

## Free Executive Summary



### **The Engineer of 2020: Visions of Engineering in the New Century**

National Academy of Engineering

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*To help maintain the nation's economic competitiveness and improve the quality of life of the world's population, engineering education in the United States must anticipate and adapt to dramatic changes in engineering practice in the coming decades, says a new National Academy of Engineering report. The report recommends ways to improve engineers' training and prepare them for the complex technical, social and ethical questions raised by emerging technologies.*

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## Executive Summary

In the past, changes in the engineering profession and engineering education have followed changes in technology and society. Disciplines were added and curricula were created to meet the critical challenges in society and to provide the workforce required to integrate new developments into our economy. Today's landscape is little different; society continually changes and engineering must adapt to remain relevant. But we must ask if it serves the nation well to permit the engineering profession and engineering education to lag technology and society, especially as technological change occurs at a faster and faster pace. Rather, should the engineering profession anticipate needed advances and prepare for a future where it will provide more benefit to humankind? Likewise, should engineering education evolve to do the same?

Technology has shifted the societal framework by lengthening our life spans, enabling people to communicate in ways unimaginable in the past, and creating wealth and economic growth by bringing the virtues of innovation and enhanced functionality to the economy in ever-shorter product development cycles. Even more remarkable opportunities are fast approaching through new developments in nanotechnology, logistics, biotechnology, and high-performance computing. At the same time, with tightening global linkages, new challenges and opportunities are emerging as a consequence of rapidly improving technological capabilities in such nations as India and China and the threat of terrorism around the world.

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 be like in 2020?” Will it be a reflection of the engineering of today and its past growth patterns or will it be fundamentally different? Most importantly, can the engineering profession play a role in shaping its own future? Can a future be created where engineering has a broadly recognized image that celebrates the exciting roles that engineering and engineers play in addressing societal and technical challenges? How can engineers best be educated to be leaders, able to balance the gains afforded by new technologies with the vulnerabilities created by their byproducts without compromising the well-being of society and humanity? Will engineering be viewed as a foundation that prepares citizens for a broad range of creative career opportunities? Will engineering reflect and celebrate the diversity of all the citizens in our society? Whatever the answers to these questions, without doubt, difficult problems and opportunities lie ahead that will call for engineering solutions and the talents of a creative engineering mind-set.

Because precise predictions of the future are difficult at best, the committee approached its charge using the technique of scenario-based planning. The benefit of the scenario approach was that it eliminated the need to develop a consensus view of a single future and opened thinking to include multiple possibilities. This technique has proven its worth for private and public entities alike in helping devise flexible strategies that can adapt to changing conditions. Specific scenarios considered in this project were (1) The Next Scientific Revolution, (2) The Biotechnology Revolution in a Societal Context, (3) The Natural World Interrupts the Technology Cycle, and (4) Global Conflict or Globalization? The story form of each scenario is presented in Appendix A. These sometimes colorful versions only partially capture the vigorous discussions and debates that took place, but they serve to illustrate and document the thinking involved in the process. Each in its own way informed the deliberations about possibilities that can shape the role that engineering will play in the future.

The “next scientific revolution” scenario offers an optimistic future where change is principally driven by developments in technology. It is assumed that the future will follow a predictable path where technologies that are on the horizon today are developed to a state where they can be used in commercial applications and their role is optimized to the

benefit of society. As in the past, engineers will exploit new science to develop technologies that benefit humankind, and in others they will create new technologies *de novo* that demand new science to fully understand them. The importance of technology continues to grow in society as new developments are commercialized and implemented.

The “biotechnology revolution” scenario speaks to a specific area of science and engineering that holds great potential but considers a perspective where political and societal implications could intervene in its use. In this version of the future, issues that impact technological change beyond the scope of engineering become significant, as seen in the current debate over the use of transgenic foods. While the role of engineering is still of prime importance, the impact of societal attitudes and politics reminds us that the ultimate use of a new technology and the pace of its adoption are not always a simple matter.

The “natural world” scenario recognizes that events originating beyond man’s control, such as natural disasters, can still be a determinate in the future. While in this case the role of future engineers and new technologies will be important to speeding a recovery from a disastrous event, it also can help in improving our ability to predict risk and adapt systems to prepare for the possibilities to minimize impact. For example, there is the likely possibility that computational power will improve such that accurate long-range weather predictions will be possible for relatively small geographic areas. This will allow defensive designs to be developed and customized for local conditions.

The final scenario examines the influence of global changes, as these can impact the future through conflict or, more broadly, through globalization. Engineering is particularly sensitive to such issues because it speaks through an international language of mathematics, science, and technology. Today’s environment, with issues related to terrorism and job outsourcing, illustrates why this scenario is useful to consider in planning for the future.

The body of the report begins in Chapter 1 with a review designed to set the stage for likely future technological changes and challenges that will impact the world and the engineering profession. Dramatic expansion of knowledge is expected that will offer exciting opportunities for engineering to develop new technologies to address the problems faced by society. The impact will be seen in medical breakthroughs, new energy devices, materials with characteristics not available today, remarkable light sources, and next-generation computers and tele-

communications developments. Engineering has contributed enormously to the quality of life we enjoy today, and the opportunities for the future are likely to be ever greater. The challenges include, among others, deteriorating infrastructure, environmental issues, and providing housing, water, and health care for a rapidly growing population.

Chapter 2 addresses the societal, geopolitical, and professional contexts within which engineering and its new technologies will exist. The coming era will be characterized by rapid population growth, which will contain internal dynamics that affect the types of problems engineers will face as well as world stability. 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 quality of life in some countries will be contrasted with more basic problems like access to water and housing in others. Within countries the demographics will change, particularly in the United States, 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 underrepresented.

While certain basics of engineering will not change, 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, a growing need for interdisciplinary and system-based approaches, demands for customerization, and an increasingly diverse talent pool. The steady integration of technology in our infrastructure and lives calls 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 pose imperatives for change that may exceed those to come from the changes expected in the technology engineers will have at their disposal in 2020. Challenges will abound, but opportunities also will exist if engineering takes the initiative to prepare for the future.

Chapter 3 builds on the context of the earlier chapters with a statement of aspirations for engineering in 2020. Its purpose is to identify those basic themes we can agree are worth striving for if engineering is to be a positive force in the future. The range of possibilities as contrasted with the realities makes this no easy task. As illustrated by the scenarios, they can be constrained by outside forces as well as by our own inaction. The aspirations chosen set the bar high but are believed

to be attainable if a course of action is set to reach them. At their core they call for us to educate engineers who are broadly educated, who see themselves as global citizens, who can be leaders in business and public service, and who are ethically grounded.

Chapter 4 takes the aspirations a step further by setting forth the attributes needed for the graduates of 2020. These include such traits as strong analytical skills, creativity, ingenuity, professionalism, and leadership.

This study suggests that if the engineering profession is to take the initiative in defining its own future, it must (1) agree on an exciting vision for its future; (2) transform engineering education to help achieve the vision; (3) build a clear image of the new roles for engineers, including as broad-based technology leaders, in the mind of the public and prospective students who can replenish and improve the talent base of an aging engineering workforce; (4) accommodate innovative developments from nonengineering fields; and (5) find ways to focus the energies of the different disciplines of engineering toward common goals.

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 a new 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 educate 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.



# THE ENGINEER OF 2020

## VISIONS OF ENGINEERING IN THE NEW CENTURY

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## Preface

The Engineer of 2020 Project centers on an effort to envision the future and to use that knowledge to attempt to predict the roles that engineers will play in the future. While of interest in itself, the exercise is also intended to provide a framework that will be used in subsequent work to position engineering education in the United States for what lies ahead, rather than waiting for time to pass and then trying to respond. This initiative is not unique in that other groups have somewhat similar efforts under way or have recently completed them. The work of the National Academy of Engineering (NAE) 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 in a global context.

Originated and chartered by the NAE's Committee on Engineering Education, the project consists of two parts, the first relating to the development of a vision for engineering and the work of the engineer in 2020. This phase of the work culminates with this report. The second part, which is yet to be completed, is to examine engineering education and ask what it needs to do to prepare engineers for the future. This report will be used to frame the discussions of the second phase.

A steering committee for the project was established in December 2001 by the NAE president to guide the work. The committee met four times over the course of the following year and developed a plan for a three-day workshop on the future of engineering that was held in Woods Hole, Massachusetts, in fall 2002. Thirty-five participants took part in the workshop representing a range of different disciplines, age groups, and points of view (see Appendix B). Keynote addresses were given by Phil Condit, Bran Ferren, and Shirley Ann Jackson.

At the outset it was agreed that predicting the future with any exactitude is not possible. Hence, scenario-based strategic planning was used to help the participants think broadly about events and issues that could shape the future. Peter Schwartz, a well-known author and strategic planning consultant, served as moderator and facilitator. During the course of the workshop, four scenarios were considered, each of which was thought to capture trends that could dramatically affect the way the future would unfold. All of the scenarios recognized that pending breakthroughs in technology from fields like nanotechnology, biotechnology, materials, computing, and logistics would be factors engendering change regardless of other conditions. It was understood that 2020 might reflect any one of the scenarios, some combination of them, or none of them. Their purpose was primarily realized through the process, which helped expand our appreciation of possibilities for the future and assisted in thinking about the future of engineering in these terms. The scenarios examine transformational changes that could derive from life-altering developments across several technological fronts, dramatic breakthroughs in biotechnology, a major natural disaster, and world division driven by growth in religious fundamentalism.

After the workshop, members of the steering committee were assigned the task of writing the report. A final meeting of the committee was held in December 2002 to critique the work of the writing groups. The final draft report was informed using the workshop keynote presentations, discussions, and scenarios as well as a steering committee consensus about new technologies that are likely to significantly influence the future course of engineering. Following the last meeting, a smaller group of the steering committee took on the task of editing the report for publication.

It is notable that this 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. The final two

chapters express a bold optimism for the engineering profession if it is willing to confront the possibilities for the future and prepare for it.

Ahead lies the challenge of considering what engineering students should learn in the university to prepare for the future and how this might differ from what is taught today. This effort will take place over the course of the coming year through a new workshop and continuing work of the steering committee.



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