Committee to Assess the Capacity of
The U.S. Engineering Research Enterprise

Meeting, June 16, 2004

Summary

<u>Dr. Vest's Comments</u>

U.S. strength in engineering has been due to major federal investment (although there has always been an ambiguous relationship between engineering and science). However over the past 30 years there has been a flat investment in physical science and engineering, while federal investment in the life sciences has increased by a factor of five. This represents a serious underinvestment in physical science and engineering.

The key policy issues are:

1. We are taken for granted, although we also take the federal government for granted.
2. We need to pay greater attention to the openness of our campuses to international students and faculty to remain global institutions.
3. There has been a major change in how DOD procures technology; it now tends to buy it off the shelf rather than develop it, with serious consequences for basic research (6.1).
4. This is compounded by the shift of major industrial research laboratories away from research to more product development.
5. We are facing increasing engineering workforce concerns, particularly in defense and security. (Note here the efforts of DOD to stimulate a new National Defense Education Act is gaining support from other federal agencies.)

~~Many economic, social changes have impacted engineering research and education:~~

- ~~U.S. research have benefited from globalization in engineering education and research~~
- ~~Federal government takes engineering for granted and vice versa~~
- ~~Changes in defense procurement, esp. use of COTS, have reduced need/support for 6.1~~
- ~~Rapid technological change gives graduates greater options than doctoral programs~~
- ~~Global competition, rapid product cycles have changed corporate approach to research, leading to decline in corporate labs, make-buy decisions on innovation.~~
- ~~U.S. now smaller portion of global engineering population/demand; corporate R&D has become global to take advantage of foreign capability, be close to markets, etc.~~

So U.S. not as dominant as once was across the board, and must compete for talent and markets. Over the past decade we have sustained competitiveness through innovation.

The most significant challenge has become the globalization of industry, engineering, and research. Here it is important to note that off-shoring is driven not just by cost but by quality and the objective of building new markets.

There is enormous opportunity for engineering today:
Most exciting period in human history in science and engineering (smaller scales, higher complexity, interdisciplinary)
But info-bio-nano is not all, since many opportunities like in systems in areas such as global sustainability, energy, food.
There is also a revitalization of technological entrepreneurship, with products "you can drop on your foot".

~~U.S. opportunities lie in systems, in areas such as food, manufacturing, product development, logistics, medical systems, energy, environment, e.g. interdisciplinary research.~~

Comments on PCAST: Congress asked PCAST to oversee national nanotechnology initiative. Current PCAST study on science, technology, mathematics workforce. (Other PCAST report summaries in meeting briefing book.)

Comments on study of DoE Science: need to improve understanding that DoE is the major science agency, and DoE needs to improve its management of its science activities. Under Secretary for Science should be established, along with new programs in energy storage, distribution, etc.; advanced computation; facilities for fundamental science. DoE leadership received the report well, but needs help making the case in Congress. (This report summary in meeting briefing book.)

Comments on Science Coalition: created in 1994 from idea of Harvard President Rudenstine, prompted by predictions of 20-30% real decline in federal research funding. Its mission is to expand federal involvement and funding science, research, etc. Started with 15 public and private universities; now membership is about 60 universities plus companies. Focus on communication, running ads in newspapers and journals, holding briefings for Congressional staff, hosting annual "Breakfast of Champions" for Congressional science supporters. Science Coalition has helped to bring coherence to the message of importance of university research and university concerns such as contract restrictions, earmarking, and F&A rates. Science Coalition is on the web at www.sciencecoalition.org.

Q&A: 1) Committee should decide whether to address physical sciences and engineering or just engineering. Dr. Vest sees virtue in "physical sciences and engineering" because the phrase has become familiar. But he also cautions this may not apply to NSF.
2) People will always begin by stressing this is a zero-sum game. Since funding for physical sciences and engineering has been essentially flat for 30 years, and since the process of doubling the NIH budget is complete, it should be possible to argue for incremental increases for engineering without concern from other fields that the increases are coming at their expense.
3) DoD has been supporting the National Defense Education Act, to provide support to U.S. citizens to study science and engineering of particular importance to defense. Other agencies are beginning to show interest.
4) State cutbacks in funds to universities have exacerbated the effects of stagnant federal funding. Several effects: less funding for infrastructure improvements, forces universities to channel investments to life sciences because improves ability to compete successfully for NIH research dollars, and also tends to limit universities' ability to resist federal restrictions on publication and use of foreign students because there are no funding alternatives.
5) Dr. Vest is optimistic about universities ability and willingness to teach and conduct research in complex, interdisciplinary systems, which will be their competitive advantage in future.

<u>Dr. Wulf's Comments</u>

Three points of advice for the committee:

1) Focus on a positive message. Rather than addressing budget declines and imbalances with life sciences, the committee should communicate the value of engineering to society. There are grand challenges that only engineering can solve, in areas such as health, security, homeland defense, environment. Communicating these challenges effectively would justify substantial increases in funding for engineering research.
2) Overcome the image problem of engineering. Surveys show a career in engineering has a mediocre image. Even academia seems to have the notion that science is better than engineering. Engineering schools won't educate non-engineers, so it is not surprising that the general public does not understand engineering. Even separate fields of engineering compete among themselves, failing to rally behind a consistent message.
3) Engineers, as represented on this committee and other current initiatives, such as those at the Council on Competitiveness, must take the initiative to change the image and to

educate Congress and the general public on both the past and potential future contributions of engineering to innovation and national needs.

Q&A: 1) Issues to focus on might include sustainability, economic security, homeland security, role of engineering in medical advances. Focus should be on connecting the grand challenges to individual needs, as life sciences have done. 2) Focus on positive relative to globalization—advances in China do not make the U.S. worse. 3) It could be useful to assess the size of federal investment in life sciences research relative to the size of the industry, then make the same argument for engineering research.

Other tasks for the committee:

1. Change the attitudes of engneers themselves (e.g., get engineering schools to hire engineers rather than simply scientists)
2. Propose a creative partnership between NSF-ENG and NAE, in which NSF provides the resources and NAE builds the prestige of the profession.
3. Perhaps we should position engineering as the key to economic security just as the life sciences were with health security.

<u>Dr. Brighton's Comments</u>

In funding this study, NSF expects the committee to make a strong argument for advancing frontiers in engineering research and education. Demonstrate the past and present impact of engineering on the economy, security, health, competitiveness, and quality of life. Engineering has made a strong contribution, but could do more given adequate resources. The committee could make the case for a new national initiative to advance the frontiers of engineering, raise awareness, appreciation, and understanding of the importance of engineering. Focus on grand challenges at the frontiers. Craft a plan with a simple message and stick to it. Collaborate with other key organizations and constituencies on the plan.

NSF's Engineering Directorate has demonstrated its willingness to collaborate with other disciplines/directorates. General impression within NSF is that engineering is not doing well. Relative to other directorates and the total NSF budget, the Engineering Directorate has fallen below the rate of increase for NSF, 58% to 62%. However, some activities in other directorates are engineering related, materials science for instance, and Computer and Information Systems Engineering is now a separate directorate.

Important to stress impact, e.g., low proposal success rate in NSF-ENG (17%) and low level of support per faculty (or per student) compared to other disciplines supported by NSF.

A different approach is needed to convey the message. Engineering societies and individual universities need to overcome their self-interest to convey a consistent message. The plan should be long-term, like that of some of the basic sciences (e.g. astronomy). The recent report on Cyberinfrastructure (summary in the meeting briefing book) could be a model for the committee's efforts, recognizing the limits of time and funding for this committee relative to the cyberinfrasturcture effort.

A caution from the committee here, since we have limited funding and time for our study, while the NSF Cyberinfrastructure study was for two years with considerably higher funding. Our effort might be only a "scoping" study for a more extensive study.

<u>Michael Crosby, Highlights from NSB's *The Science and Engineering Workforce: Realizing America's Potential*</u>

No immediate crisis but long-term trends: growing demand for S&E talent in U.S. but dependent on foreign talent (approx. 21% foreign born, 37% of PhDs not including faculty) and now strong global competition for talent. Meanwhile, U.S. S&E workforce is aging (over half over 40) while insufficient (?) growth in new graduates. Given lag in producing new scientists and engineers, need to act now.

- H-1B visas down 50% in ‘02: 200k in ‘01 to 100k in 2002. (but about 140k in ‘00)
- Rate of 1st degrees in natural S&E has increased since ’75 maybe 2% but not as fast as other countries. (U.S. triple Chinese rate)
- S&E student retention 50%; S&E studies inflexible and expensive
- U.S. citizen S&E grad students peaked in ’93 at 330k; 330k in ‘01
- Foreign S&E grad students in ’01 almost 40%; 60% for engineering. Sharp increase since ‘97
- Despite data used, data sources are insufficient to capture dynamics
- Define eng workforce as those who use engineering skills, so may include non-engineers who not captured in data on S&E students

Feds and other stakeholders must initiate efforts to increase U.S. citizens studying S&E and maintain opportunities for foreigners to study and work in S&E in U.S.

- support to both students and institutions
- grad student support should fill real econ needs, promote wider options
- need better data on status, skill needs, supply/demand, attraction strategies
- visa and immigration policies must recognize U.S. dependence on foreign-born

Q&A: 1) One key area addressed in the report is the state of K-12 education and the need to have a more literate population in science, engineering, and mathematics. 2) The report also address the need to diversify engineering education, for instance by including study abroad. 3) This study should be a little different from many past studies because the world has changed over the last decade. New countries are more competitive in S&E and the competition for the global S&E workforce is increasing. In this new environment, this study frames the question in terms of what it will take for the United States to maintain global leadership in research and innovation. 4) Engineering curricula hasn’t changed much in 40 years, and schools currently are doing a poor job of addressing industry needs. Changing is difficult because most engineering faculty have little industry experience and most are unwilling to innovate in their curricula. (Apparently, neither university presidents nor engineering deans have much leverage in achieving the necessary changes.) Improving interaction between working engineers and students might improve the relevance of curricula.

<u>Miscellaneous Comments</u>

Committee needs to be careful in how it addresses the issue of foreign-born engineers. Universities have become dependent on foreign graduate students. Training foreign engineers helps economic development abroad, but also trains competitors. NAE has proposals to conduct a study on offshoring.

Arguably, excess federal investment in life sciences has resulted in an over-supply of doctorates and post-doctorates in those fields, evidenced by the itinerant work of many post-docs.

Engineering’s essential contributions to medical advances, such as imagery, should be highlighted. Before biology discovered quantitative tools enabled by engineering, it was mostly taxonomy.

Consider the microeconomic issues. What would NSF do with another $200m? Would the funds support more people or more capital investment? What would the balance be? What is the correlation between research funding and the output of human capital? Depends on the field to some extent. In nanotechnology, tools are expensive so building capacity is expensive. Balance is different in other fields, but regardless of field, sustained development of human capital requires investment.

Development of human capital must include life-long learning for engineers already in the workforce.

Open courseware at MIT and a few other schools is a way to improve curricula everywhere, but it could also drive further off-shoring.

How much investment is enough? Federal investment in research, including engineering research, has been going up. Some of the investment in life sciences funds engineering research; for instance, half the research engineering funding at Pitt comes from NIH. Yes, but overall, the excess investment in life sciences has caused distortion at research universities in capital investments, infrastructure development, which has been amplified by cuts in state funding.

Primary audience is Congress, particularly Congressional appropriators and their staffs. What problems does Congress perceive and what engineering can do to solve them?

Just calling for more money will not be effective. A device is needed. The Engineering Research Centers were such a device in the 1980s. A grand challenge could be the required device, or a call for a new institution.

Rather than focusing on the importance of enhanced federal investment in engineering research and education, why don't we instead focus on the investments needed to preserve out nation's leadership in innovation.

Our ability to innovate has been not only a hallmark for the nation, but for the past decade it has been the key to our global economic competitiveness. Technological innovation will also be the key to address some of the most compelling challenges and opportunities faced by our society (e.g., global sustainability).

Our national leadership in innovation is derived in part from our American culture, characterized by openness, democratic values, and a market economy.

Focusing on innovation is a way to distinguish between engineering and science. Also a way to get Congressional interest, emphasizing current risks to U.S. ability to sustain innovation and specific opportunities to apply innovation to national needs.

Success will require strong industry support. Industry is already involved in key advocacy efforts such as the Science Coalition and ASTRA. Industry recognizes their dependency on sustained innovation.

What is the definition of engineering research? ABET has a definition. Kristina suggested, "Engineers solve problems important to society." NAE used the following definition in 1995: "Basic research in engineering is …concerned with the discovery and systematic conceptual structuring of knowledge. Engineers develop, design, produce or construct, and operate devices, structures, machines, and systems of economic and societal value. Virtually all engineering research is driven by the anticipated value of an application."[1]

This committee's mandate is broader than NSF. If arguments that increased investments are needed to sustain American innovation, and that sustaining innovation is essential to maintain America's place in the world, then the role of NSF in achieving the needed results should be evident.

Final consensus is that sustaining innovation should be the keystone for the committee's report. A message corresponding to the following diagram, discussed and modified during the meeting,

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[1] NAE, *Forces Shaping the U.S. Academic Engineering Research Enterprise*, 1995.

will be the basis for initial outline development. A fairly detailed outline will be developed in the coming weeks for discussion and refinement at the next meeting.