THE ENGINEER'S TOOLKIT

Consider digital media (iPhones, wearable sensors, Google Glass) as the counterpart of microscopes and mass spectrometers: measuring, recording and probing in the realm of social phenomena. If we accept that "technology is exploiting phenomena for useful purposes," these phenomena ought not to be only physiochemical and biological, but also social and digital.

"THIS IS THE MOST EXCITING ERA FOR SCIENCE AND ENGINEERING IN HUMAN HISTORY."

Charles Vest, President Emeritus, NAE
NAE Grand Challenges Summit, USC
October 6-8, 2010

USC Viterbi at a Glance

USC Engineering began in 1905

Student Population
Approximately 2,400 undergraduate students and 4,400 graduate students

Faculty
177 tenure-track faculty, with 56 endowed chairs and professorships, 55 NSF Career Awardees, 19 full-time, tenure-track NAE members (34 total) and 7 junior faculty listed on the MIT TR35 list since 2009

Academic Departments
Eight

Alumni
More than 60,000

Annual Research Expenditures
More than $173 million, with more than 45 research centers and institutes

Research Centers and Institutes

Home to:

» Information Sciences Institute (ISI)
» The Ming Hsieh Institute
» The Daniel J. Epstein Institute
» Two National Science Foundation (NSF) Engineering Research Centers (ERC)
  › Integrated Media Systems Center (IMSC)
  › Biomimetic MicroElectronic Systems Center (BMESC)
» University Center of Excellence of the U.S. Department of Homeland Security - Center for Risk and Economic Analysis of Terrorism Events (CREATE)
» Department of Energy Frontiers Research Center (EFRC) – Center for Energy Nanoscience at USC
» Biomedical Informatics Research Network (BIRN)
» HTE@USC (Health, Technology and Engineering@USC)
» LADWP/DOE Smart Grid Demonstration Project
» Center for Interactive Smart Oil Field Technology (CiSoft)
» Pratt & Whitney Institute for Collaborative Engineering (PWICE)
» Airbus Institute for Engineering Research (AIER)
» Center for Research and Education in Advanced Software Technologies (CAST)
» NIH Center on Genomics and Phenomics of Autism
» Viterbi Student Innovation Institute (VSI^2)
» USC Energy Institute

Affiliated with:

» Alfred E. Mann Institute for Biomedical Engineering (AMI)
» Institute for Creative Technologies (ICT)
» USC Stevens Center for Innovation

Education Centers

» Division of Engineering Education
» KIUEL (Klein Institute for Undergraduate Engineering Life)
» VAST: Viterbi Adopt-a-School, Adopt-a-Teacher

USC Viterbi | School of Engineering

THE EVOLUTION OF TECHNOLOGY

EXPLOITING THE POWER OF PHYSICAL, CHEMICAL, BIOLOGICAL . . . AND *SOCIAL* PHENOMENA?

DEAN'S REPORT 2013

Excerpts and adaptations from a keynote address delivered at the annual meeting of the National Academy of Engineering (NAE) February 7, 2013.

Chuck Vest, former NAE President, aptly noted: "We live in the most exciting era for science and technology in human history." Spectacular advances driven by Moore's Law continue to spawn great innovation with deep technological roots, empowering society in unprecedented ways.

This begs the question: what exactly is technology? I prefer the definition given by Brian Arthur in his book, "The Nature of Technology": *Technology is the exploitation of a phenomenon for useful purposes* (Panel 1). I would characterize "exploiting" as controlling, adapting, transforming, manipulating and other such actions.

In the past, traditionally the phenomenon exploited was mostly physical or chemical (think semiconductors, photoelectric effect, combustion, etc.) and the resulting technology is what is traditionally associated with engineers (sensors, computers, airplanes and so on).

In 2003, the NAE published "A Century of Innovation: Twenty Engineering Achievements That Transformed Our Lives." Nineteen of the top twenty achievements listed were based on exploiting a physical or chemical phenomenon — with "health technologies" the single exception (Panel 2).

Increasingly over the past few decades, of course, the rapid advances in biology have given rise to "biotechnology" and "bioengineering," bringing about unprecedented innovation in health and medicine and accelerating the spectacular convergence between biology, engineering and medicine we witness today.

In a study commissioned by the NSF, the NAE was tasked to identify the new Grand Challenges for Engineering. Completed in 2008, the Grand Challenges identify 14 globe-spanning challenges that can be addressed by engineers (Panel 3). They set our discipline in a grander, global context, carrying inspiration and societal relevance with them.

Many think that the Grand Challenges can be categorized in four figurative buckets: Sustainability, Health, Security and Enrichment of Life. Indeed, not unlike Maslow's hierarchy of needs list, the Grand Challenges can be anthropomorphized.

But we are also now witnessing, and at an unprecedented pace, the appearance of technologies that exploit social, rather than physical, chemical or biological phenomena (Panel 1). This brings engineering to a new domain, rich with possibilities.

In this context, a fifth bucket may be missing. Humans are social animals, and as technology increasingly converges with our social interactions, societal phenomena (possibly societal organization) become relevant to the Grand Challenges that engineers must address (Panel 4). These will likely engender new challenges, including engendering economic growth and innovation.

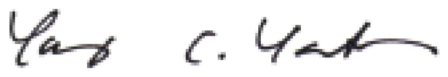
One of the points I'd like to highlight at the intersection of engineering and the social sciences is the application of technology in the scientific method and similarities and differences therein (Panels 5 & 6).

Typically in the natural sciences, phenomena are discovered by probing, recording, sensing, manipulating and exploring (panel 5). A similar approch is followed in uncovering social phenomena (Panel 6).

Technology (in the form of "digital media" or "social media") is vital to communicate, probe, record/sense, manipulate, and control, as well as to advance further discovery (e.g. through virtual reality, the advancing of which is yet another NAE GC). Moreover, much of the "sensing" is recorded through what is now becoming the field of Big Data. In many ways, what microscopes and mass spectrometers are to the natural sciences, digital and social media are becoming to the social sciences. And the rapidly emerging field of Big Data will be used to make sense of the phenomena, first through uncovering correlations and then by postulating new laws.

Whether in their original postulation or, even better, through the incorporation of societal aspects, the Grand Challenges serve as a call to action. They help to change the conversation by placing engineering at the center of the advancing of solutions to global challenges (Panel 7). But if we want engineering to empower society, society must also empower engineering in a complementary and symmetric way (Fig. 8). In David Deutsch's book "The Beginning of Infinity," the position is stated that knowledge and discovery advance by free inquiry, by the diversity of thoughts and ideas and by the ability to critically test them (Panel 9). I believe that this position is right — it places the open society at the center of innovation and discovery and the diversity of thought and experimentation at the core of this endeavor and underline the importance of society empowering engineering.

In outlining the NAE 14 Grand Challenges, there is an inherent optimism — that we can change the world. Each challenge reflects the human aspiration to strive for an always better future. David Deutsch says (Panel 10), "Problems are inevitable. But all problems are soluble (through science, engineering and technology)." With the caveat that such problems do not include those proposed by Gödel, the same aspiration as that of the NAE Grand Challenges — to advance the four (or perhaps five) buckets.



Yannis C. Yortsos
Dean, USC Viterbi
School of Engineering

The original can be found at: www.viterbi.usc.edu/grandchallenges

1

TECHNOLOGY: EXPLOITING A PHENOMENON FOR USEFUL PURPOSES

Brian Arthur, "The Nature of Technology"

- **PHYSICAL** (e.g. Photoelectric Effect)
- **CHEMICAL** (e.g. Fischer-Tropsch Synthesis)
- **BIOLOGICAL** (e.g. Genome)
- ***SOCIAL...?***

2

A CENTURY OF INNOVATION, NAE

1. Electrification
2. Automobile
3. Airplane
4. Water Supply and Distribution
5. Electronic
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning and Refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Health Technologies
17. Petroleum and Petrochemical Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials

3

THE NAE GRAND CHALLENGES

Make Solar Energy Economical
Provide Energy from Fusion
Develop Carbon Sequestration Methods
Manage the Nitrogen Cycle
Provide Access to Clean Water
Engineer Better Medicines
Advance Health Informatics
Reverse Engineer the Brain
Secure Cyberspace
Prevent Nuclear Terror
Restore and Improve Urban Infrastructure
Enhance Virtual Reality
Advance Personalized Learning
Engineer the Tools of Scientific Discovery

4

1 **SUSTAINABILITY**
Make Solar Energy Economical, Provide Energy from Fusion, Develop Carbon Sequestration Methods, Manage the Nitrogen Cycle, Provide Access to Clean Water

2 **SECURITY**
Secure Cyberspace, Prevent Nuclear Terror, Restore and Improve Urban Infrastructure

3 **HEALTH**
Engineer Better Medicines, Advance Health Informatics, Reverse Engineer the Brain

4 **ENRICHING LIFE**
Enhance Virtual Reality, Advance Personalized Learning, Engineer the Tools of Scientific Discovery

5 **SOCIETAL ORGANIZATION?**
Exploiting Social Phenomena Through Digital Media

5

PHENOMENA IN THE NATURAL SCIENCES

The experimenter usually does the following:

- Probes **matter** with tools and stimuli
- Observes and records **responses** through sensors
- Characterizes accurately the **physical/chemical/biological state**
- Speculates/Hypothesizes/Tests and Verifies the **physical/chemical/biological underlying laws**
- Explores the **range** of behavior by further probing to solidify findings
- Postulates a **theory of the phenomenon**

Technology then exploits the phenomenon for useful purposes.

6

PHENOMENA IN THE SOCIAL SCIENCES

The experimenter, through digital and social media, and a variety of stimuli does the following:

- Probes **subsets of people** with stimuli that reaches them (primarily digitally)
- Observes and records **responses** through digital media and collects **Big Data**
- Characterizes (but incompletely, I would argue, due to the lack of a sound mathematical basis) **common behavioral response**
- Speculates/Hypothesizes/Tests and Verifies the **(social or cultural) underlying laws** or simply **exploits Big Data** to uncover correlations
- Explores the **range** of behavior by further probing to solidify findings
- Postulates a **theory of the phenomenon**

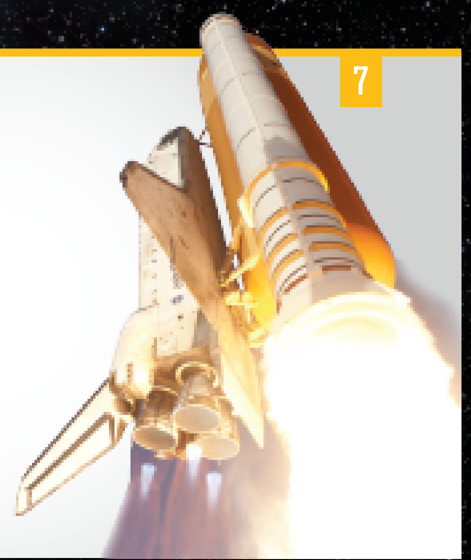
Technology then exploits the phenomenon for useful purposes.

WHAT MICROSCOPES AND MASS SPECTROMETERS ARE TO THE NATURAL SCIENCES, DIGITAL MEDIA ARE TO THE SOCIAL SCIENCES.

7

THE NAE GRAND CHALLENGES: A CALL TO ACTION

CHANGING THE CONVERSATION



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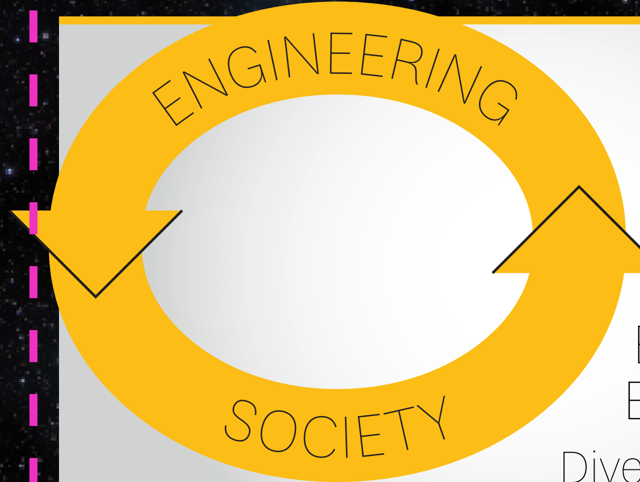

SOCIETY EMPOWERING ENGINEERING:
Diversity, Free Inquiry

9

THE EVOLUTION OF KNOWLEDGE (*Hence Education?*)

David Deutsch, "The Beginning of Infinity"

- Variation creates new options, ideas, conjectures
- Selection favors those that pass criticism and tests
- Both require open dialogue and discussion, hence interactivity

10

"PROBLEMS ARE INEVITABLE. ALL PROBLEMS ARE SOLUBLE."*

David Deutsch, "The Beginning of Infinity"

*Excludes Gödel-type problems