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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Executive Summary

This report is a 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.

While 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 BS degree should be considered as a pre-engineering or "engineer in training" degree.
- Engineering programs should be accredited at both the BS and MS levels, so the MS degree can be recognized as the engineering "professional" degree.
- Institutions should take advantage of the flexibility inherent in the ABET EC2000 accreditation criteria 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.
- That, 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 learning 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 2-year engineering programs.
- Institutions should encourage domestic students to obtain the MS and/or PhD 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.
- NSF should collect or assist collection of data on program approach and student outcomes for engineering departments/schools so 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, while in advanced countries the population will age. Issues related to improving quality of life through advanced technologies in some countries will be contrasted with more basic problems like access to water and housing in others. Within countries the demographics will change, including in the U.S., where the numbers of minorities will grow rapidly while 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 under-represented.

While certain basics of engineering will not change, the explosion of knowledge, the global economy and the way engineers will work will reflect an on-going 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

[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.

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. But, 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. While 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 which 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 public understanding of engineering, technology literacy of the public 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.

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NOTICE: To arrive at the findings and recommendations of this report, the National Academy of Engineering has used a process that involves careful selection of a balanced and knowledgeable committee, assembly of relevant information and peer review of the resultant report. Over time, this process has proven to produce authoritative and balanced results.

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NORMAN FORTENBERRY, Director, Center for the Advancement of Scholarship in Engineering Education
NATHAN KAHL, Project Assistant
PROCTOR REID, Director, Program Office

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This report was reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Academies. The purpose of this independent review is to provide candid and critical comments that will assist the authoring committee and the NAE in making he published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the charge for this activity. The contents of the review comments and draft manuscripts remain confidential to protect the integrity of the deliberative process.

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Preface

The Engineer of 2020 Project centers on an effort to envision the future two decades from now, to use this knowledge in an attempt to predict the roles engineers will play in the future and to position engineering education in the United States for what lies ahead, rather than waiting for time to pass and then trying to respond. It is driven by concern that engineering students of today may not be appropriately educated to meet the demands that will be placed on the engineer of 2020 and that, without refocusing and reshaping the undergraduate engineering learning experience, America's engineering preeminence could be lost. It takes as a given that the nation's societal goals will not be met absent a robust engineering community in the country. It asks what restructuring of program, reallocation of resources and refocusing of faculty and professional society time and energy are required so that our educational infrastructure can educate engineers prepared to tackle the challenges of the future. It questions how we can more effectively share with students– current and potential– our passion for designing systems, structures and devices to solve problems and our conviction that engineering is a profession that offers rich rewards for serving the interest of society.

In addressing a Summit on Engineering Education held in conjunction with this project in July of 2004, MIT President Charles Vest encouraged the assembled educators and stakeholders to think about the students when considering how the engineering education system should be re-engineered by stating, "This is the most exciting period in human history for science and engineering. The explosive advances in knowledge, instrumentation, communication, and computational capabilities create a mind-boggling playing field for the next generation….As we think about the plethora of challenges, it is important, in my view, to remember that students are driven by passion, curiosity, engagement and dreams….Despite our best efforts to plan their education, to a large extent we simply help to wind them up, and then step back to watch the amazing results." Gretchen Kalonji, Professor of Materials Science and Engineering at the University of Washington, expanded on Vest's desire to engage the passion and curiosity of students stating that "[a]s we move forward, I think we need to undertake a far more bold re-formulation of engineering education. Bluntly speaking, with existing models, we are losing the battle for the imagination of our youth….What I would argue for is a dramatic and fundamental transformation of the educational process."

Originated and chartered by the Committee on Engineering Education (CEE) of the National Academy of Engineering, the Engineer of 2020 project consists of two parts, the first related to the development of a vision for engineering and the work of the engineer in 2020. A report of the first phase was published in the Spring of 2004. The second part, the subject of this report, is to examine engineering education, in the broadest context, and ask what it needs to do to enrich the education of engineers who will practice in 2020. This initiative is not unique in that other groups have somewhat similar efforts underway or have recently completed them. The work of the National Academy of Engineering differs in that it considers the issues with respect to all the diverse branches of engineering and examines them from the broadest possible perspective. Its principal focus is on the future of undergraduate engineering education in this country, although it is appreciated that to understand the full perspective, engineering practice and engineering education must be considered within a global context.

A Steering Committee for the Phase II project was established in February 2004 by the NAE president to guide the work. The committee met in July of 2004, coincident with the Summit on

Engineering Education, which was held at the National Academies' Constitution Avenue location in Washington DC, attended by approximately 100 participants. As background information for the summit, a series of papers was prepared by education experts on a variety of subjects, including co-operative education, the NSF engineering education coalitions, the Olin College experience, diversity, the Greenfield Coalition, the Pedagogies of the Professions Program of the Carnegie Foundation, accreditation systems and the history of efforts to realign engineering education. These papers are included in Appendix A.

The Summit featured keynote addresses by Ruth David, Charles Vest (see Appendix B), Shirley Ann Jackson and Nicholas Donofrio and, between the plenary sessions of the Summit, five breakout groups met to allow more detailed and interactive discussions on various aspects of the engineering education system. The Summit agenda is in Appendix C.

Immediately following the workshop, the Steering Committee met to review the workshop discussions and was assigned the task of preparing this report. Final review of the report by the Steering Committee to critique its conclusions and recommendations was conducted by email.

It is notable that the Phase I report posits a statement of aspirations for the engineer of 2020 and closes with a statement of attributes thought suitable for the engineer of 2020 that match the aspirations. These aspirations and attributes express a bold optimism for the engineering profession if it is willing to confront the possibilities for the future and to prepare for it.

Ahead lays the challenge of debating and adopting where appropriate the recommendations of this report for adapting engineering education to the new century. The committee recognizes that "one size does not fit all" and has attempted to suggest a suite of interventions, not all of which will "work" in every institution. We expect that debate on these interventions will take place over the course of the coming year and we hope that their introduction into the engineering education infrastructure will rapidly follow so that today's students will indeed be prepared to practice engineering effectively in 2020.

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