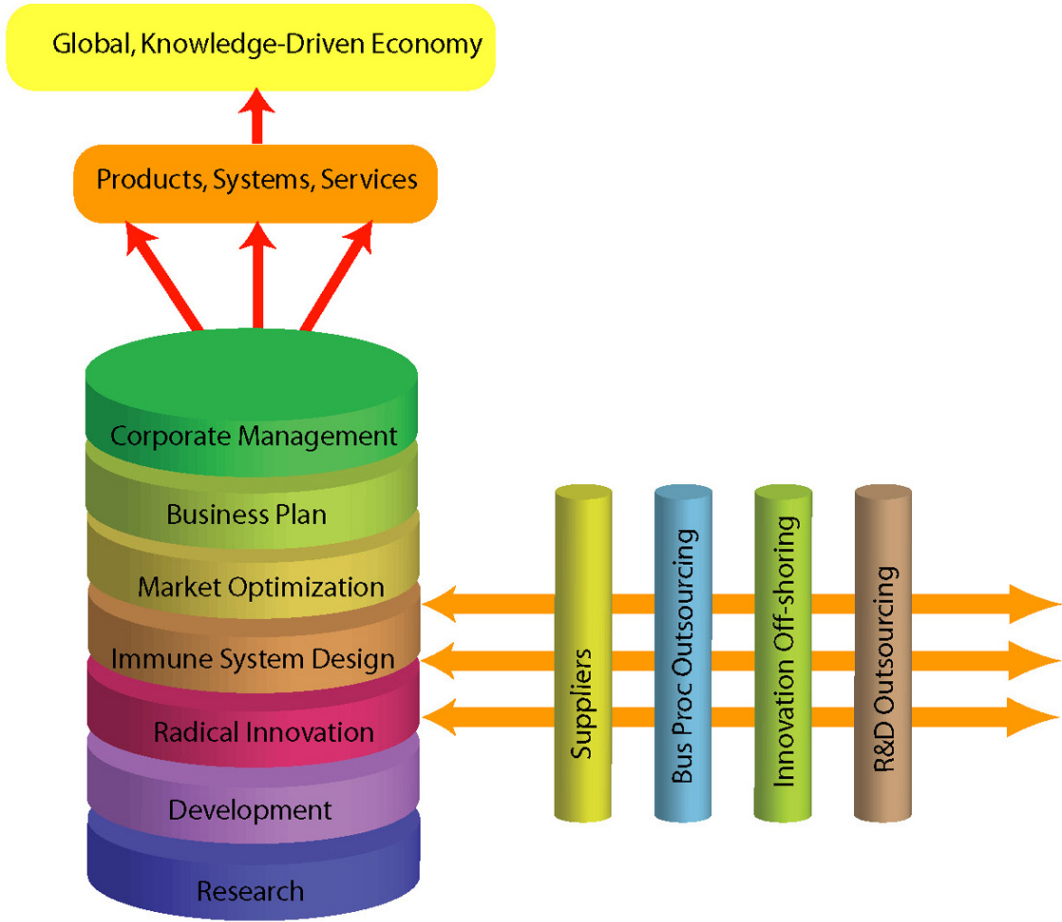
Innovation and Globalization

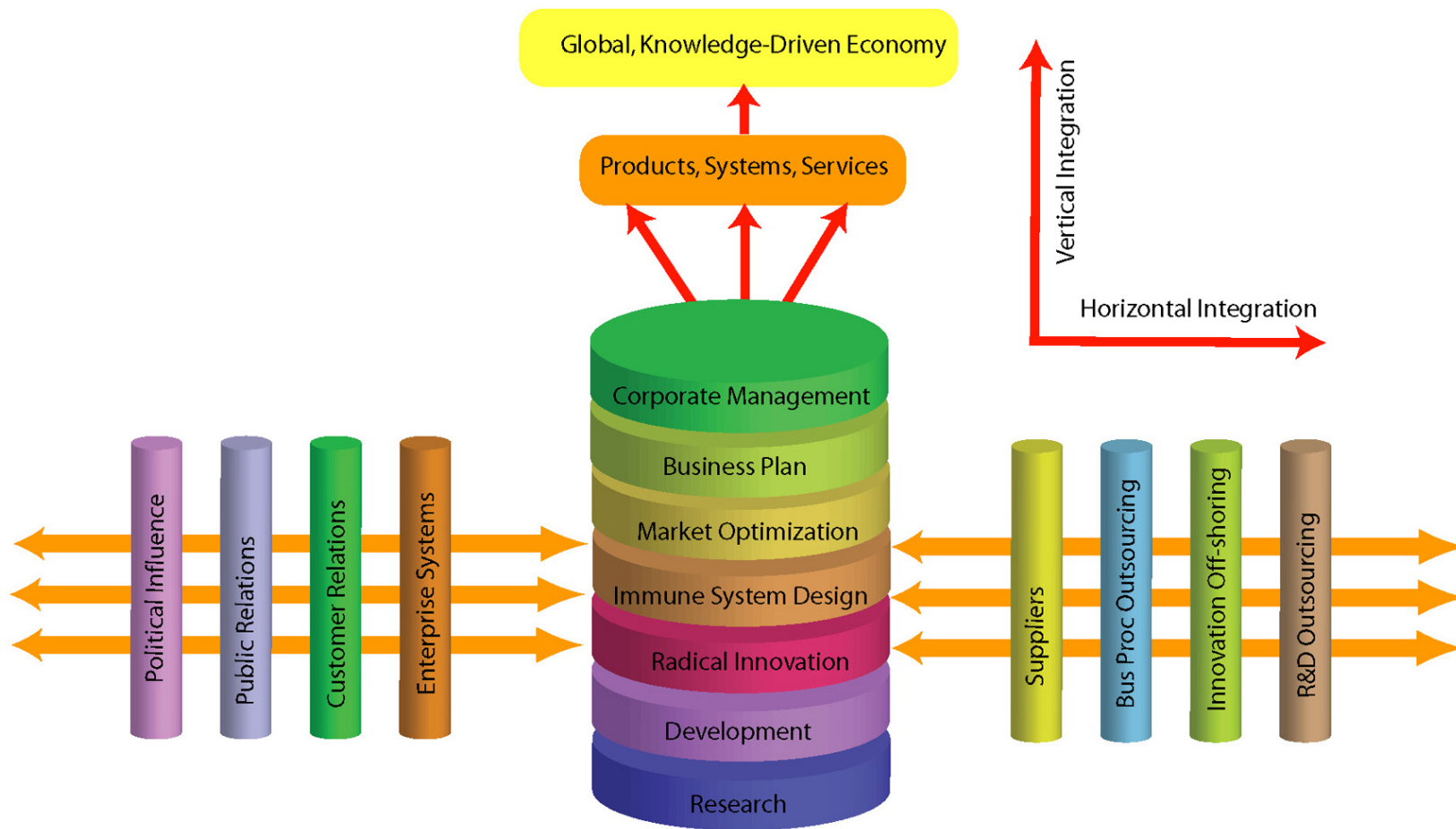


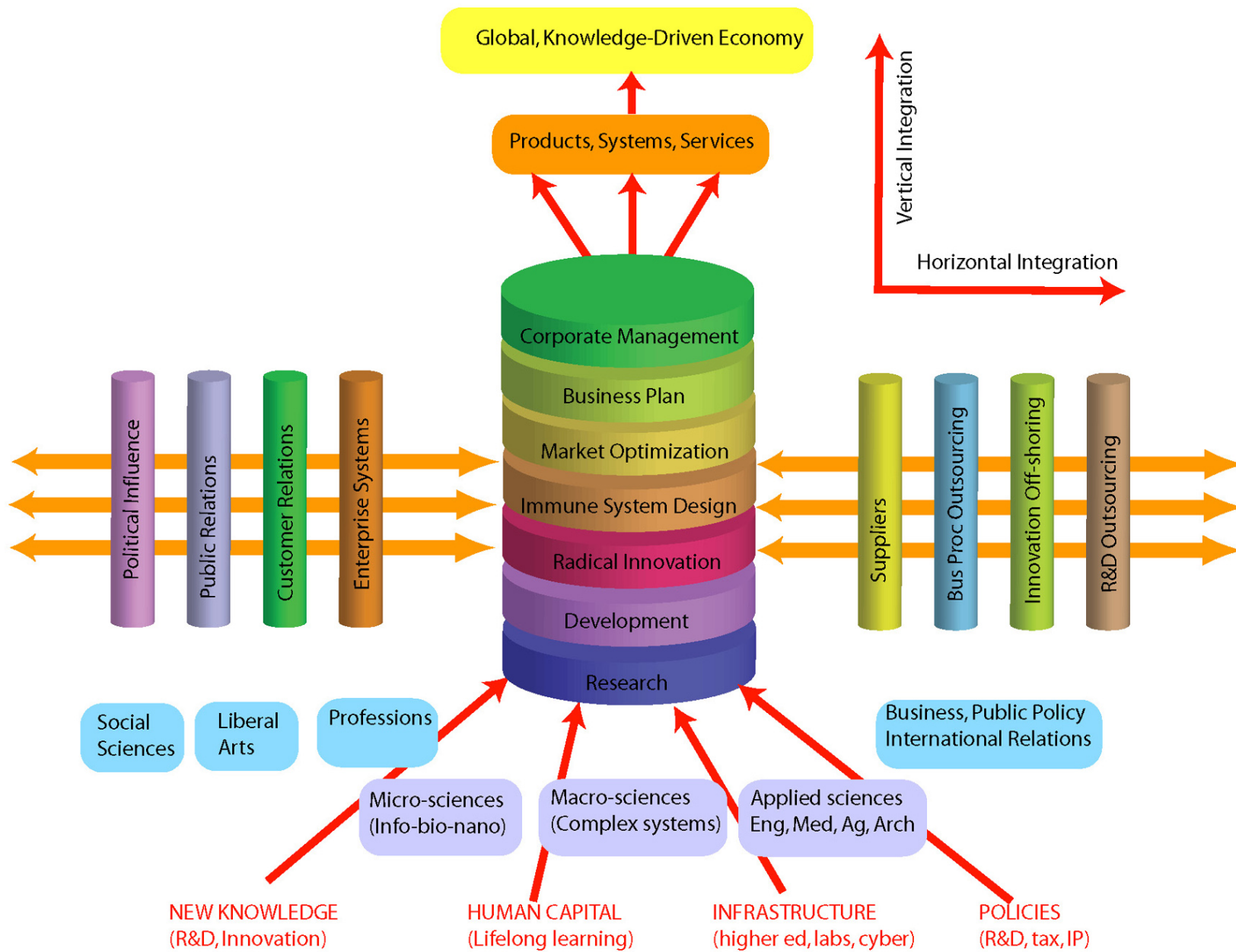
- A radically new system for creating wealth has emerged that depends upon the creation and application of new knowledge and hence upon educated people and their ideas.
- “Intellectual work and capital can be delivered from anywhere—disaggregated, delivered, distributed, produced, and put back together 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



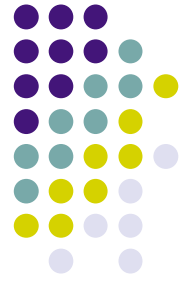
- Today's global corporations manage their technology activities to take advantage of the most capable, creative, and cost-effective engineering talent, wherever they find it.
- The rapid evolution of high quality engineering services in developing economies with low labor costs raises a serious question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



The Challenge to U.S. Engineers

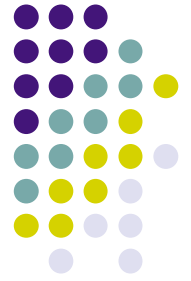


- Engineers must develop the capacity of working in **global markets characterized by great cultural diversity**.
- This requires a **much faster pace of innovation**, shorter product cycles, lower prices, and higher quality than ever before.
- Global innovation requires a shift from traditional problem solving and design skills to more innovative solutions imbedded in an **array of social, environmental, cultural, and ethical issues**.
- U.S. 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.
- Industry managers are **limited in increasing head count of U.S. engineers relative to off shoring**; many said they would not recommend engineering to their children.
- 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. The only crisis the U.S. thinks it is in today is the war on terrorism. It’s not!” (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)

EXECUTIVE SUMMARY

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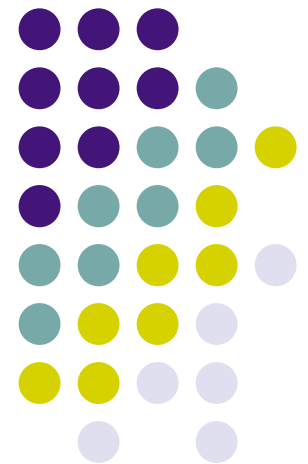
RISING ABOVE THE GATHERING STORM

*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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Engineering Research



Concerns

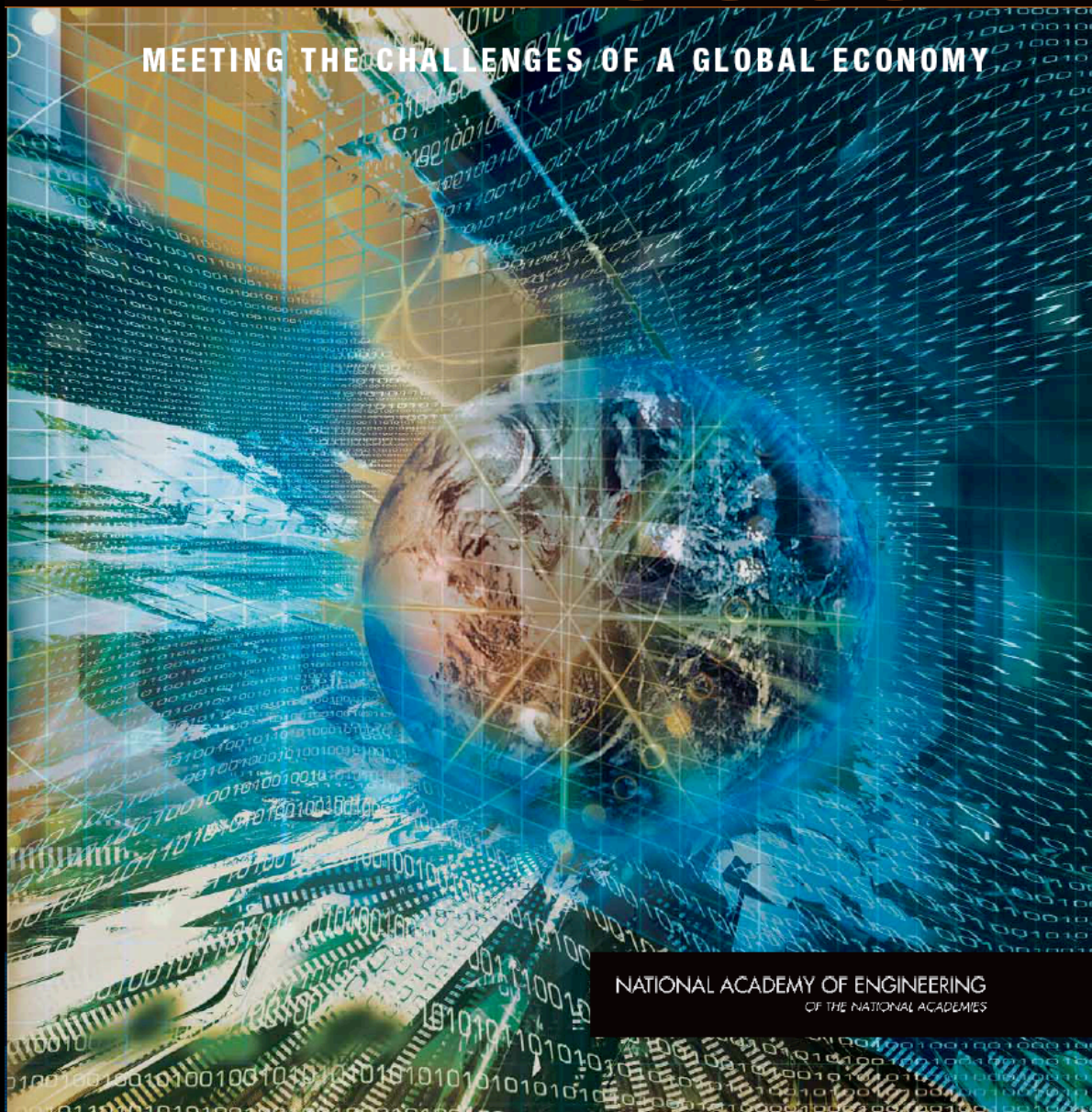


- Large and growing imbalance in federal R&D funding (e.g., NIH = \$30 B, NSF = \$6 B)
- Federal R&D has declined from 70% of national R&D in 1970s to less than 30% today.
- Increased emphasis on short-term R&D in industry and government-funded R&D
- Deterioration of engineering research infrastructure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

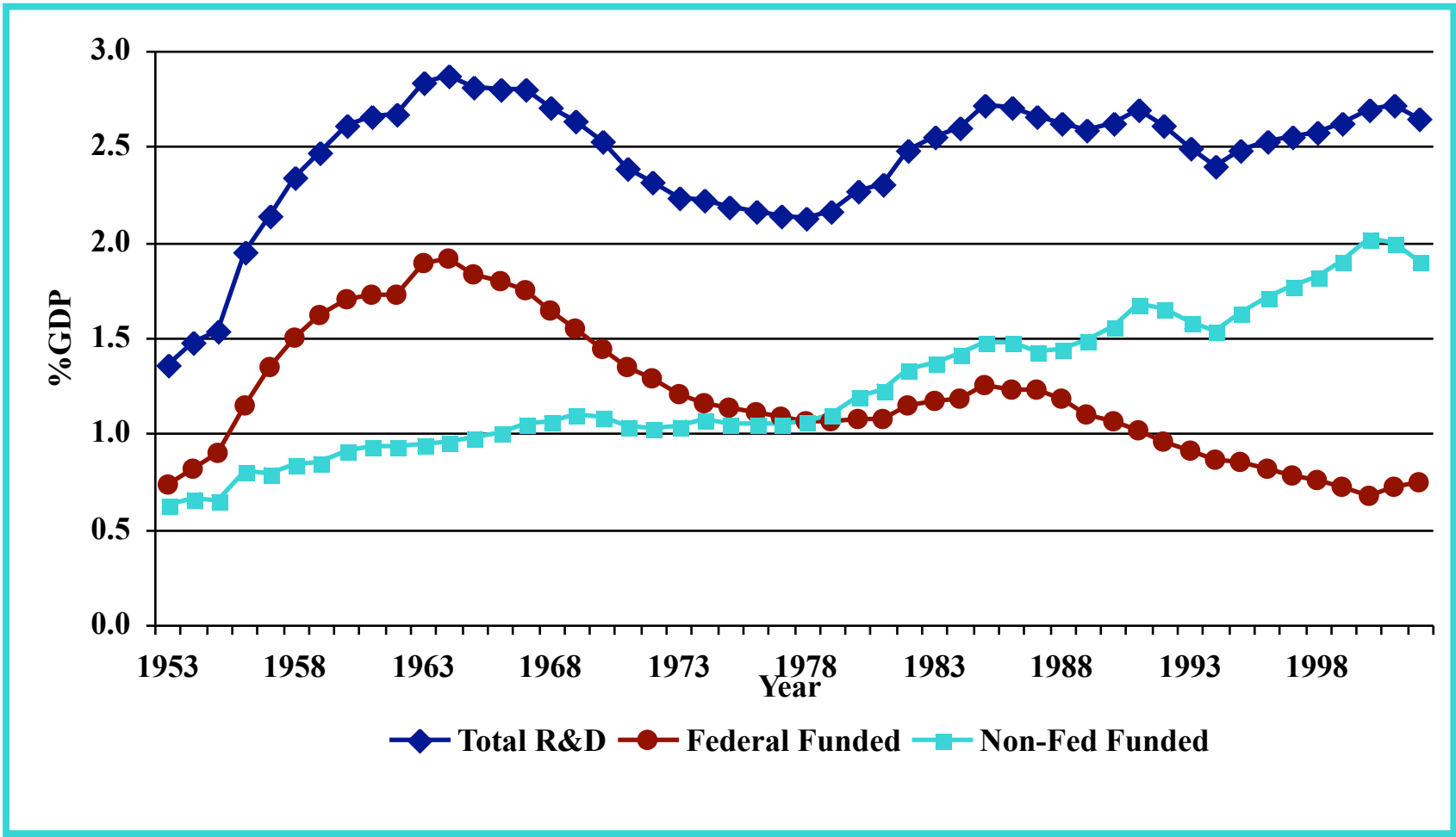
ENGINEERING RESEARCH AND AMERICA'S FUTURE

MEETING THE CHALLENGES OF A GLOBAL ECONOMY

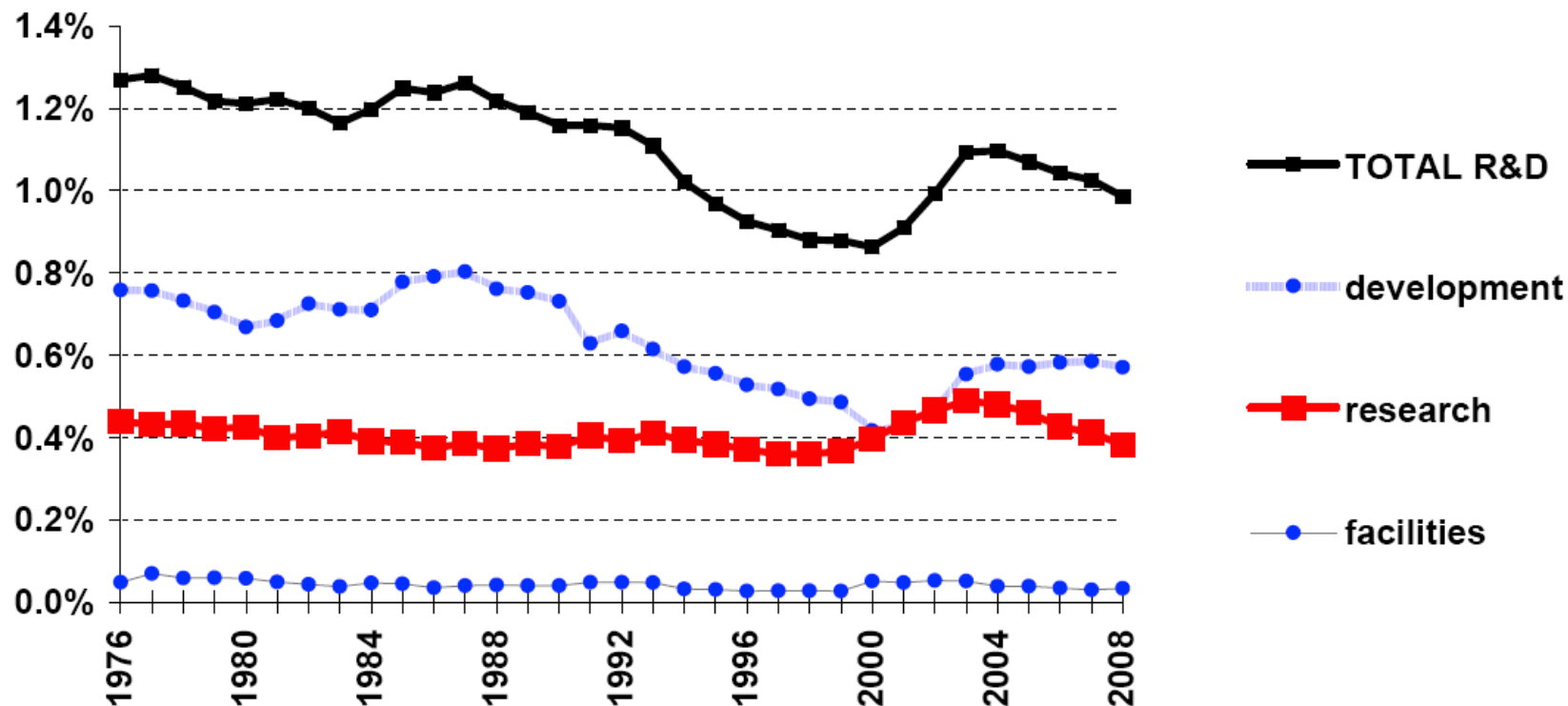
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Federal vs. Nonfederal R&D as Percent of GDP



Trends in Federal R&D as % of GDP, FY 1976-2008

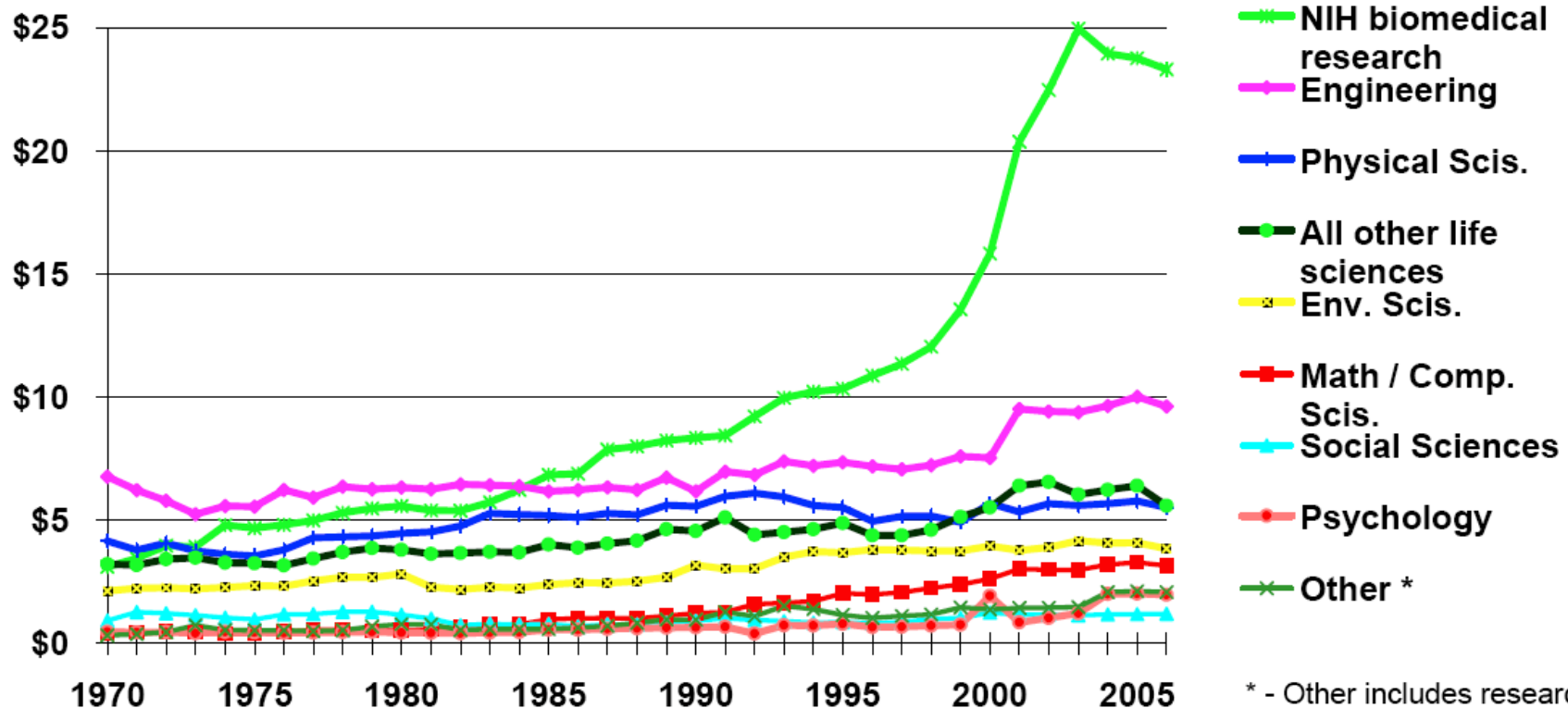


Source: AAAS analyses of R&D in annual AAAS R&D reports. FY 2008 figures are President's request. R&D includes conduct of R&D and R&D facilities. Data to 1984 are obligations from the NSF Federal Funds survey. GDP figures are from OMB, Budget of the U.S. Government FY 2008. MARCH '07 REVISED © 2007 AAAS



Trends in Federal Research by Discipline, FY 1970-2006

obligations in billions of constant FY 2007 dollars



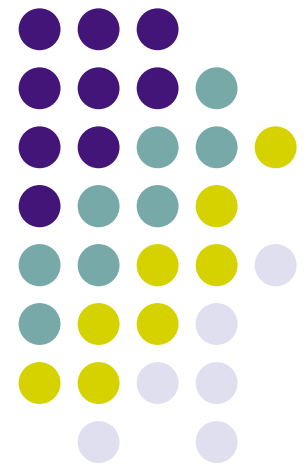
* - Other includes research not classified (includes basic research and applied research; excludes development and R&D facilities)

Life sciences - split into NIH support for biomedical research and all other agencies' support for life sciences.

Source: National Science Foundation, *Federal Funds for Research and Development FY 2004, 2005, 2006, 2006*. FY 2005 and 2006 data are preliminary. Constant-dollar conversions based on OMB's GDP deflators. FEB. '07 © 2007 AAAS



Engineering Education



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).



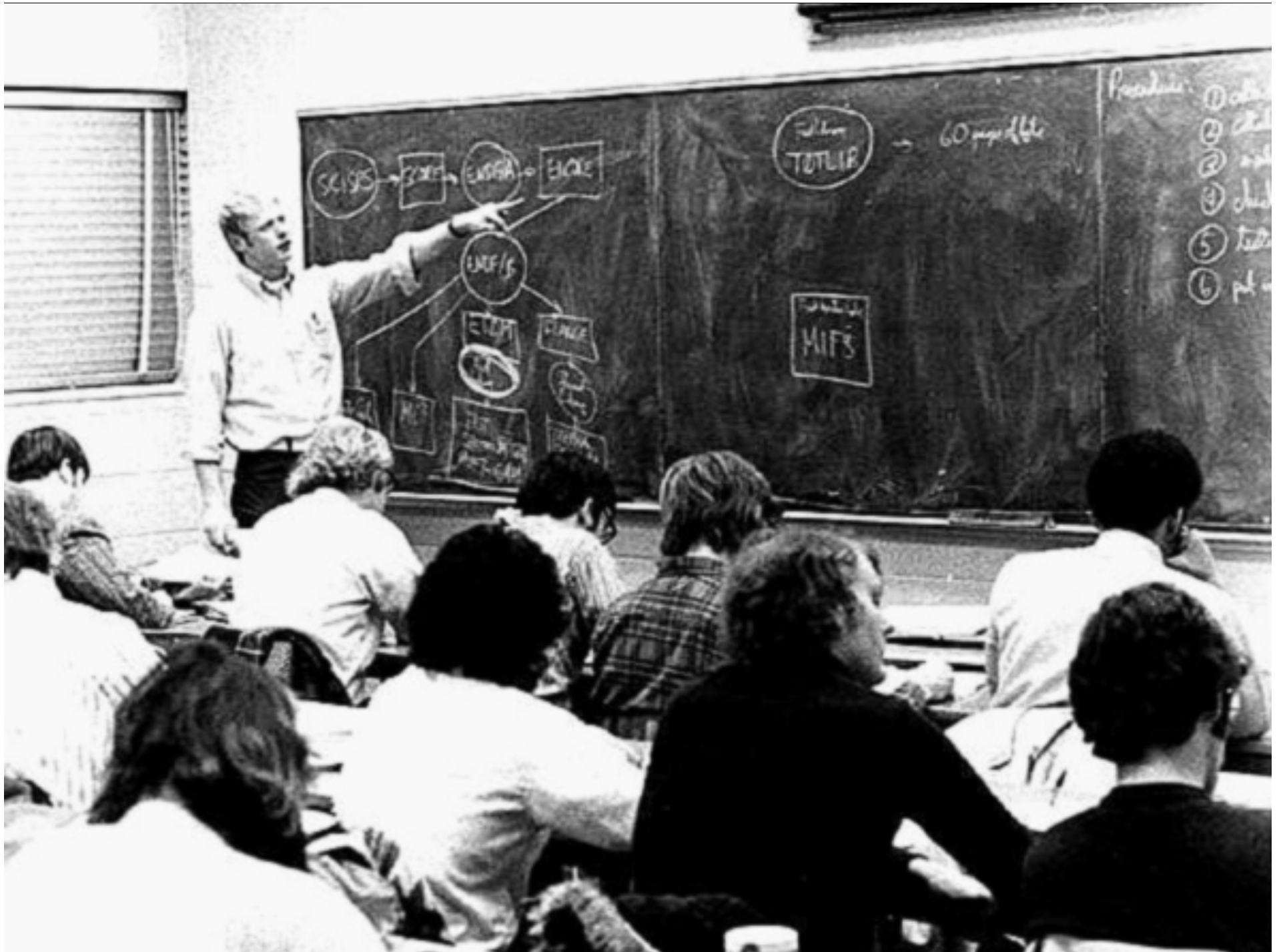
International Comparisons

- 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!



Transforming Engineering Education



"For too long traditional engineering education has been characterized by narrow, discipline-specific approaches and methods, an inflexible curriculum focused exclusively on educating engineers (as opposed to all students), an emphasis on individual effort rather than team projects, and little appreciation for technology's societal context. Engineering education has not generally emphasized communication and leadership skills, often hampering engineers' effectiveness in applying solutions. Engineering is perceived by the larger community to be specialized and inaccessible, and engineers are often seen as a largely homogenous group, set apart from their classmates in the humanities, social sciences, and natural sciences. Given these perceptions, few women and minorities participate in engineering, and non-engineering students are rarely drawn to engineering courses."

Princeton, 2005

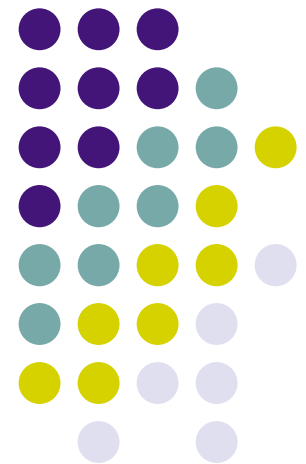
We need new paradigms...



- 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.

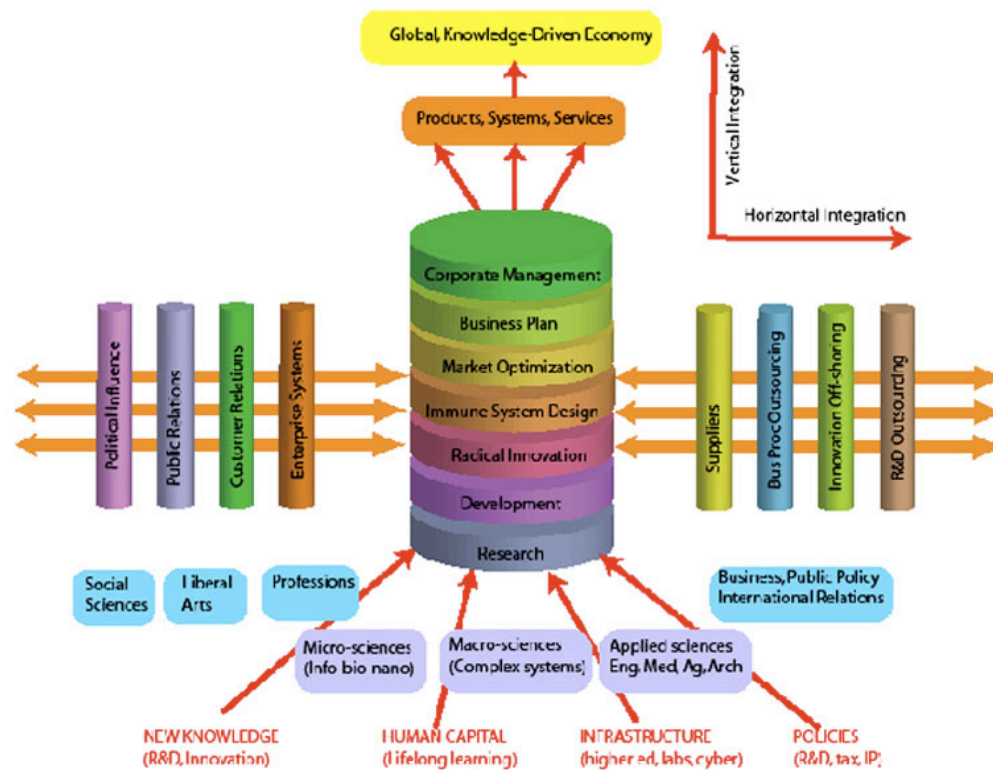


A Roadmap to 21st Century Engineering



Engineering for a Changing World

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



The Millennium Project
The University of Michigan

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

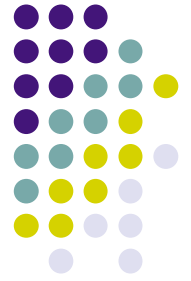
Professional Societies

National Academy

ABET

NSF

Higher Education



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



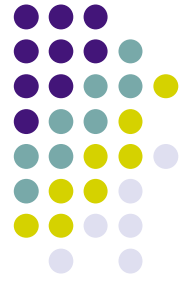
From this perspective **the key to producing such world-class engineers** is to take advantage of the fact that the comprehensive nature of American universities provide the opportunity for **significantly broadening the educational experience of engineering students**. Essentially all other learned 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

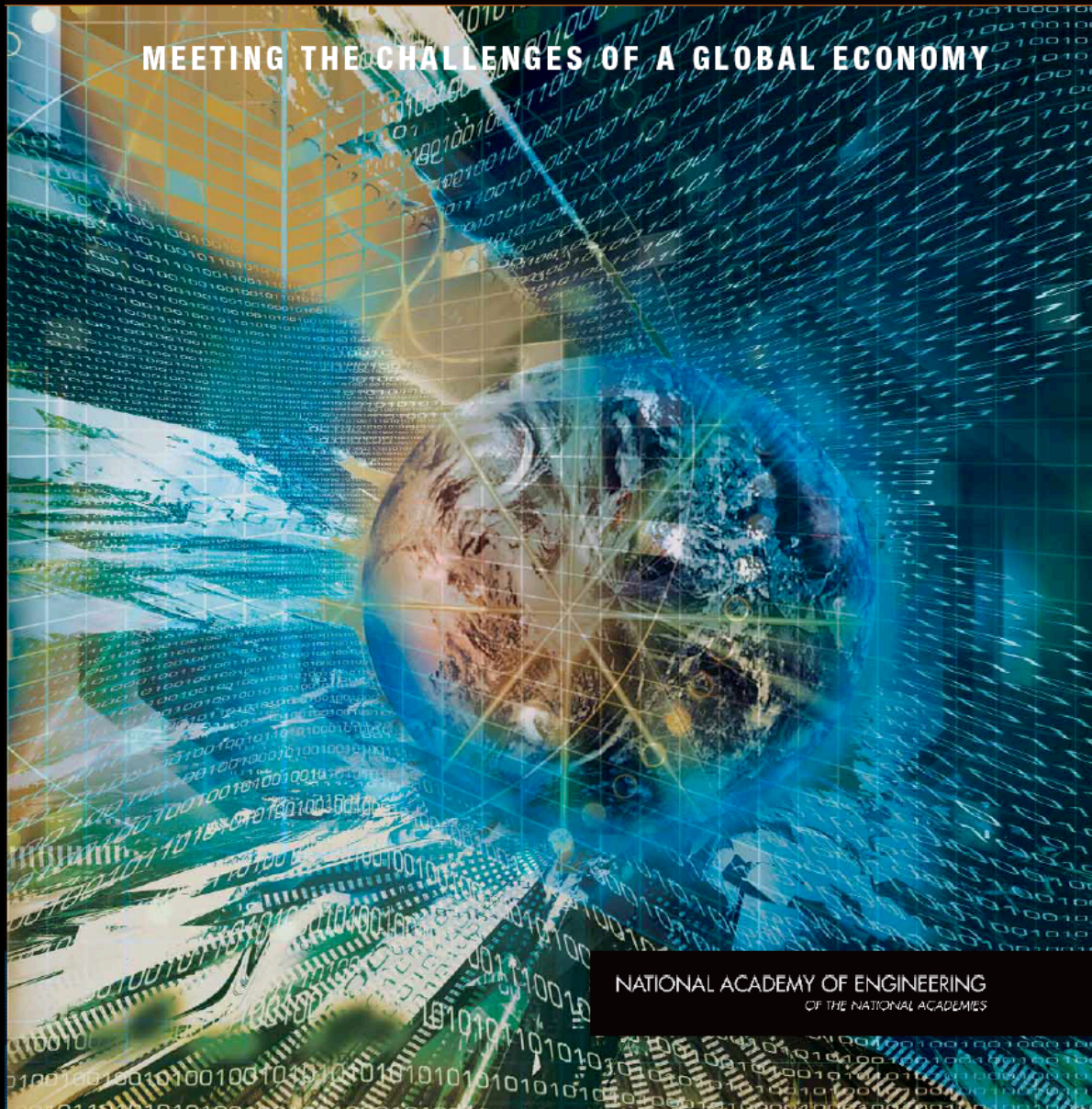


Goal: To redefine the nature of basic and applied engineering research, developing new research paradigms that better address compelling social priorities than those characterizing scientific research.

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

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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

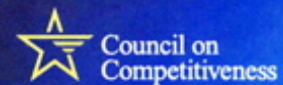
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OF THE NATIONAL ACADEMIES

educate next-generation innovators
deepen science and engineering skills
explore knowledge intersections
equip workers for change
support collaborative creativity
energize entrepreneurship
reward long-term strategy
build world-class infrastructure
invest in frontier research
attract global talent
create high-wage jobs

INNOVATE AMERICA

NATIONAL INNOVATION INITIATIVE SUMMIT AND REPORT
thriving in a world of challenge and change





AMERICAN COMPETITIVENESS INITIATIVE

LEADING THE WORLD IN INNOVATION



***DOMESTIC POLICY COUNCIL
OFFICE OF SCIENCE AND TECHNOLOGY POLICY***

FEBRUARY 2006

Committee on Science and Technology

U.S. HOUSE OF REPRESENTATIVES



BART GORDON, CHAIRMAN



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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.



U.S. 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, CR&D, federal agencies, national laboratories)

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**

Proposed Action



The federal government, in close collaboration with industry, should launch a large number of *Discovery Innovation Institutes* at American universities with the mission of linking fundamental scientific discoveries with technological innovations to build the knowledge base essential for new products, processes, and services to meet the needs of society.

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)



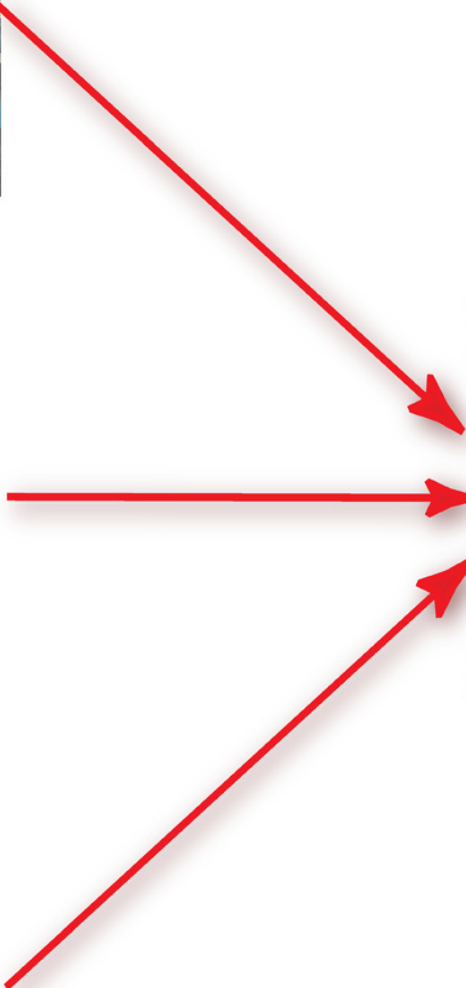
Agricultural Extension (Michigan State)



Academic Medical Center (Michigan)



Discovery Innovation Institute???

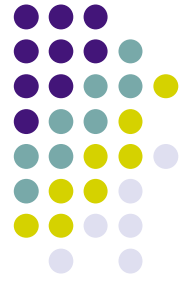


Discovery-Innovation Institutes



- 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 U.S. Advantage

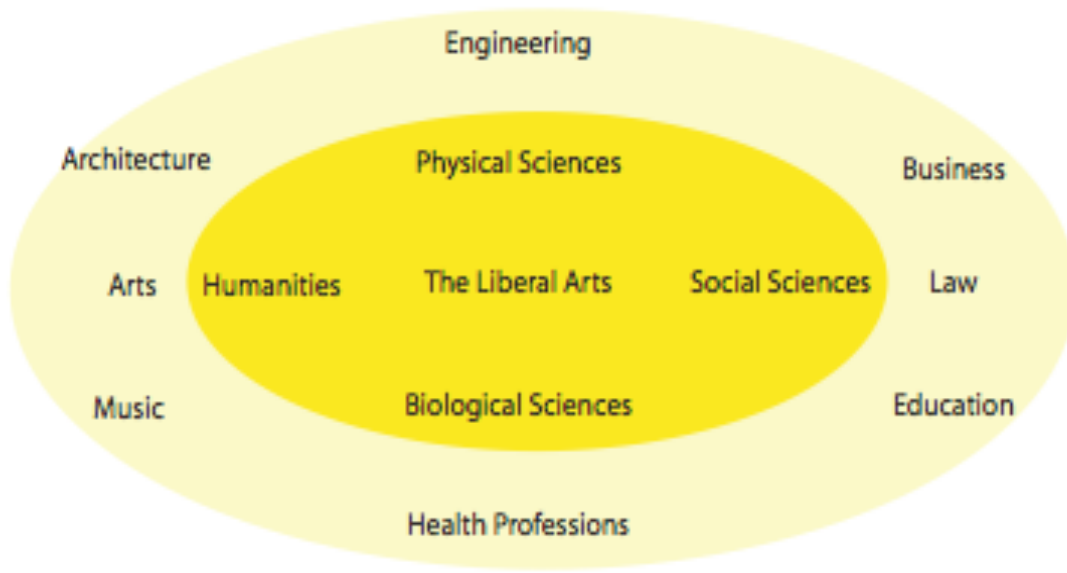


- The comprehensive nature of universities in which most engineering education occurs, spanning the range of academic disciplines and professions, from liberal arts to law, medicine, and other learned professions.
- American universities have the **capacity to augment STEM education with the broader 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.

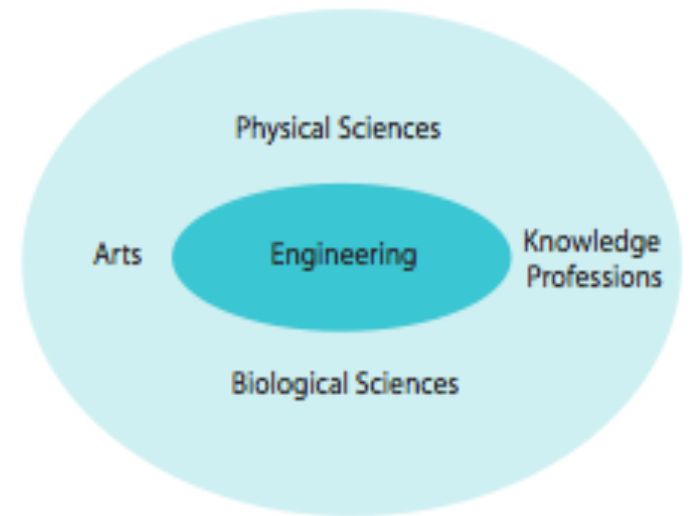
A new paradigm



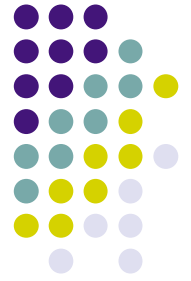
- U.S. universities have the **unique capacity to develop a new paradigm for engineering education that takes full advantage of their comprehensive nature** to create a new breed of engineer, capability of adding much higher value in a global, knowledge economy.
- But this will require a **separation**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



Engineering as a Profession



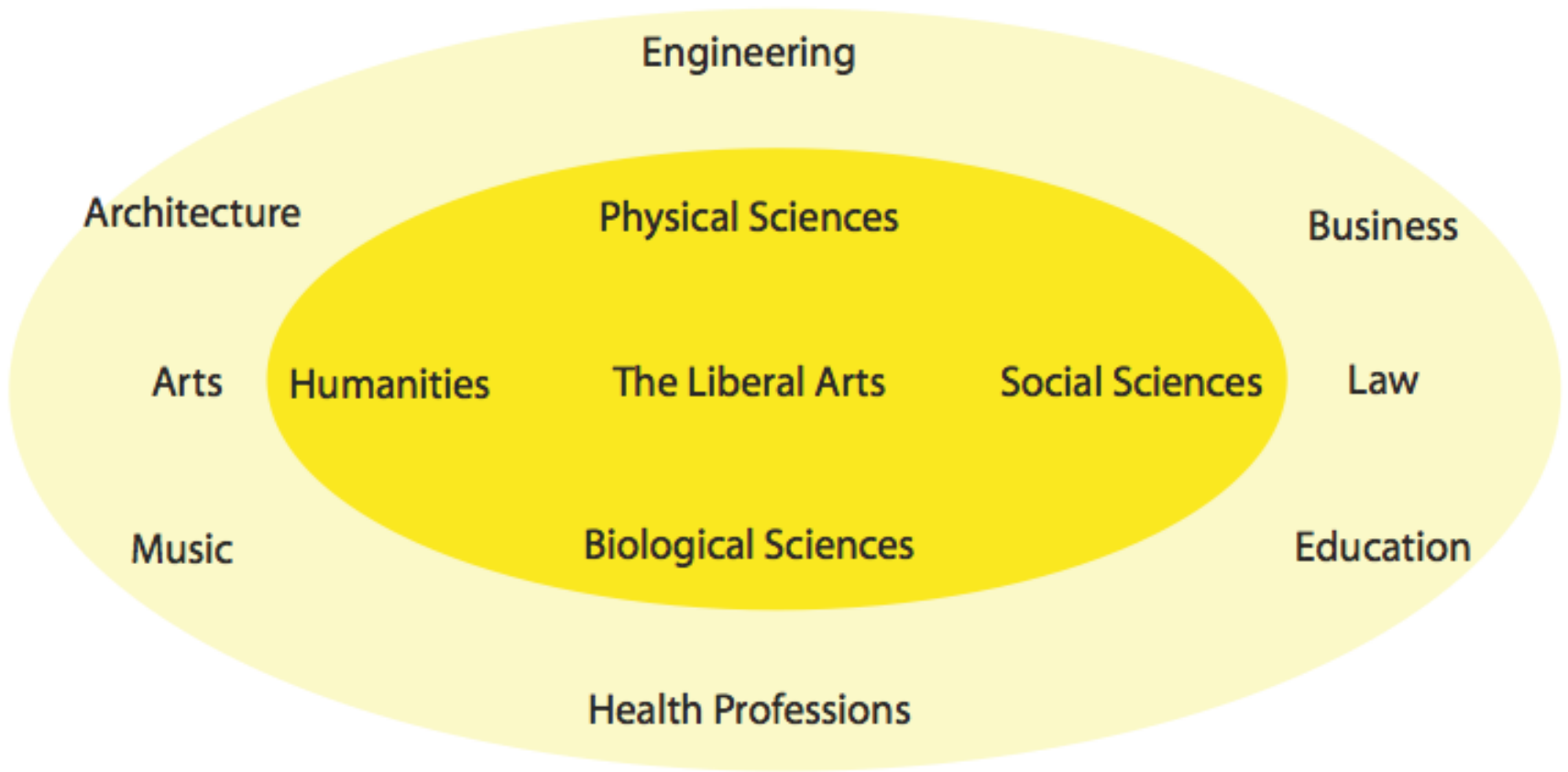
Engineering as a Liberal Arts Discipline



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

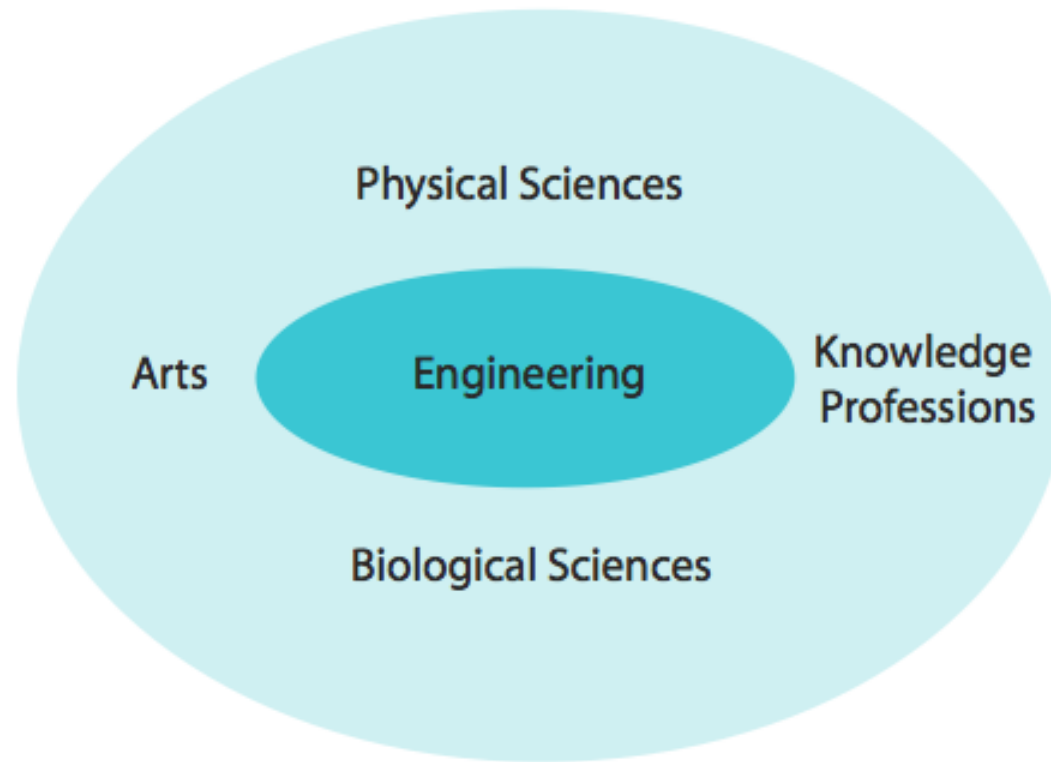


- Shifting the professional education and training of engineers to **two- or three-year practice-focused degree programs**.
- Staffed by **faculty** with strong backgrounds **in practice** and **scholarly interests** in areas such as design, innovation, entrepreneurial activities, and global systems.
- 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 the comprehensive American university with the goal of preparing them for a lifetime of further learning rather than professional practice.



Engineering as a Liberal Arts Discipline

Opportunities



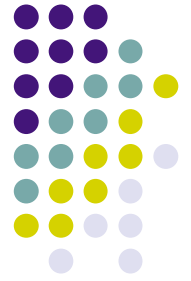
- **Removing burdens of professional accreditation** would allow UG engineering to be reconfigured as other academic disciplines, thereby providing students with more flexibility to benefit from the broader educational opportunities offered by the comprehensive university.
- This would **reverse the 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 21st 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*)

Liberal arts for the 21st C



- Recall the "liberal arts" are an ancient concept that earns studies intended to provide general knowledge and intellectual skills rather than occupational or professional skills.
- In **proposing that engineering be added to the liberal arts** we are not referring to the foundation of science, mathematics, and engineering science but rather those unique concepts one must master to understand technology such as **synthesis** and **design, innovation** and **entrepreneurial** activities, **technology development** and management, benefit-risk analysis, and **knowledge integration** across horizontal and vertical intellectual spans.

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
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Education

Biomedical Sciences
Physician Training
Residencies

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

Research

Basic Research
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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

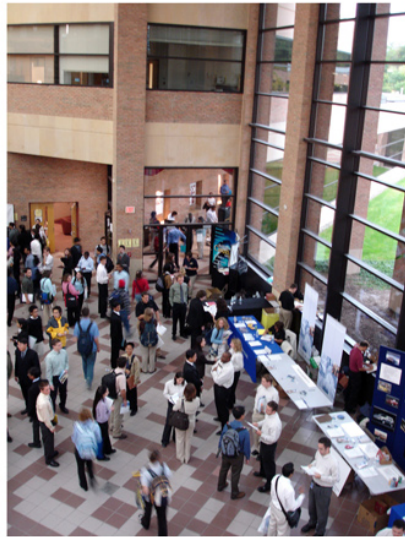
Basic Research
Applied Research
Systems Development

Publications
Patents
Systems, Products

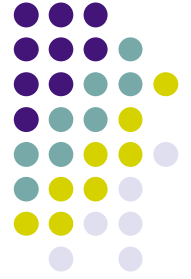
Organizations

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, **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

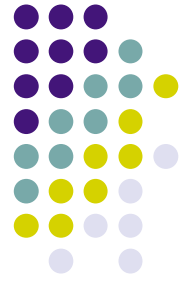
NSF

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.



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).

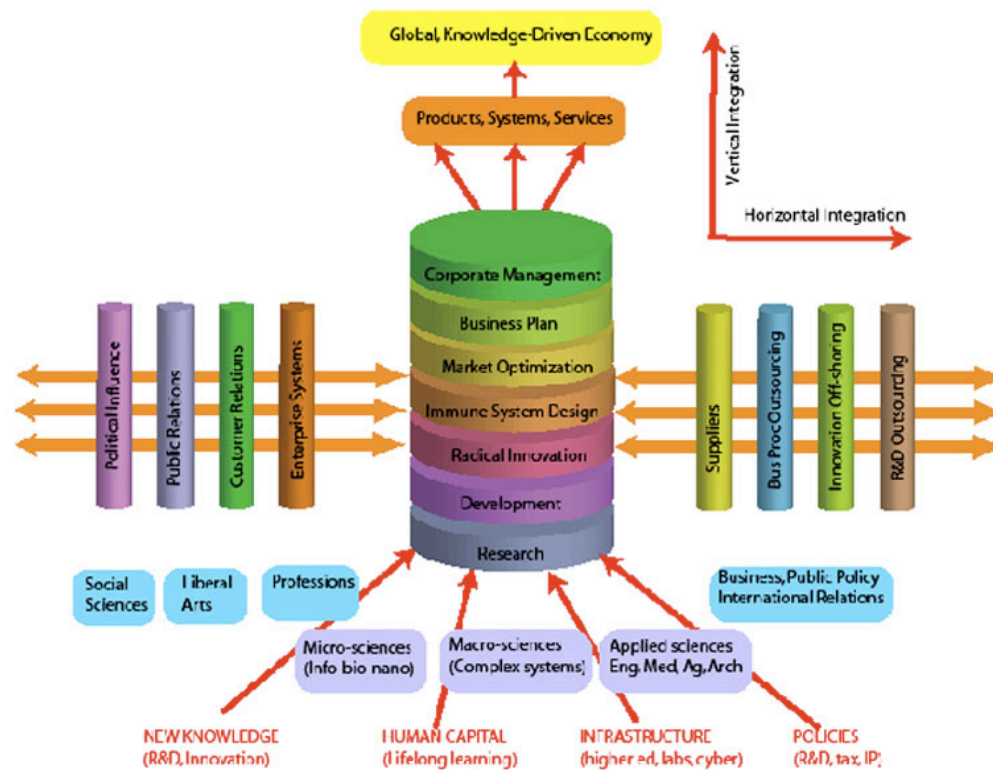
Take Heart...



“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)

Engineering for a Changing World

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



The Millennium Project
The University of Michigan

