Free Executive Summary

Educating the Engineer of 2020: Adapting Engineering Education to the New Century

Committee on the Engineer of 2020, Phase II, Committee on Engineering Education, National Academy of Engineering

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Educating the Engineer of 2020: Adapting Engineering Education to the New Century Phase I in the "Engineer of 2020" project, "Visions of Engineering in the New Century," described a set of attributes that are expected to be necessary for engineers that will perform well in a world that is driven by rapid technological advancement, national security needs, aging infrastructure in developed countries, environmental challenges brought about by population growth and diminishing resources, and the creation of new disciplines that exist at the interfaces between engineering and science. These attributes call for us to educate technically proficient engineers who are broadly educated, see themselves as global citizens, can be leaders in business and public service, and who are ethically grounded. This Phase II report provides a suite of recommendations that can guide engineering educators, employers of engineers, professional societies, and government agencies in their efforts to engage and reengineer the "system of systems" that are part of the engineering education process.

Executive Summary

This report is the result of an initiative of the National Academy of Engineering that attempts to prepare for the future of engineering by asking the question, "What will or should engineering education be like today, or in the near future, to prepare the next generation of students for effective engagement in the engineering profession in 2020?" It accepts as a given that, first and foremost, engineering education must produce technically excellent and innovative graduates, but it does not attempt to define a "core" curriculum, recognizing that individual institutions need to design their own. It asks, rather, how to enrich and broaden engineering education so that those technically grounded graduates will be better prepared to work in a constantly changing global economy. It notes the importance of improving the recruitment and retention of students, and making the learning experience more meaningful to them. It discusses the value of considering changes in engineering education in the broader context of enhancing the status of the engineering profession and improving the public understanding of engineering.

Although the report comments on education beyond the baccalaureate, its primary focus is undergraduate education, not the academic engineering research enterprise. The success of academic engineering research is undeniable. It helped shape this nation's industrial capabilities and it continues to do so in an increasing degree as more complex products and systems based on advanced technologies are emerging in

the marketplace and in the social and economic infrastructure. Many of the most hi-tech companies have been spun off from university research. The end of the Cold War and the shift from defense work has put pressure on university research to accept funding from industry for shorter term product- or process-oriented research. Meanwhile, industry has decreased its own in-house fundamental engineering research, making it even more important that universities conduct advanced basic research. Thus, this is a part of the engineering education infrastructure that must be preserved, but, at the same time, it must not lead to the neglect of the undergraduate engineering education experience. Indeed, if domestic engineering students are energized by their undergraduate education experience, it will enhance the possibility that they will be retained and graduate as engineers *and* aspire to advanced degrees through the academic engineering research enterprise.

In response to the issues facing undergraduate engineering education, the committee presents a suite of recommendations in this report, including the following:

- The B.S. degree should be considered as a preengineering or "engineer in training" degree.
- Engineering programs should be accredited at both the B.S. and M.S. levels, so that the M.S. degree can be recognized as the engineering "professional" degree.
- Institutions should take advantage of the flexibility inherent in the EC2000 accreditation criteria of ABET, Incorporated (previously known as the Accreditation Board for Engineering and Technology) in developing curricula, and students should be introduced to the "essence" of engineering early in their undergraduate careers.
- Colleges and universities should endorse research in engineering education as a valued and rewarded activity for engineering faculty and should develop new standards for faculty qualifications.
- In addition to producing engineers who have been taught the advances in core knowledge and are capable of defining and solving problems in the short term, institutions must teach students how to be lifelong learners.
- Engineering educators should introduce interdisciplinary learn-

ing in the undergraduate curriculum and explore the use of case studies of engineering successes and failures as a learning tool.

- Four-year schools should accept the responsibility of working with local community colleges to achieve workable articulation[1] with their two-year engineering programs.
- Institutions should encourage domestic students to obtain M.S. and/or Ph.D. degrees.
- The engineering education establishment should participate in efforts to improve public understanding of engineering and the technology literacy of the public and efforts to improve math, science, and engineering education at the K-12 level.
- The National Science Foundation should collect or assist collection of data on program approach and student outcomes for engineering departments/schools so that prospective freshman can better understand the "marketplace" of available engineering baccalaureate programs.

The report is grounded by the observations, questions, and conclusions presented by the Phase I report, *The Engineer of 2020: Visions of Engineering in the New Century.* That report begins with a review of the likely technological changes and challenges that will impact the world and the engineering profession. It notes that a dramatic expansion of knowledge is expected that offers exciting opportunities for engineering to develop new technologies to address the problems faced by society. It addresses the societal, geopolitical, and professional context within which engineering and its new technologies will exist. It notes that the coming era will be characterized by rapid population growth, which will contain internal dynamics that may affect world stability as well as the types of problems engineers will face. Growth will be concentrated in less developed countries where a "youth bulge" will occur, whereas in advanced countries the population will age. Issues related to improving quality of life through advanced technologies in some countries will be

[1]Articulation agreements establish rules that govern transfer credits that students earn at one institution (typically the community college) and are recognized and accepted by the partner institution (typically a four-year institution) for particular major courses of study.

contrasted with more basic problems such as access to water and housing in others. Within countries, the demographics will change, including in the United States, where the numbers of minorities will grow rapidly whereas those of the traditional majority will decline in a relative sense. This has major implications for the future of engineering, a profession where minorities and women remain underrepresented.

Although certain basics of engineering will not change, the explosion of knowledge, the global economy, and the way engineers will work will reflect an ongoing evolution that began to gain momentum a decade ago. The economy in which we will work will be strongly influenced by the global marketplace for engineering services, evidenced by the outsourcing of engineering jobs, a growing need for interdisciplinary and system-based approaches, demands for new paradigms of customization, and an increasingly international talent pool. The steady integration of technology in our public infrastructures and lives will call for more involvement by engineers in the setting of public policy and in participation in the civic arena. The external forces in society, the economy, and the professional environment will all challenge the stability of the engineering workforce and affect our ability to attract the most talented individuals to an engineering career. However, amid all these challenges, exciting opportunities also will exist if the engineering community takes the initiative to prepare for the future.

If the United States is to maintain its economic leadership and be able to sustain its share of high-technology jobs, it must prepare for this wave of change. Although there is no consensus at this stage, it is agreed that innovation is the key and engineering is essential to this task; but engineering will only contribute to success if it is able to continue to adapt to new trends and provide education to the next generation of students so as to arm them with the tools needed for the world as it will be, not as it is today. It is within this context that this Phase II report considers recommendations for changes in engineering education.

Reinventing engineering education requires the interaction of engineers in industry and academe. The entire engineering enterprise must be considered so that the changes made result in an effective system. Because most engineers work in industry and do not interact one-on-one with people who directly benefit from their services, as do physicians, lawyers, and teachers, the public is unclear about what most engineers do, and secondary students (and their parents and advisors) have poorly formed ideas about what an engineering education offers and

how they can serve society through engineering practice. Engineering needs to develop iconic images that the public immediately recognize and respond to in a positive way. Those "icons" should include simple images of the options for engineering education, their implications for future career paths, and the image of a person who never stops learning.

This report is intended to begin a dialog about reinventing engineering education, but it makes recommendations that are broader than the curricular challenges indicated in the Phase I report. In the spirit of considering engineering education as a system and as part of a system of systems, consideration is given herein to important factors such as improving the public's understanding of engineering, its technological literacy, and K-12 education, which can have an important but indirect effect on engineering in terms of encouraging secondary school students to consider an engineering education and preparing them intellectually so that an engineering education is accessible to them.