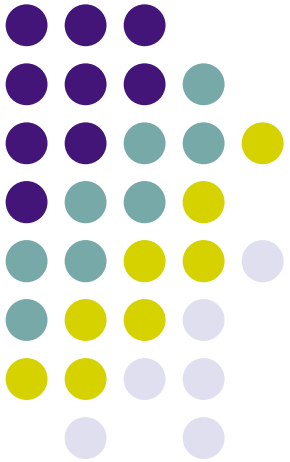
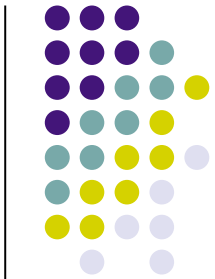
A Roadmap to 21st Century Engineering

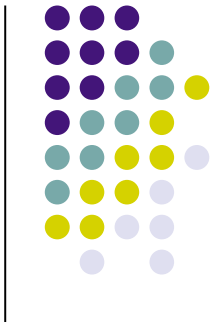


Conclusion 1



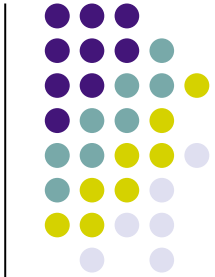
In a global, knowledge-driven economy, technological innovation—the transformation of knowledge into products, processes, and services—is critical to competitiveness, long-term productivity growth, and the generation of wealth. Preeminence in technological innovation requires leadership in all aspects 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



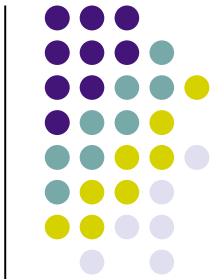
To compete with talented engineers in other nations in far greater numbers and with far lower wage structures, American engineers must be able to add significantly more value than their counterparts abroad through their greater intellectual span, their capacity to innovate, their entrepreneurial zeal,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

Conclusion 3



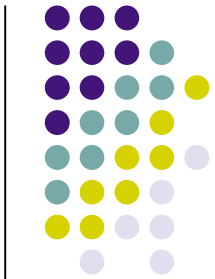
It is similarly essential to elevate the status of the engineering profession, providing it with the prestige and influence to play the role it must in an increasingly technology-driven world while creating sufficiently flexible and satisfying career paths to attract outstanding students.

Conclusion 4



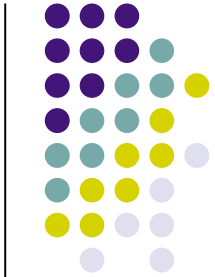
From this perspective the key to producing such world-class engineers is to take advantage of the fact that universities in the United States are more comprehensive and hence capable of providing broader educations, provided engineering schools, accreditation agencies such as ABET, and the marketplace is willing to embrace such an objective. 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.

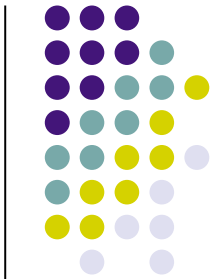
Proposed Action



Proposed Action: Engineering professional and disciplinary societies, working with engineering leadership groups such as the NAE, ABET, and AAEE, 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 cliends and society.

A Guild Culture



Note the transition:

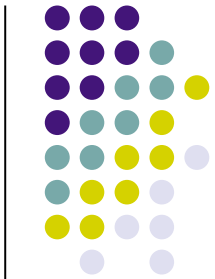
Engineers: from employees to professionals

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.

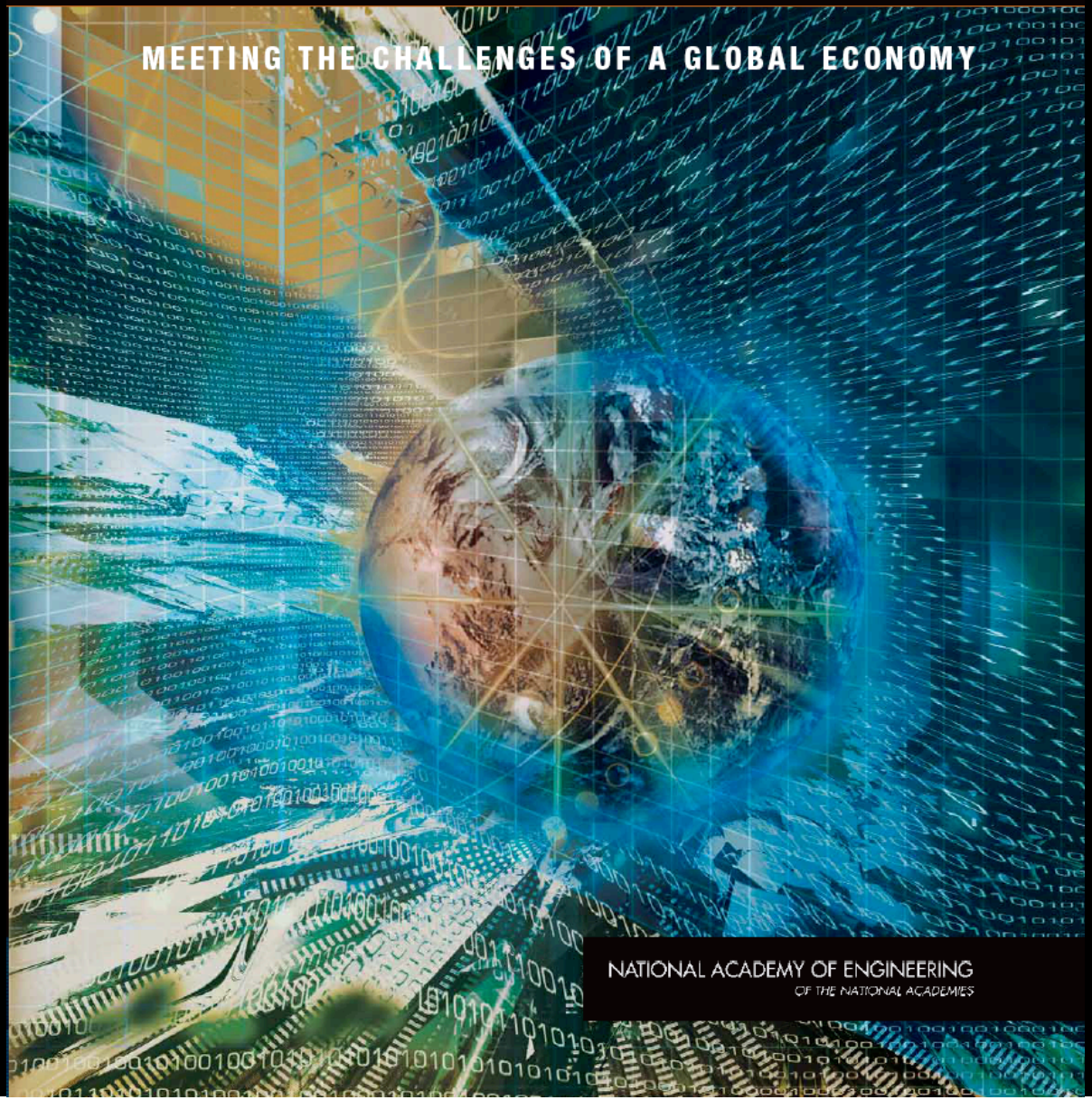
Engineering Research



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.

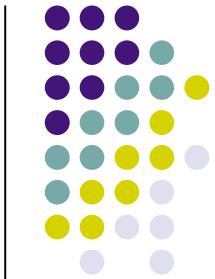
ENGINEERING RESEARCH AND AMERICA'S FUTURE

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

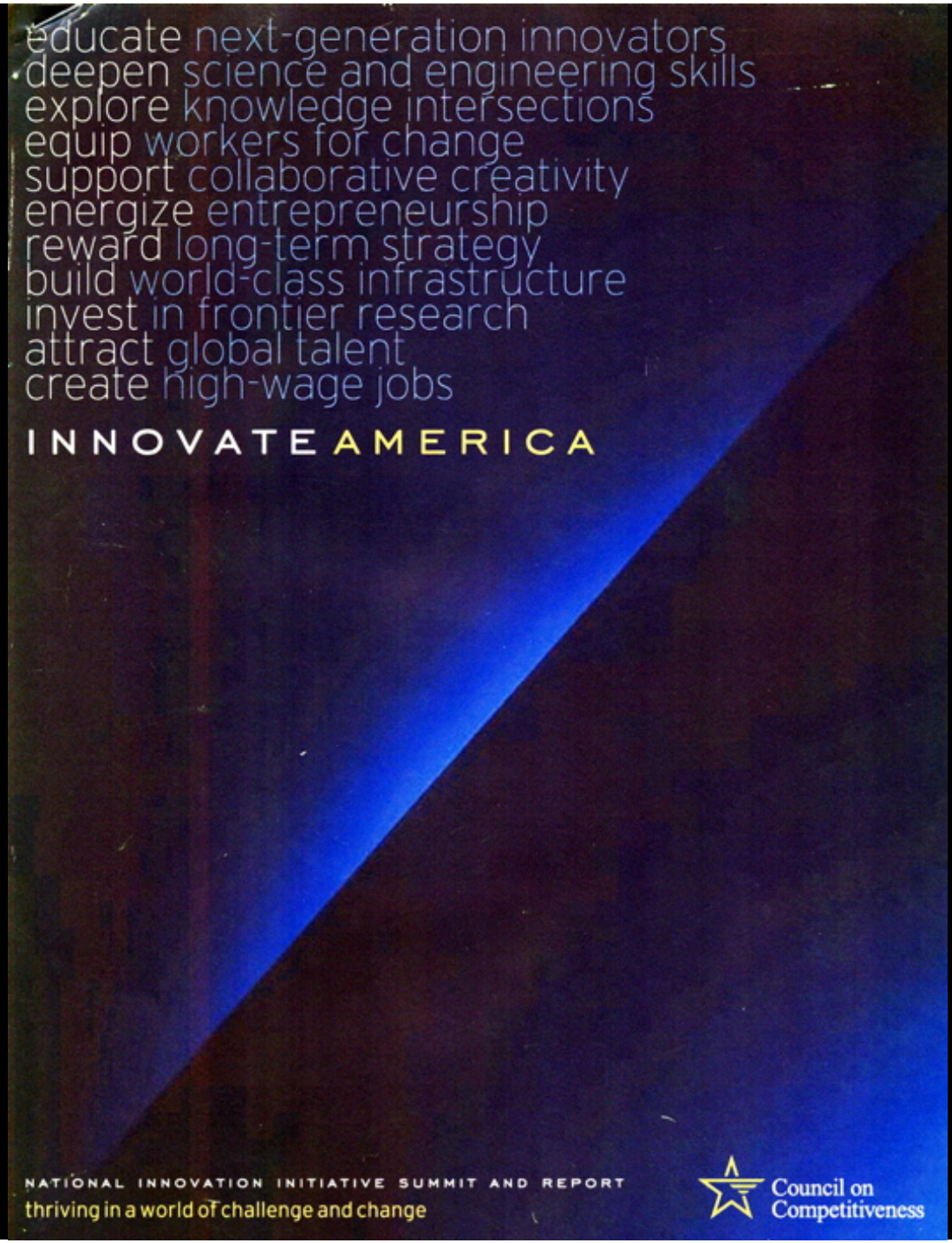
EXECUTIVE SUMMARY

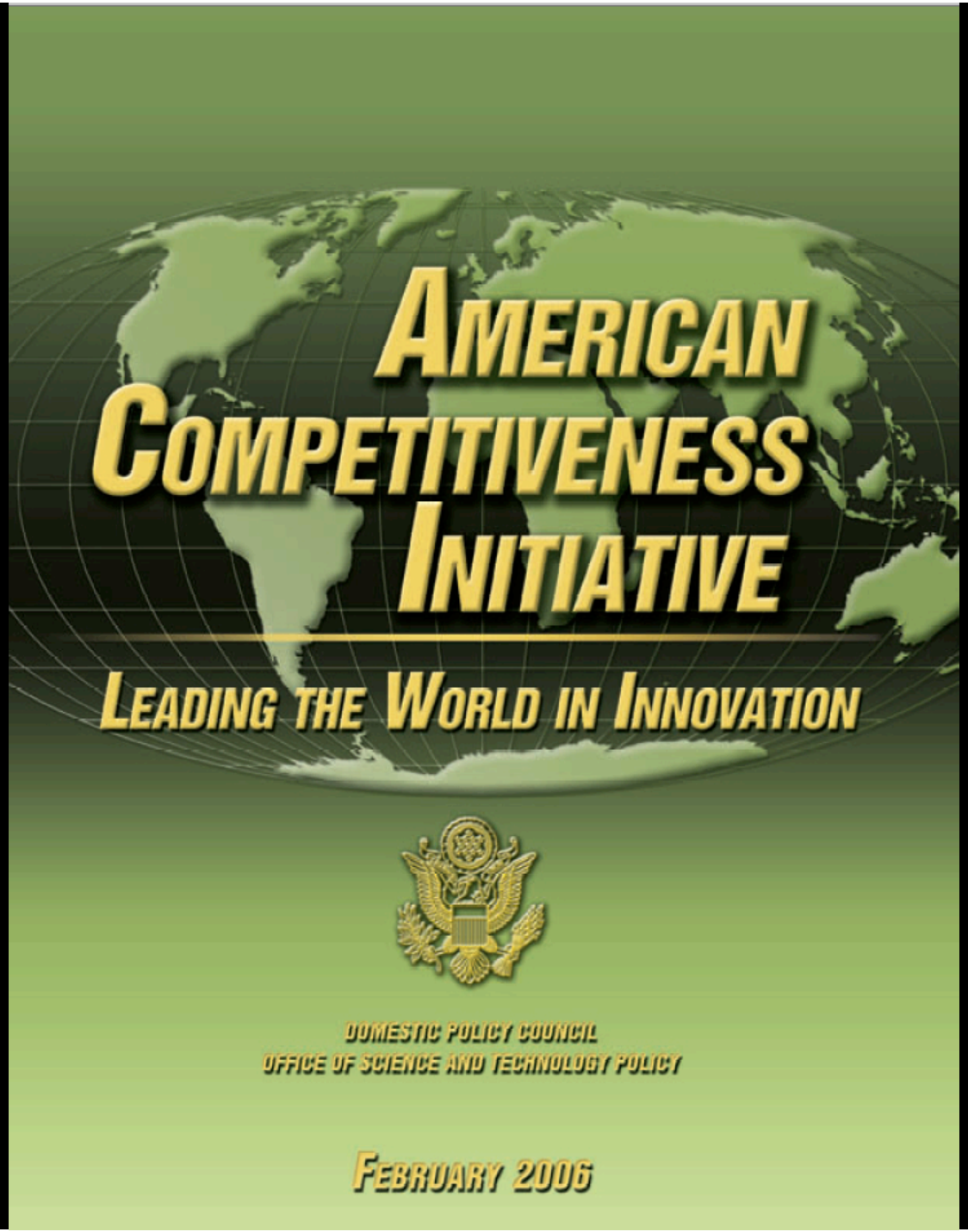
Prepublication Copy

RISING ABOVE THE GATHERING STORM

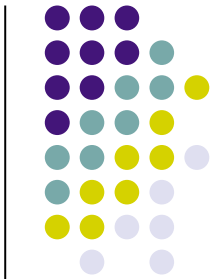
Energizing and Employing America for a Brighter Economic Future

NATIONAL ACADEMY OF SCIENCES,
NATIONAL ACADEMY OF ENGINEERING, AND
INSTITUTE OF MEDICINE
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
Council on Competitiveness

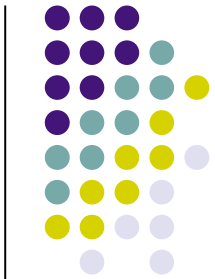

AMERICAN COMPETITIVENESS INITIATIVE
LEADING THE WORLD IN INNOVATION
DOMESTIC POLICY COUNCIL
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
FEBRUARY 2006

The American Competitiveness Initiative



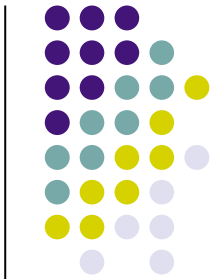
- Double federal investment in basic research in physical science and engineering (from $9.75 B/y to $19.45 B/y) over next 10 years, focused on NSF, DOE-OS, NIST.
- Major investment in STEM education
- Tax policies designed to stimulate private sector R&D
- Streamlining intellectual property policies
- Immigration policies that attract the best and brightest scientific minds from around the world
- Building a business environment that stimulates and encourages entrepreneurship through free and flexible labor, capital, and product markets that rapidly diffuse new productive technologies.

Recommendations



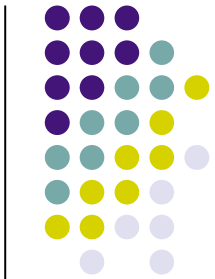
- Balancing Federal R&D Portfolio
- Re-establishing Basic Engineering Research As A Priority of Industry
- Strengthening Linkages Between Industry and Research Universities
- Human Capital
- Discovery-Innovation Institutes

Proposed Action



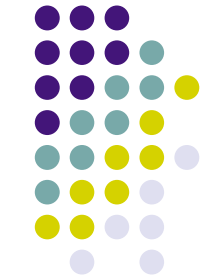
The federal government, in close collaboration with industry, should launch a large number of *Discovery Innovation Institutes* at American universities with the mission of linking fundamental scientific discoveries with technological innovations to build the knowledge base essential for new products,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

U.S. Leadership in Innovation will Require Changes

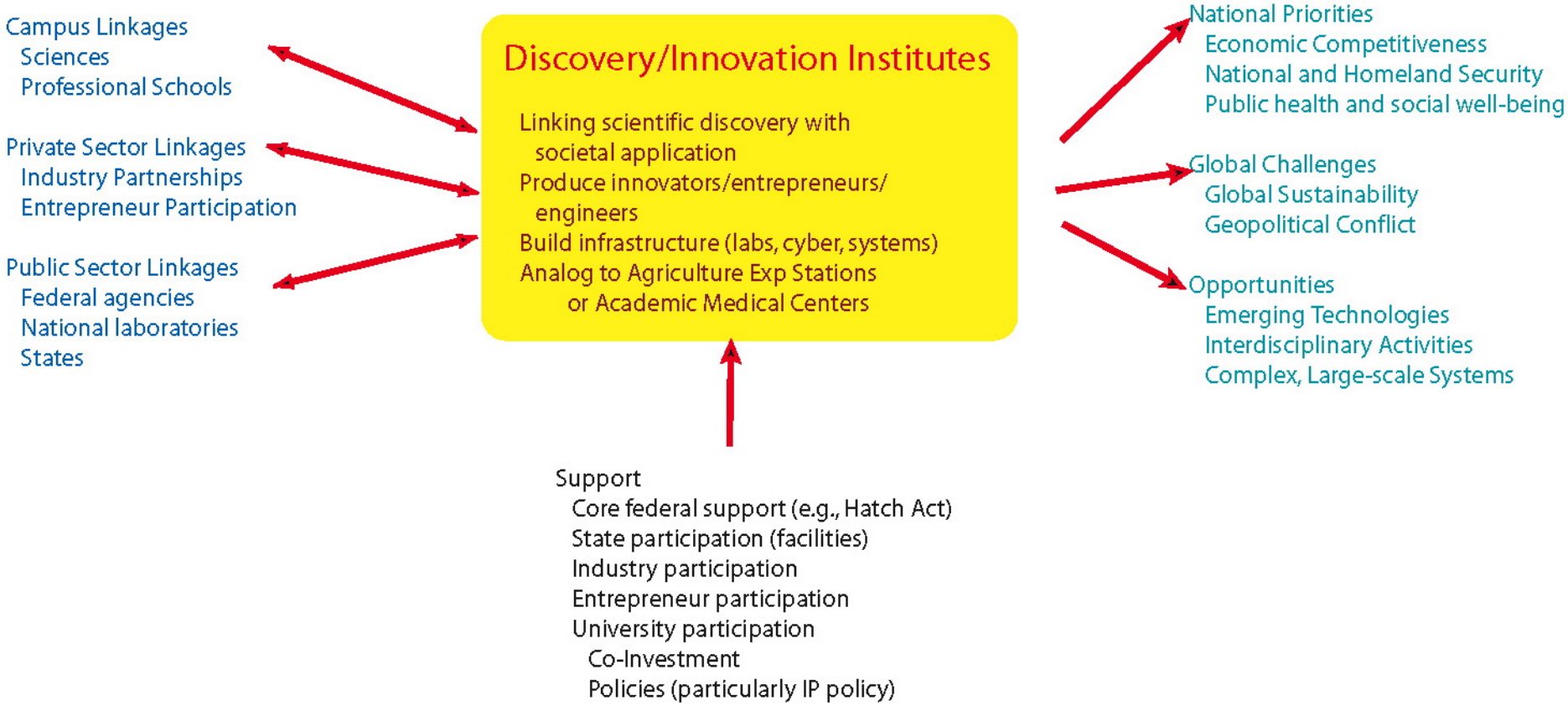


- In the way research is prioritized, funded, and conducted.
- In the education of engineers and scientists.
- In policies and legal structures such as intellectual property.
- In strategies to maximize contributions from institutions (universities, CR&D, federal agencies, national laboratories)

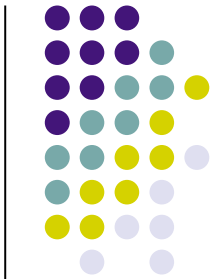
Discovery Innovation Institutes



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.


Campus Linkages
Sciences
Professional Schools
Private Sector Linkages
Industry Partnerships
Entrepreneur Participation
Public Sector Linkages
Federal agencies
National laboratories
States
Discovery/Innovation Institutes
Linking scientific discovery with societal application
Produce innovators/entrepreneurs/ engineers
Build infrastructure (labs, cyber, systems)
Analog to Agriculture Exp Stations or Academic Medical Centers
National Priorities
Economic Competitiveness
National and Homeland Security
Public health and social well-being
Global Challenges
Global Sustainability
Geopolitical Conflict
Opportunities
Emerging Technologies
Interdisciplinary Activities
Complex, Large-scale Systems
Support
Core federal support (e.g., Hatch Act)
State participation (facilities)
Industry participation
Entrepreneur participation
University participation
Co-Investment
Policies (particularly IP policy)

Discovery-Innovation Institutes



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

Michigan Agricultural Experiment Station

Environmental Stewardship and Natural Resources Policy and Management
(4.7 MB, PDF)
Environmental stewardship and natural resources policy and management is one of five target areas driving the MAES research agenda over the next decade. It is a broad area, encompassing land use, air quality, soil conservation, waste management, landscape ecology, ecosystem management and water research. In this issue of Futures, we highlight just a small fraction of the MAES research being done in these areas.

The MAES is conducting a national search for a director. For more information, please visit the **MAES Director Search** web page.

MICHIGAN AGRICULTURAL EXPERIMENT STATION
Michigan State University

- **MSUE Director Named**
- **MAES Scientists Honored at Founders' Day Celebration**
- **MAES Welcomes New Scientist**
- **U.S.-Canada Forestry Symposium to Address Trade**
- **March Water Policy Workshops Focus on River Science and Drinking Water**
- **Understanding Pesticides in Tree Fruit Is Topic of March Workshop**
- **Food and Agriculture Entrepreneur Workshops Offered Across Michigan**
- **MAES Research Contributes to Launch of New Bean Products**
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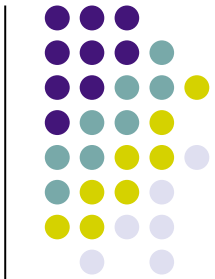
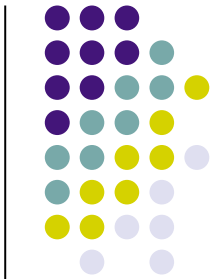
Discovery-Innovation Institutes



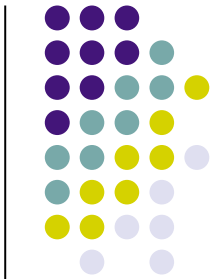
- Although primarily associated with engineering schools, DIIs would partner with other professional schools (e.g., business, medicine, law) and academic disciplines.
- To ensure the necessary transformative impact, the DII program should be funded at levels comparable to other major federal initiatives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

In summary



- DIIs would be engines of innovation that would transform institutions, policy, and culture and enable our nation to solve critical problems and maintain leadership in a global, knowledge-driven society.
- The DII proposal is designed to illustrate the bold character and significant funding level we believe are necessary to secure the nation's leadership in technological innovation.

Engineering Education

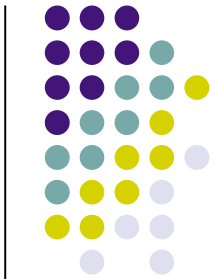


Goal 1: To adopt a systemic approach to the reform of engineering education, recognizing the importance of diverse approaches–albeit characterized by quality and rigor–to serve the highly diverse technology needs of our society.

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.

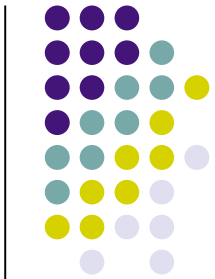
Goal 3: To achieve far greater diversity among the participants in engineering, the roles and types of engineers needed by our nation, and the programs engaged in preparing them for professional practice.

A Significant U.S. Advantage

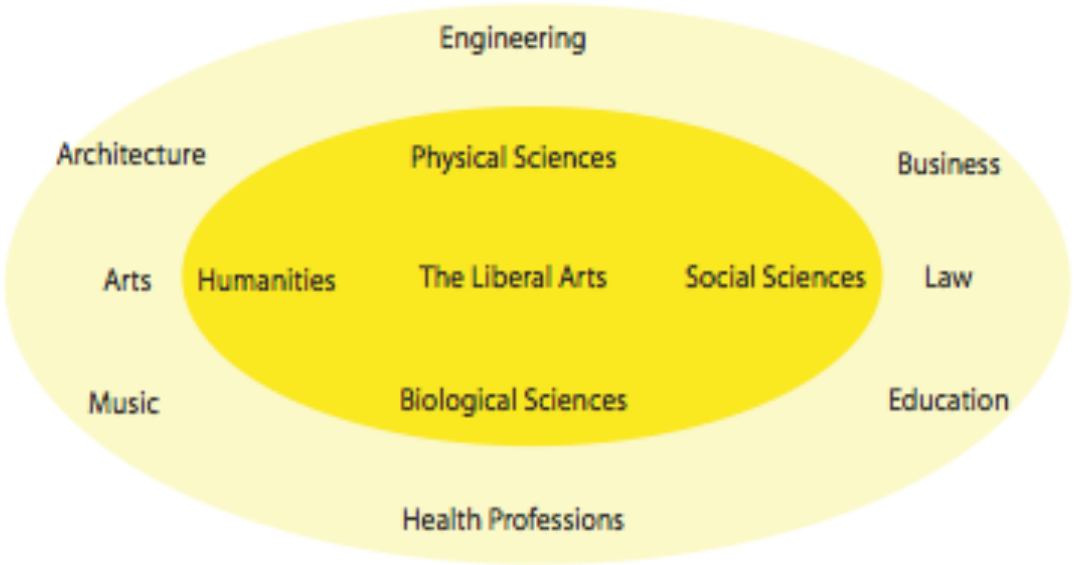


- The comprehensive nature of universities in which most engineering education occurs, spanning the range of academic disciplines and professions, from liberal arts to law, medicine, and other learned professions.
- American universities have the capacity to augment STEM education with the broader exposure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

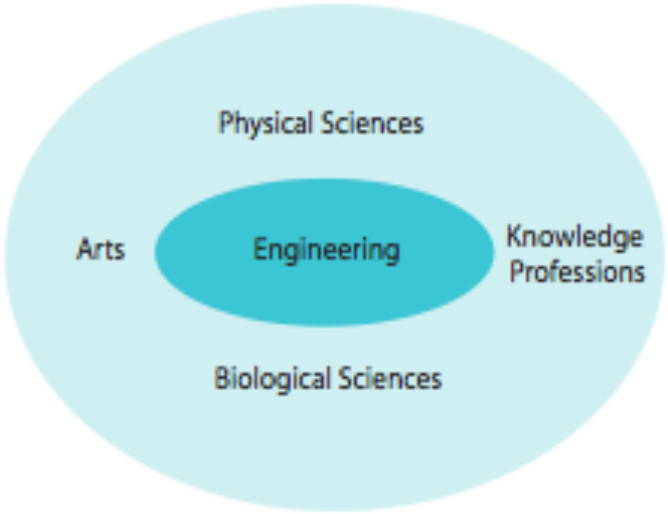
A new paradigm



- 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!

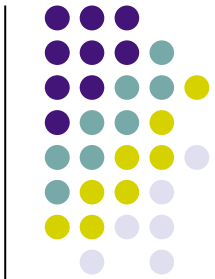


Engineering as a Profession



Engineering as a Liberal Arts Discipline

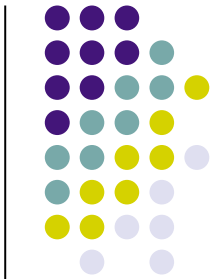
Proposed Actions



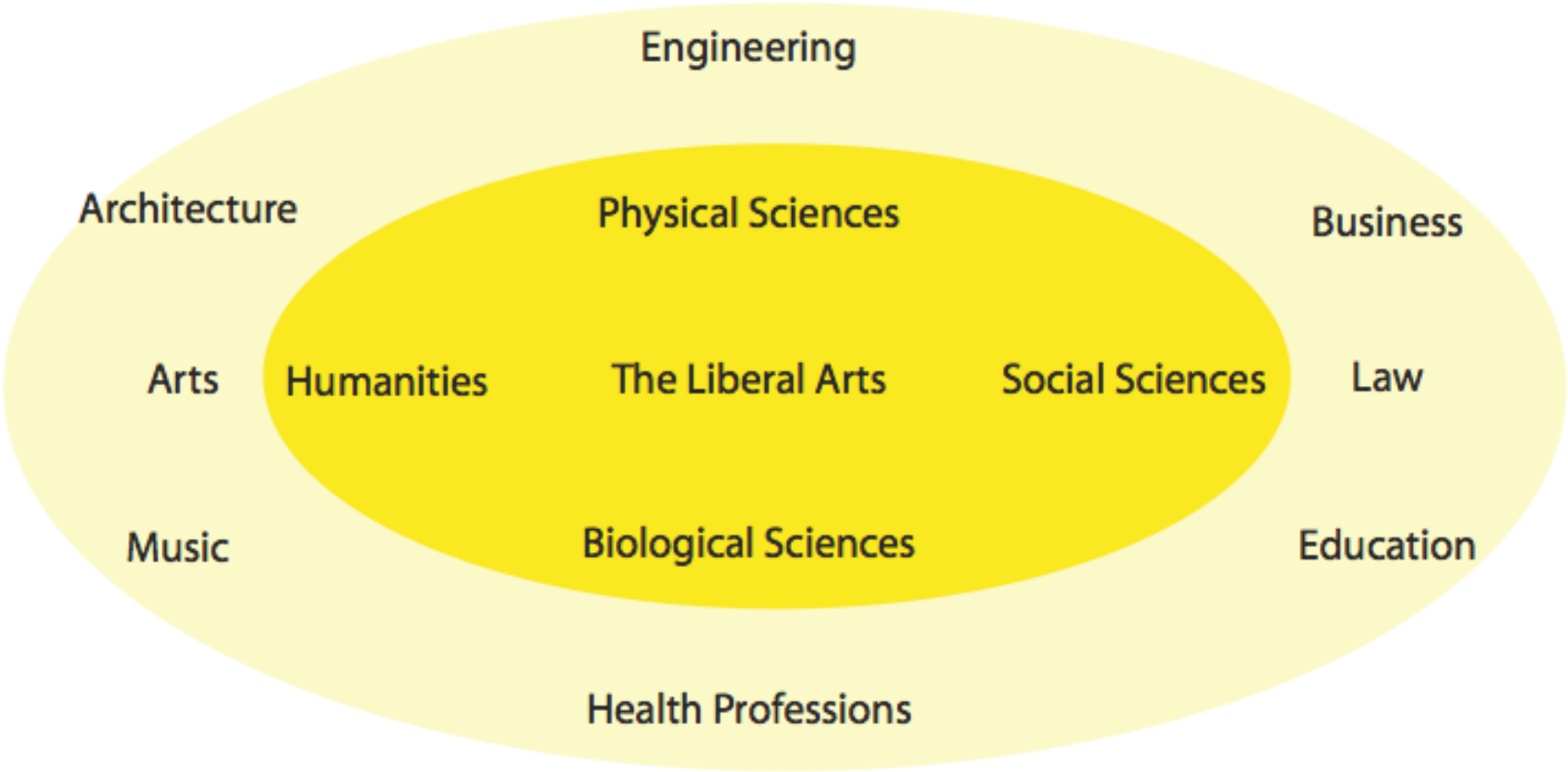
Action 1: Working closely with industry and professional societies, higher education should establish *graduate professional schools of engineering* that would offer practice-based degrees at the post-baccalaureate level as the entry degree into the engineering profession.

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.

Professional Schools

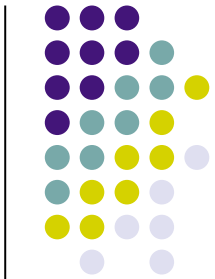


- Shifting the professional education and training of engineers to two- or three-year practice-focused degree programs.
- Staffed by faculty with strong backgrounds in practice and scholarly interests in areas such as design, innovation, entrepreneurial activities, and global systems.
- Students drawn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



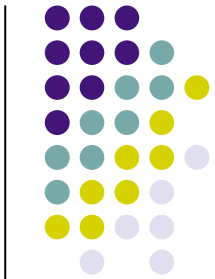
Engineering as a Profession

Proposed Actions (cont.)

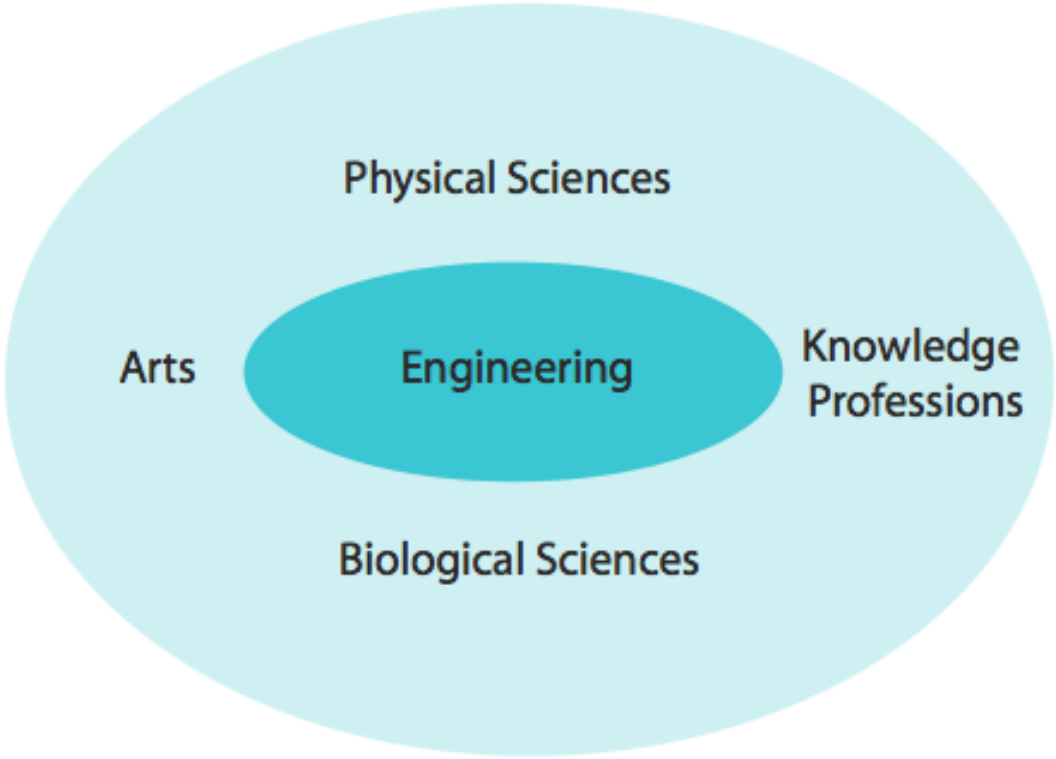


Action 2: *Undergraduate engineering* should be reconfigured as an *academic discipline*, *similar to other liberal arts disciplines* in the sciences, arts, and humanities, thereby providing students with more flexibility to benefit from the broader educational opportunities offered by the comprehensive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

Opportunities

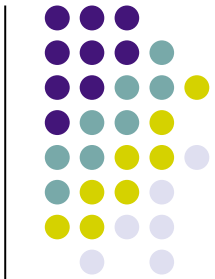


- Removing burdens of professional accreditation would allow UG engineering to be reconfigured as other academic disciplines, thereby providing students with more flexibility to benefit from the broader educational opportunities offered by the comprehensive university.
- This would reverse the trend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



Engineering as a Liberal Arts Discipline

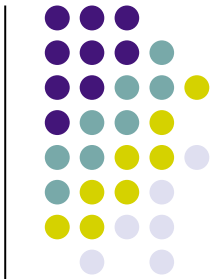
Proposed Action (cont.)



Action 3: 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.

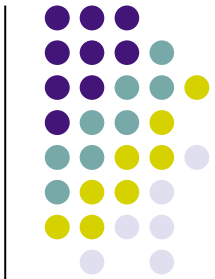
In a world increasingly dependent upon technology, it seems appropriate that the engineering discipline be added to the liberal arts core of a general education, much as the natural sciences were added a century ago to the classical liberal arts (the *trivium* and *quadrivium*)

Liberal arts for the 21st C



- Recall the liberals 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.

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?

	Education	*Research*	*Organizations*
Academic Medical Center	Biomedical Sciences Physician Training Residencies	Basic Research Clinical Research Clinical Trials	Teaching Hospitals Research Centers
	Degrees …M.D., Ph.D.	Publications Patents	Clinical Care Spinoff Companies

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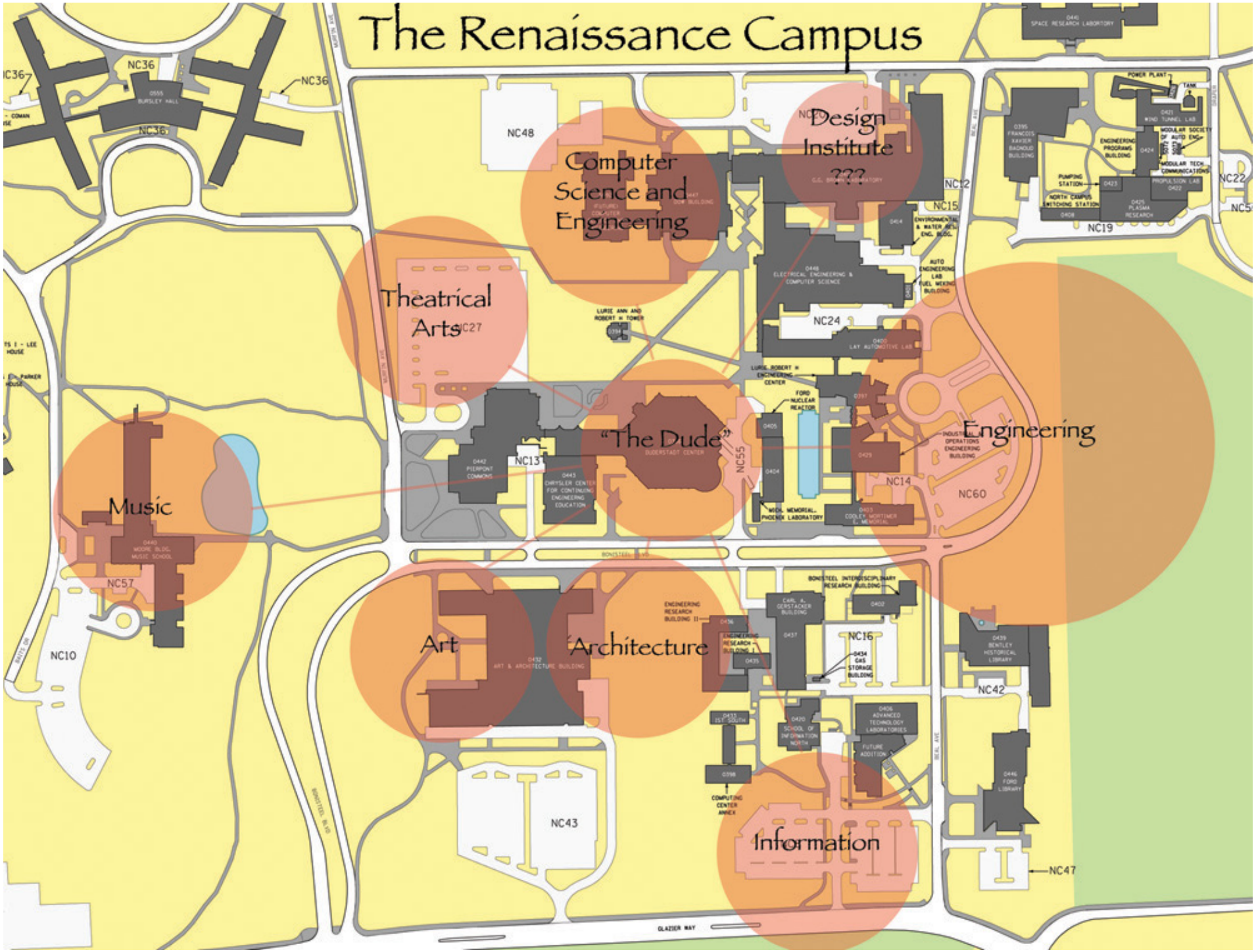
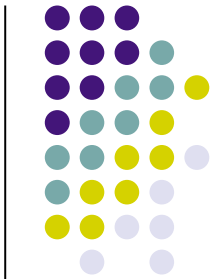
Engineering School	Undergraduate Graduate Professional	Basic Research Applied Research Systems Development	Discovery-Innovation Centers Captive Consulting Companies Practice Schools
	Degrees …B.S., B.A. …M.S., Ph.D. …M.Eng., D. Eng..	Publications Patents Systems, Products	Engineering Services Systems, Products Spinoff Companies


The Renaissance Campus
Design Institute ???
Computer Science and Engineering
Theatrical Arts
"The Dude"
Engineering
Music
Art
Architecture
Information
NC36
NC48
NC12
NC15
NC24
NC27
NC13
NC55
NC14
NC60
NC57
NC10
NC16
NC42
NC43
NC47
NC19
NC22
BONISTEEL BLVD
GLAZIER WAY
BEAL AVE
STATE ST

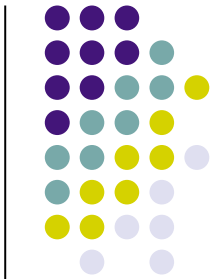
Wm Wulf, NAE President



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!”

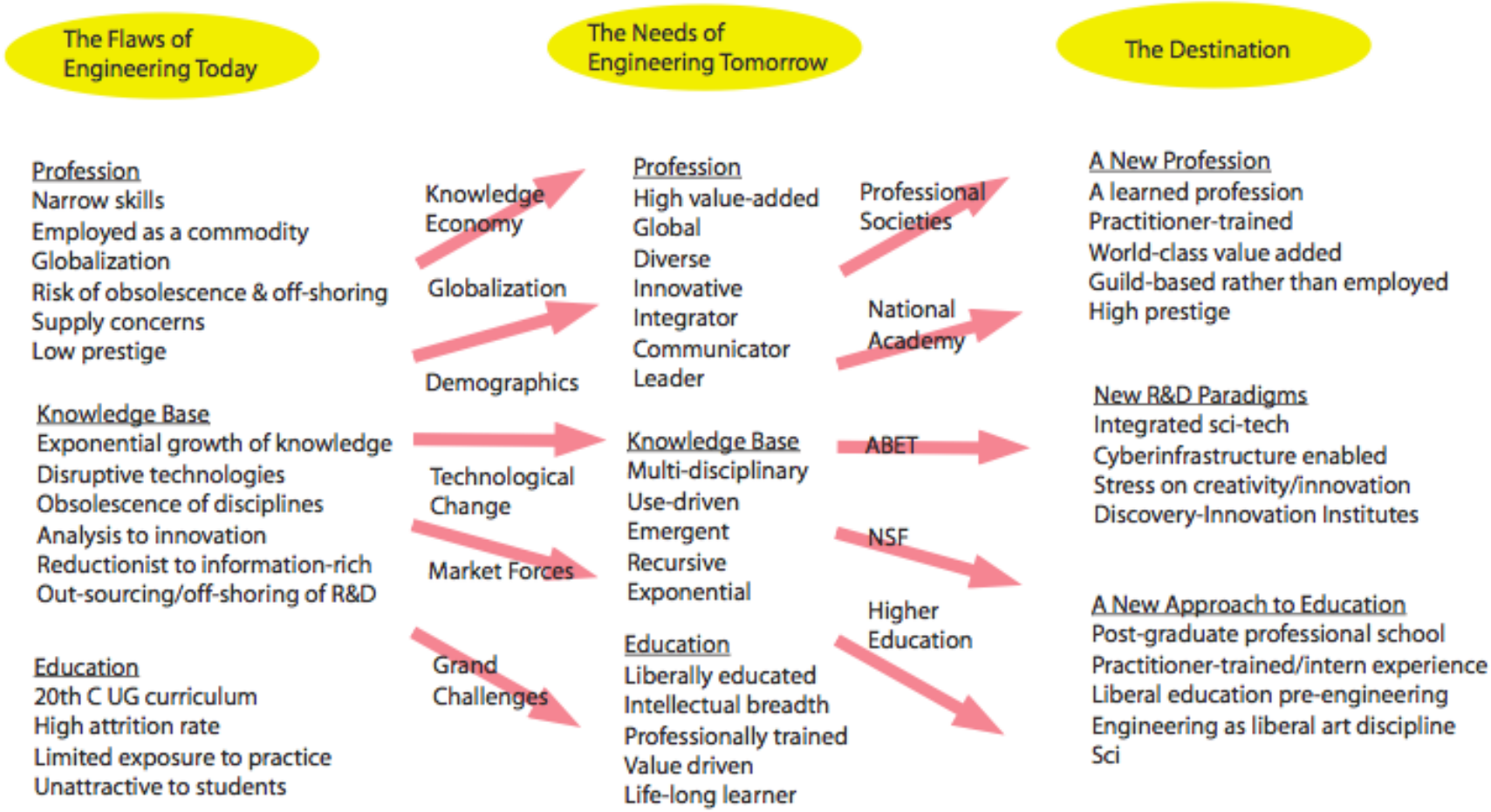
He then went on to observe: “I honestly don’t know the answer, but I have a hypothesis–namely, that most do not believe change is necessary. They are following the time-tested adage---"if it ain’t broke, don’t fix it."

JJD's View

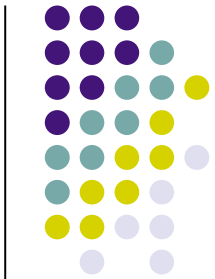


"Well, American engineering IS broke, at least when measured against the emerging technology capabilities of the rest of the world. Otherwise it would not be outsourced and off-shored! We can no longer afford simply chipping away at the edges of fundamental transformation of the engineering profession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

"Radical transformation will require radical actions!"

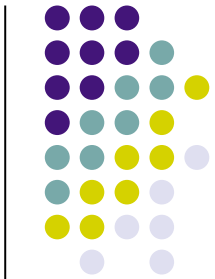

The Flaws of Engineering Today
The Needs of Engineering Tomorrow
The Destination
Profession
Narrow skills
Employed as a commodity
Globalization
Risk of obsolescence & off-shoring
Supply concerns
Low prestige
Knowledge Base
Exponential growth of knowledge
Disruptive technologies
Obsolescence of disciplines
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
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
Liberally educated
Intellectual breadth
Professionally trained
Value driven
Life-long learner
Professional Societies
National Academy
ABET
NSF
Higher Education
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
Engineering as liberal art discipline
Sci

What's Next?



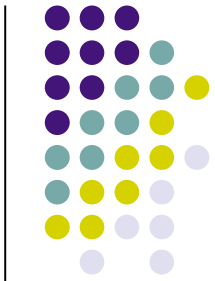
- Option 1: Benign Neglect: Simply continue the status quo, accepting the current global market realities, and reacting as best one can to new requirements such as the need for global engineers…and wait until conditions deteriorate sufficiently to stimulate bolder action.
- Option 2: Evolution (Education 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)