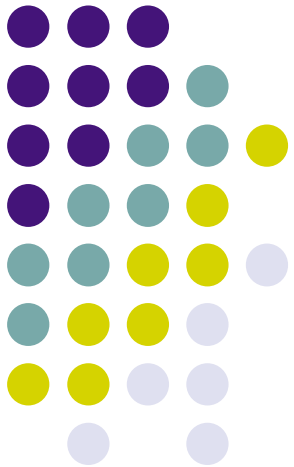
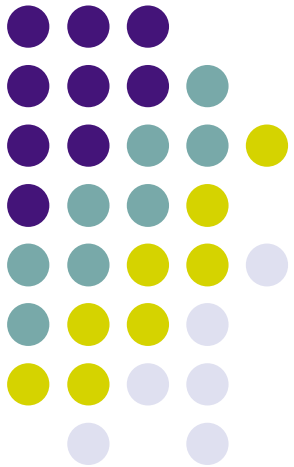
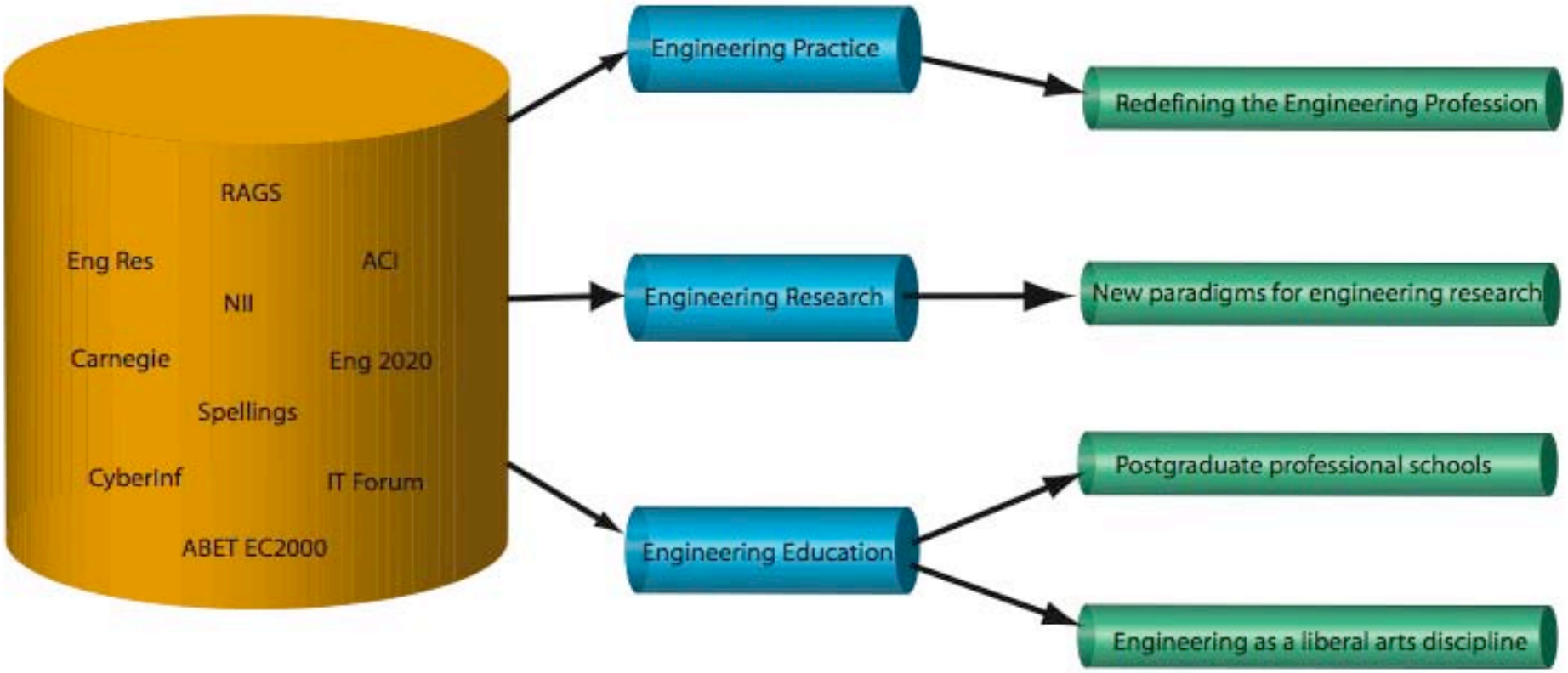
How Do We Get From Here to There?



A Roadmap to 21st Century Engineering




RAGS
Eng Res
ACI
NII
Carnegie
Eng 2020
Spellings
CyberInf
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ABET EC2000
Engineering Practice
Engineering Research
Engineering Education
Redefining the Engineering Profession
New paradigms for engineering research
Postgraduate professional schools
Engineering as a liberal arts discipline


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
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Profession
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Global
Diverse
Innovative
Integrator
Communicator
Leader
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Use-driven
Emergent
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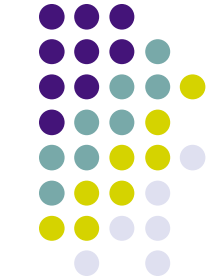
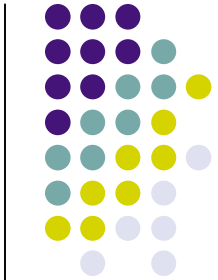
Exponential
Education
Liberally educated
Intellectual breadth
Professionally trained
Value driven
Life-long learner
Professional Societies
National Academy
ABET
NSF
Higher Education
A New Profession
A learned profession
Practitioner-trained
World-class value added
Guild-based rather than employed
High 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

Possible Strategic Intents



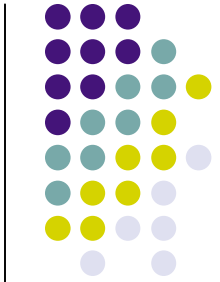
- PRACTICE: To establishing engineering practice as a true learned profession, similar in rigor, intellectual breadth, preparation, stature, and influence to medicine and law, with extensive post-graduate education and culture more characteristic of professional guilds than corporate employees.

Possible Strategic Intents



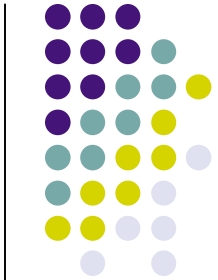
- RESEARCH: To redefine the nature of basic and applied engineering research, developing new research paradigms that better address compelling national and social priorities that those characterizing scientific research.

Possible Strategic Intents



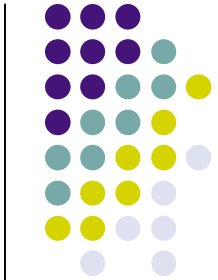
- EDUCATION: To establish engineering as a true liberal arts discipline, similar to the natural sciences, social sciences, and humanities, by imbedding it in the general education requirements of a college graduate for an increasingly technology-dependent society of the 21st century.

Conclusion 1



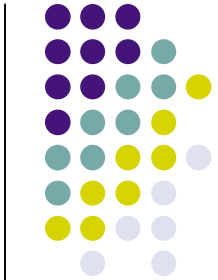
In a global, knowledge-driven economy, technological innovation—the transformation of knowledge into products, processes, and services—is critical to competitiveness, long-term productivity growth, and the generation of wealth. Preeminence in technological innovation requires leadership in all aspects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



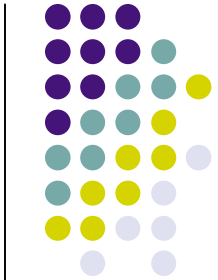
To compete with talented engineers in other nations with far lower wage structures, American engineering must be able to add significantly more value than their counterparts abroad through their greater intellectual span, their capacity to innovate, their entrepreneurial zeal, and their ability to address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

Conclusion 3



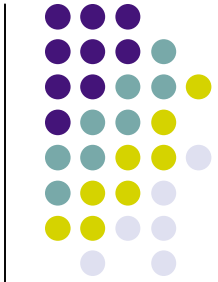
From this perspective the key to producing such world-class engineers is to take advantage of the fact that universities in the United States are more comprehensive and hence capable of providing broader educations, provided engineering schools, accreditation agencies such as ABET, and the marketplace is willing to embrace such an objective. Essentially all other learned professions are moving in this direction (law, medicine, business), requiring a broad liberal arts baccalaureate education as a prerequisite for professional education at the graduate level.

Conclusion 4



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.

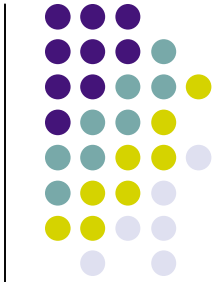
Transforming the Profession



The first challenge is to transform engineering from an occupation or a career to a true learned profession, where professional identify with the unique character of engineering practice is more prevalent than identification with employment.

Hence perhaps the initial goal should be to re-create a guild culture for engineering, where engineers identify more with their profession than their employer, taking pride in being a part of a true profession whose services are highly valued both by clients and society.

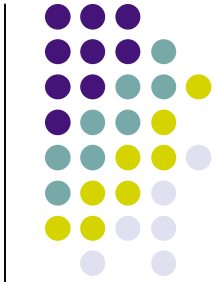
However…



It seems clear that a rapidly evolving knowledge base coupled with the need to gain sufficient prestige and influence to provide technology leadership will require that the level of education required for professional practice simply must be elevated to the graduate level and augmented by a requirement for continuous further education.

The key is for the American engineering profession to shift from simply reacting to market pressure to a more concerted effort to define and control the marketplace, much like other learned professions (e.g., medicine and law).

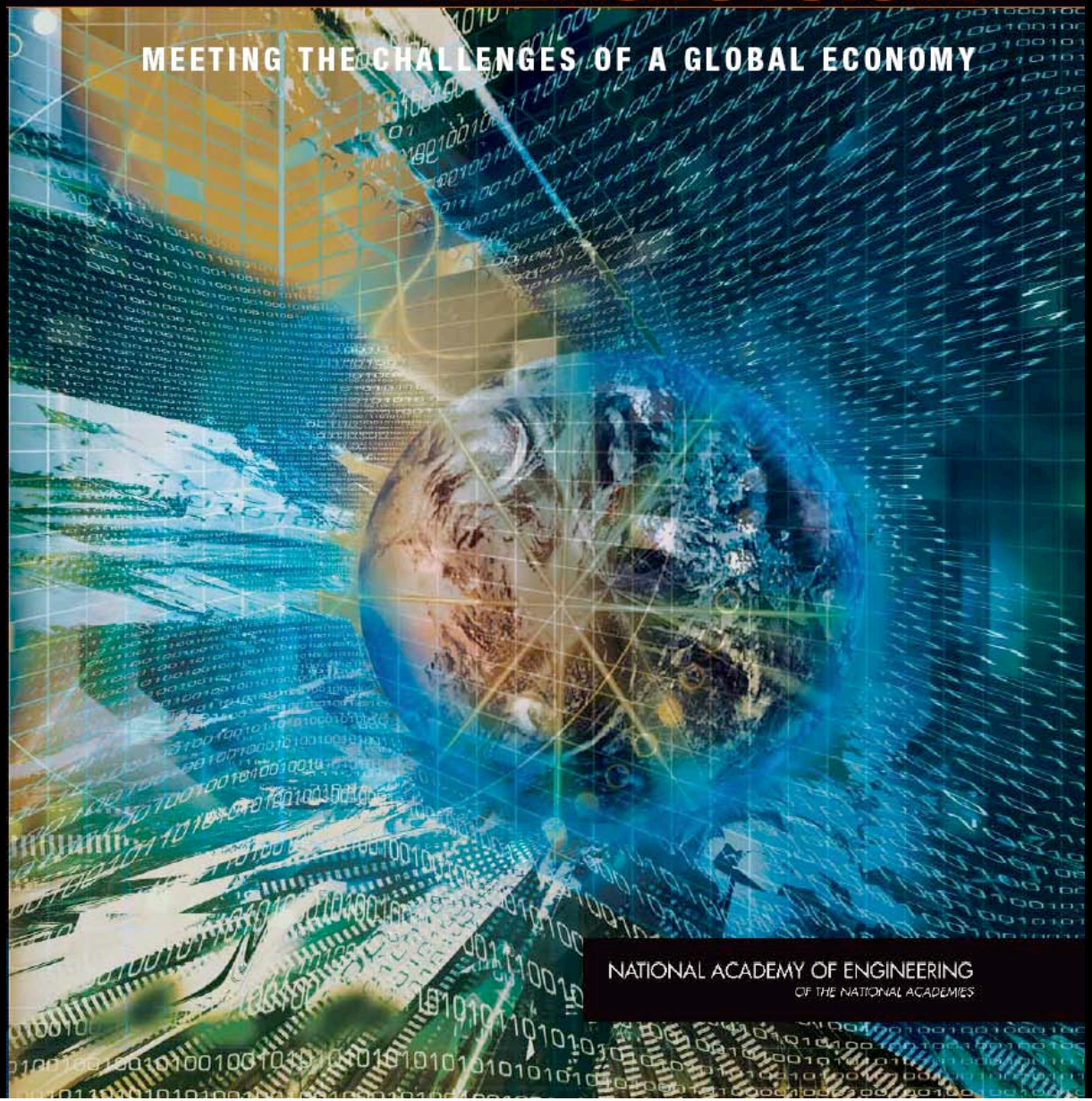
Transforming Engineering Research



As Chuck Vest frames it, for America to prosper and achieve security, it must do two things: (1) discover new scientific knowledge and technological potential through research and (2) drive high-end, sophisticated technology faster and better than anyone else. We must make new discoveries, innovate continually, and support the most sophisticated industries.

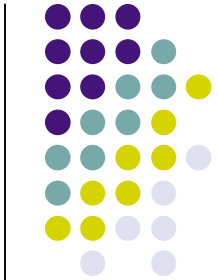
ENGINEERING RESEARCH AND AMERICA'S FUTURE

MEETING THE CHALLENGES OF A GLOBAL ECONOMY



NATIONAL ACADEMY OF ENGINEERING
OF THE NATIONAL ACADEMIES

NAE Committee



- James J. Duderstadt
- Erich Bloch
- Ray M. Bowen
- Barry Horowitz
- Lee L. Huntsman
- James Johnson
- Kristina M. Johnson
- Linda Katehi
- David C. Mowery
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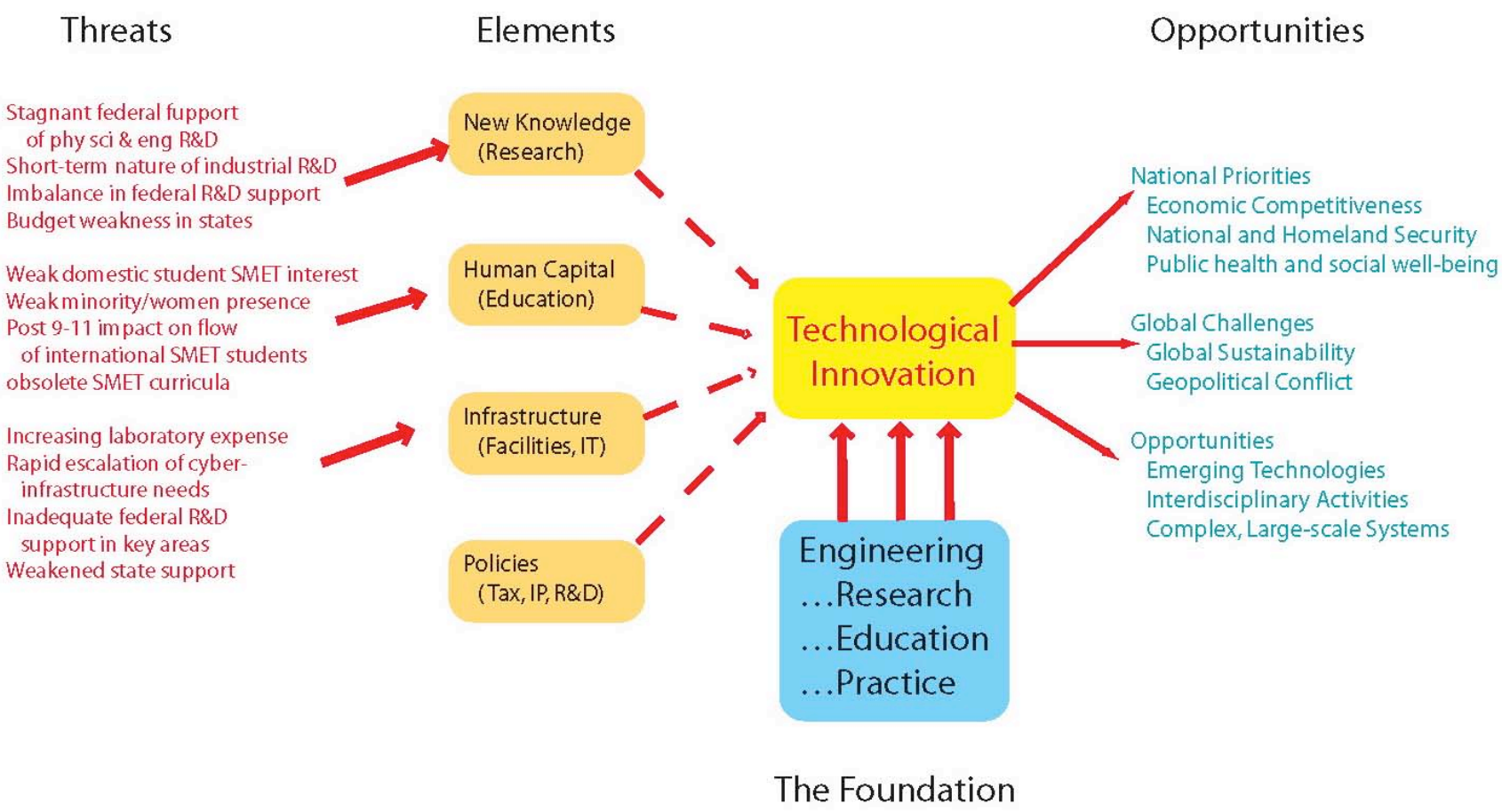
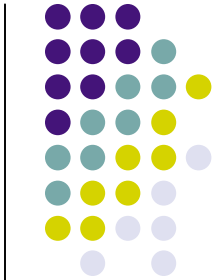
- Malcolm R. O'Neill
- George Scalise
- Ernie Smerdon
- Robert F. Sproull
- David Wormley
- Proctor P. Reid


Threats
Elements
Opportunities
Stagnant federal fupport
of phy sci & eng R&D
Short-term nature of industrial R&D
Imbalance in federal R&D support
Budget weakness in states
Weak domestic student SMET interest
Weak minority/women presence
Post 9-11 impact on flow
of international SMET students
obsolete SMET curricula
Increasing laboratory expense
Rapid escalation of cyber-
infrastructure needs
Inadequate federal R&D
support in key areas
Weakened state support
New Knowledge
(Research)
Human Capital
(Education)
Infrastructure
(Facilities, IT)
Policies
(Tax, IP, R&D)
Technological
Innovation
Engineering
…Research
…Education
…Practice
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
The Foundation

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

Recommendations



- Balancing Federal R&D Portfolio
- Re-establishing Basic Engineering Research As A Priority of Industry
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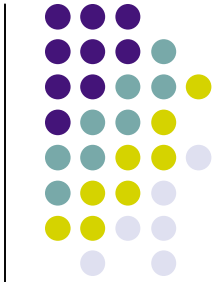
- Discovery-Innovation Institutes

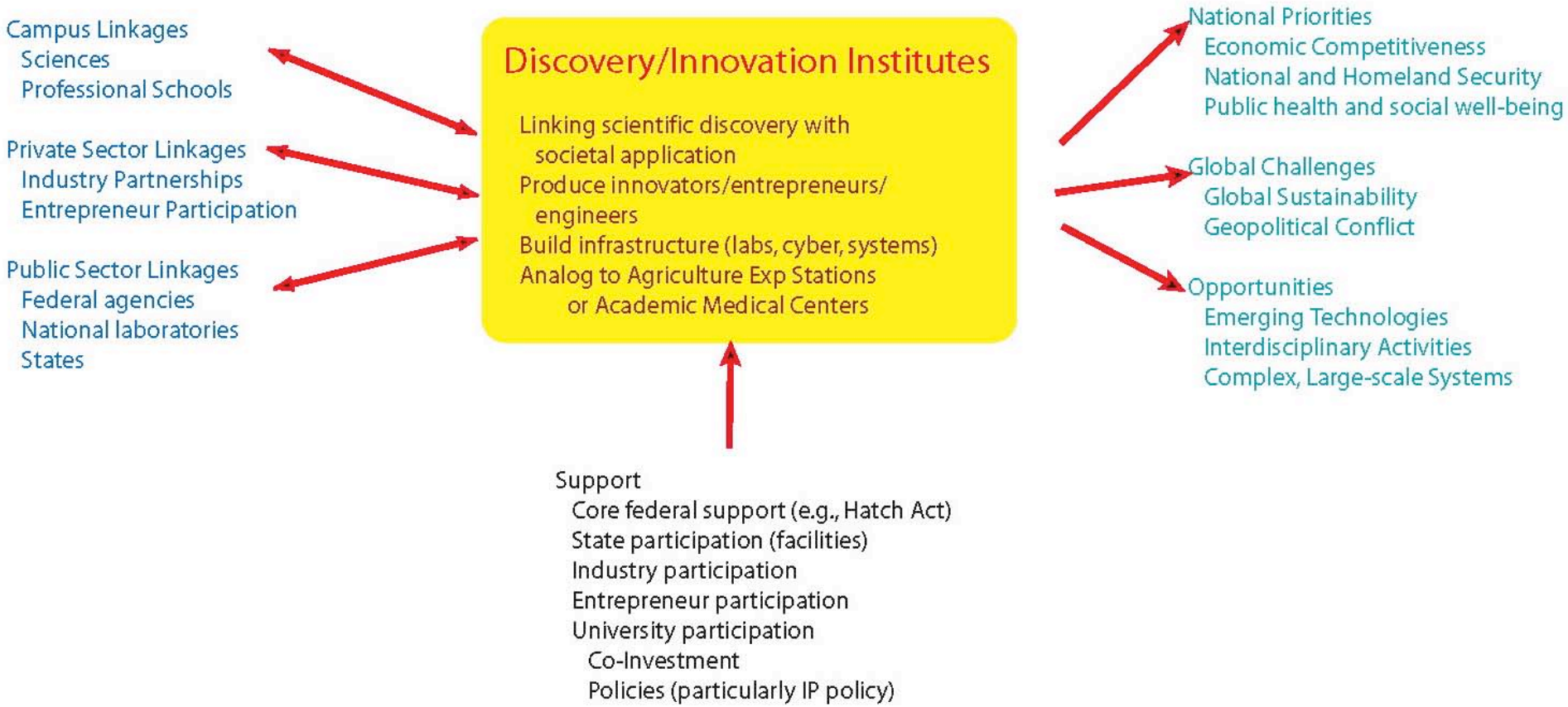
U.S. Leadership in Innovation will Require Changes



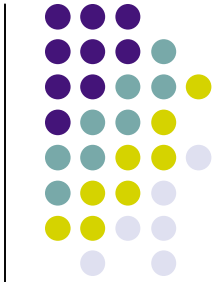
- In the way research is prioritized, funded, and conducted.
- In the education of engineers and scientists.
- In policies and legal structures such as intellectual property.
- In strategies to maximize contributions from institutions (universities, CR&D, federal agencies, national laboratories)

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**
- **MAES Scientists Awarded $1 Million for Swine Research**

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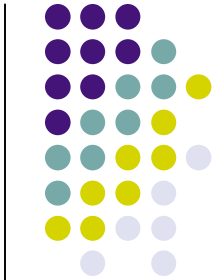
Discovery-Innovation Institutes

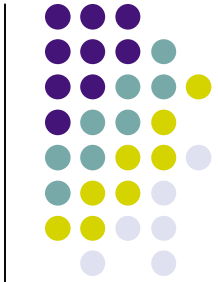
- Although primarily associated with engineering schools, DIIs would partner with other professional schools (e.g., business, medicine, law) and academic disciplines.
- To ensure the necessary transformative impact, the DII program should be funded at levels comparable to other major federal initiatives 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.

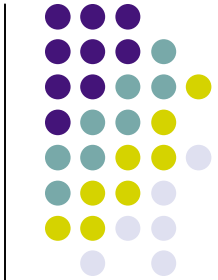
Transforming Engineering Education



"For too long traditional engineering education has been characterize 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."

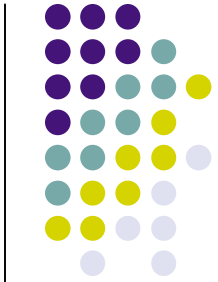
Princeton, 2005

The Vision



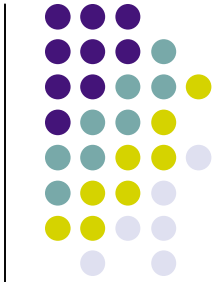
The transformation of engineering into a true *learned profession*, comparable in rigor, prestige, and influence to medicine and law, by shifting the professional education and training of engineers to post-baccalaureate professional schools offering three-year, practice-focused degree programs (e.g., D. Eng. or Diploma of Engineering). The faculty of these schools would have strong backgrounds in engineering practice with scholarly interests in the key elements of engineering, e.g., design, innovation, entrepreneurial activities, technology management, systems integration, and global networking, rather research in engineering sciences. Students would be drawn from a broad array of possible undergraduate degrees with strong science and mathematics backgrounds, e.g., from the basic sciences or perhaps through a "pre-engineering" programs (similar to the pre-med programs preparing students for further study in medicine.) The engineering professional schools would be augmented by university-owned engineering services companies capable of providing internship experiences in engineering practice (similar to the teaching hospitals supporting medical education)

The Vision (continued)

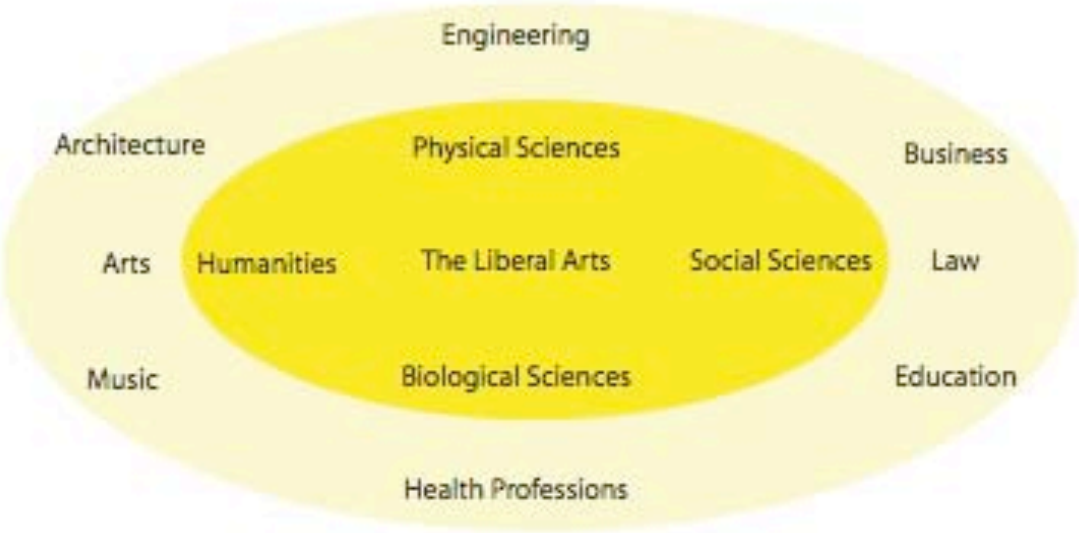


The *discipline* of engineering would be taught by existing engineering schools through both degree programs at the undergraduate and graduate level and courses provided to all undergraduates as a component of a new 21st century liberal arts core curriculum. Because of the strong research interests and background of most current engineering faculty, the curriculum and degrees offered in the discipline of engineering would have more of an engineering and applied science character and would not necessary require ABET certification, thereby allowing more opportunity for a broader liberal education on the part of undergraduates.

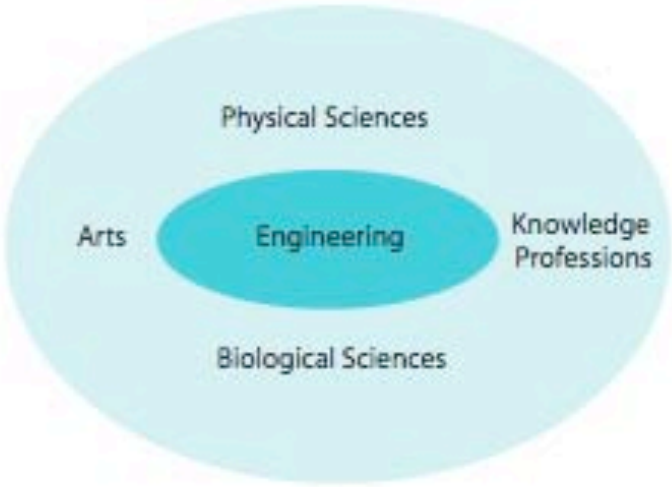
The Vision (continued)



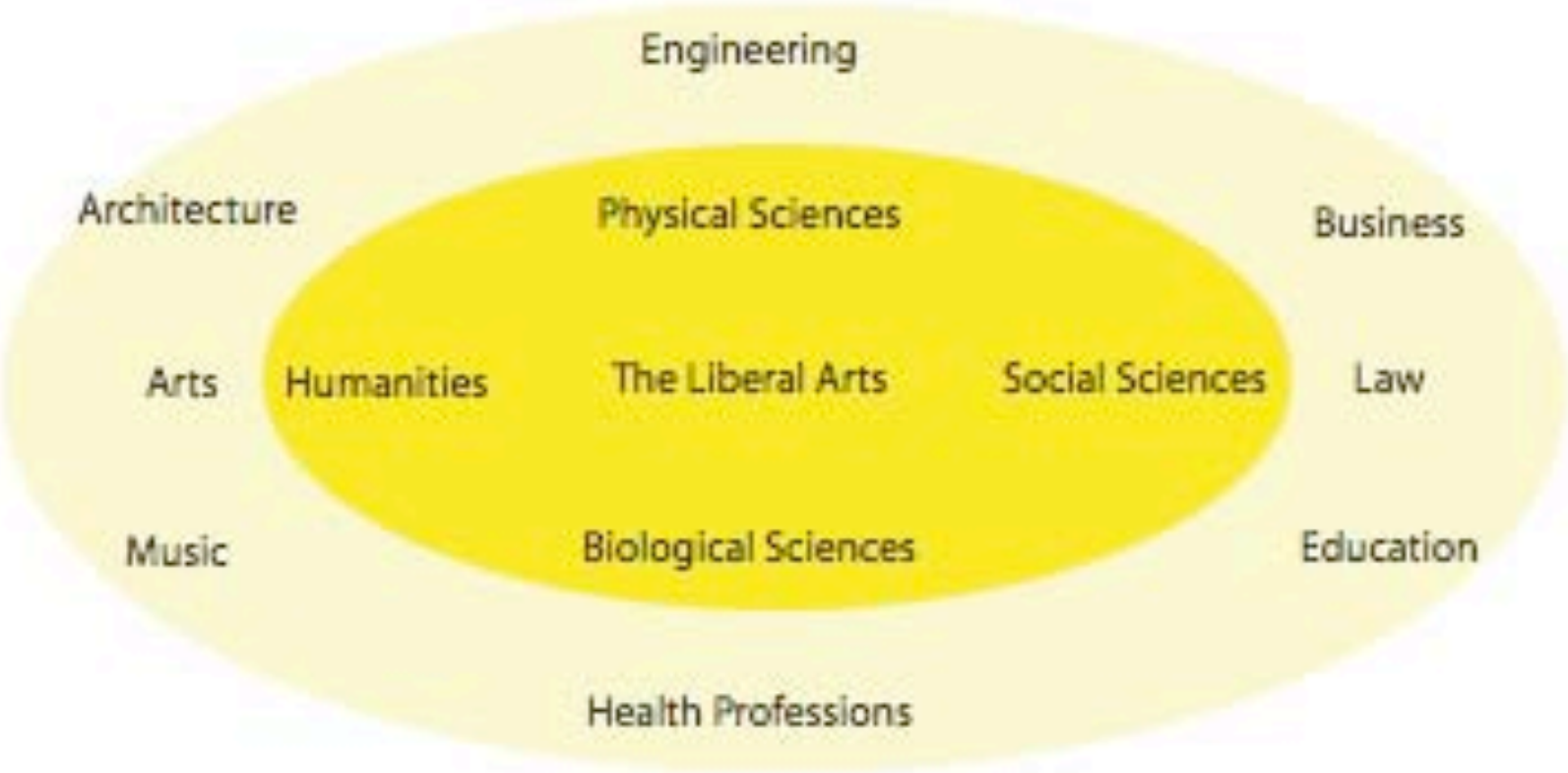
Finally, the engineering discipline would be added to the liberal arts core of a general education, appropriate for undergraduate students seeking a liberal education for the 21st century, much as the natural sciences were added a century ago to the classical liberal arts (classical languages, grammer, logic, rhetoric–the classical *trivium* and *quadrivium).*



Engineering as a Profession

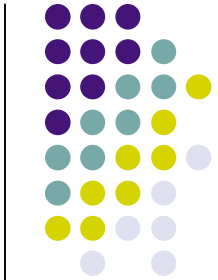


Engineering as a Liberal Arts Discipline

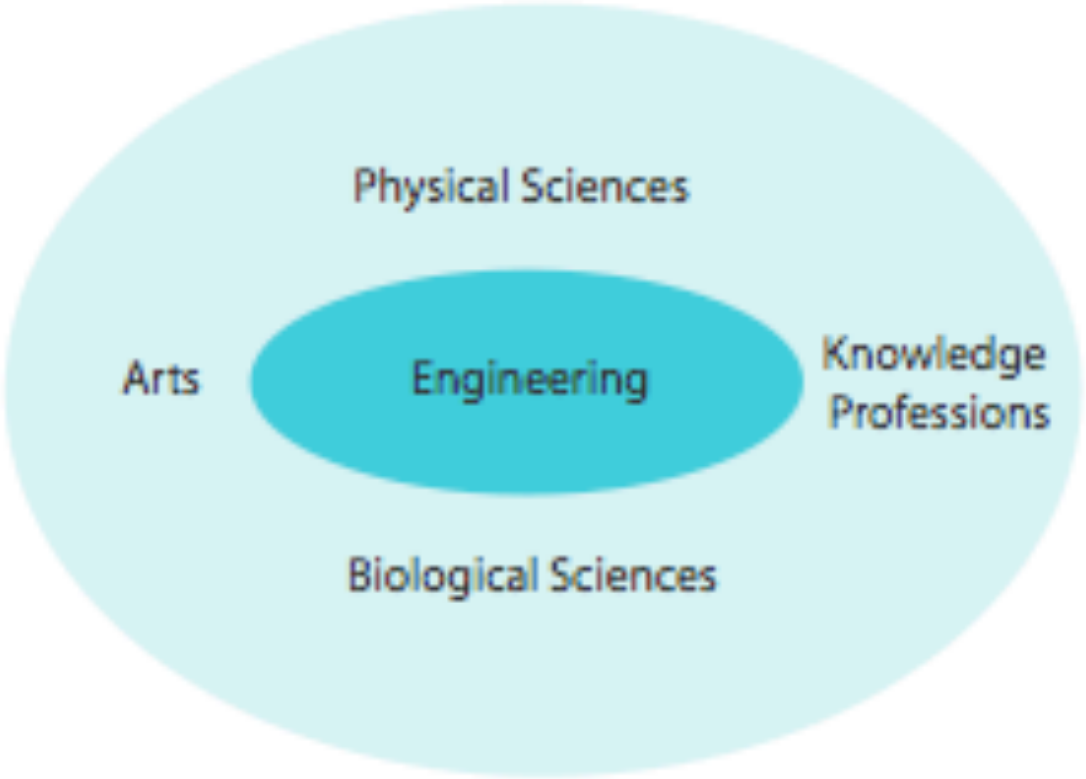


Engineering as a Profession

Professional Schools

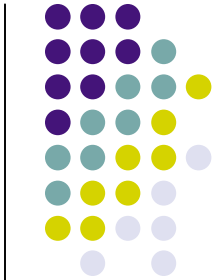


Perhaps the most effective way to raise the value, prestige, and influence of the engineering profession is to create true post-baccalaureate professional schools, with practice-experienced faculty, and providing clinical practice experience for students, similar to medicine and law. Yet here we face the formidable problem that we have no existing models to build upon–in the way that Abraham Flexner utilized Johns Hopkins University as his model for the future of medical education. Instead most of our existing engineering schools are heavily discipline-based, providing the science, mathematics, and engineering science instruction that undergird engineering, but with very little of the professional training and experience that professional schools in other disciplines provide (e.g., moot courts or clinical rounds).



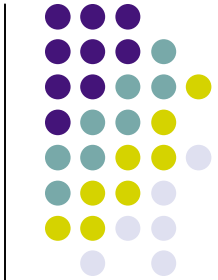
Engineering as a Liberal Arts Discipline

Engineering as a Discipline



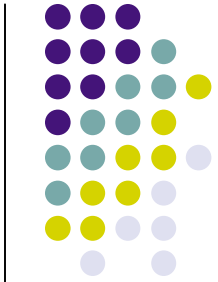
If the professional elements of an engineering education were shifted to a true post-graduate professional school, it might provide a very significant opportunity to address many of the challenges that various studies have concluded face engineering education today at the undergraduate level. In particular, removing the burdens of professional accreditation from undergraduate engineering degree programs would allow them to be reconfigured much as other academic disciplines in the sciences, arts, and humanities, thereby providing students majoring (or concentrating) in engineering with more flexibility to benefit from the broader educational opportunities offered by the comprehensive university.

A Liberal Education



Of most interest here is the possibility that those students intending to enter the profession of engineering would no longer be subject to the overburdened curriculum characterizing ABET-accredited undergraduate degree programs and instead could earn more general liberal arts degrees in science, mathematics, engineering science, or even the arts, humanities, or social sciences with an appropriate pre-engineering foundation in science and mathematics, as preparation for further study in an engineering professional school. In this way they would have the opportunity for a true liberal education as the preparation for further study and practice in an engineering profession characterized by continual change, challenge, and every increasing importance.

Engineering as a Liberal Art



One could make a strong case that today engineering–or at least technology–should be added to the set of liberal arts disciplines, must as the natural sciences were added to the *trivium* and *quadrivium* a century ago. Here we are not referring to the foundation of science, mathematics, and engineering sciences for the engineering disciplines, but rather those unique tools that engineers master to develop and apply technology to serve society, e.g., structured problem solving, synthesis and design, innovation and entrepreneurialism, technology development and management, risk-benefit 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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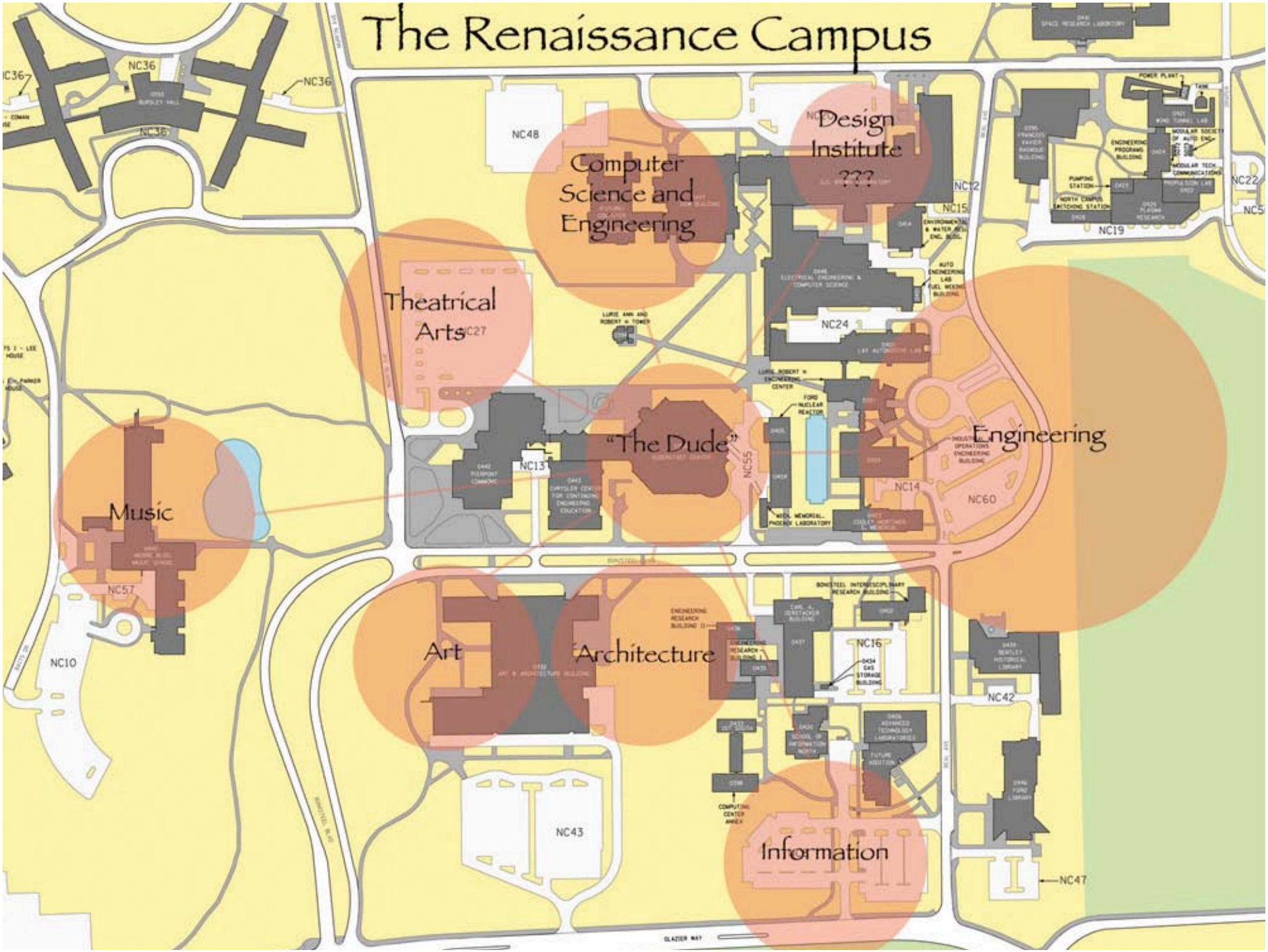
	Education	Research	Organizations
Engineering School	Undergraduate Graduate Professional	Basic Research Applied Research Systems Development	Discovery-Innovation Centers Captive Consulting Companies Practice Schools
	Degrees …B.S., B.A. …M.S., Ph.D. …M.Eng., D. Eng..	Publications Patents Systems, Products	Engineering Services Systems, Products Spinoff Companies

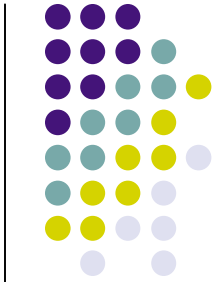

The Renaissance Campus
Design Institute ???
Computer Science and Engineering
Theatrical Arts
"The Dude"
Engineering
Music
Art
Architecture
Information
NC36
NC48
NC12
NC15
NC24
NC27
NC13
NC55
NC14
NC60
NC57
NC10
NC16
NC42
NC43
NC47
NC19
NC22

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