THE ENGINEER OF 2020

VISIONS OF ENGINEERING IN THE NEW CENTURY

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Aspirations for the Engineer of 2020

Throughout the ages humankind has sought to divine the future, in the past by consulting the Delphic oracle, today by creating massive computer models. However, life has a habit of reminding us that our predictions are rarely accurate. Despite the fickle nature of events over time, two constants persist. One is that we continue to prepare ourselves for an uncertain future as we always have, and the second is a steady growth of the influence of technology in our lives.

Engineering, through its role in the creation and implementation of technology, has been a key force in the improvement of our economic well-being, health, and quality of life. Three hundred years ago the average life span was 37 years, the primary effort of the majority of humans was focused on provisioning their tables, and the threat of sudden demise due to disease was a lurking reality (Kagan et al., 2001). Today, human life expectancy is approaching 80 years in many parts of the world as fundamental advances in medicine and technology have greatly suppressed the occurrence of and mortality rates for previously fatal diseases and the efforts of humankind are focused largely on enhanced quality of life (Central Intelligence Agency, 2001). Only 150 years ago travel from the East Coast of the United States to the West Coast entailed a hazardous journey that took months to accomplish. Weeks were needed to transmit a letter from one coast to the other. Today, in the developed world, we take it for granted that transportation is affordable and reliable, good health care is accessible, information

and entertainment are provided on call, and safe water and healthy food are readily available.

To be sure, there have also been negative results of technology. Pollution, global warming, depletion of scarce resources, and catastrophic failures of poorly designed engineering systems are examples. Overall, however, engineers and their inventions and innovations have helped shape the changes that have made our lives more productive and fruitful.

With the prospect of the exciting new developments expected to come from such fields as biotechnology, nanotechnology, and high-performance computing, the year 2020 can be a time of new choices and opportunities. The years between the present and 2020 offer engineering the opportunity to strengthen its leadership role in society and to define an engineering career as one of the most influential and valuable in society and one that is attractive for the best and the brightest. If we are to take full advantage of this opportunity, it is important to engage all segments of the population in a vigorous discussion of the roles of engineers and engineering and to establish high aspirations for engineers that reflect a shared vision of the future.

VISIONS OF THE COMMITTEE

Our Image and the Profession

Without engineers working both in technical endeavors and as leaders who serve in industry, government, education, and nonprofit organizations, progress would stagnate. Engineering offers men and women an unparalleled opportunity to experience the joy of improving the quality of life for humankind through development of engineering solutions to societal problems. Many engineers pursue career paths in fields that are traditionally defined as engineering. However, a significant number use their engineering backgrounds as points of departure into other fields such as law, medicine, and business. The opportunities offered by an engineering education are multifold, and this is not fully realized by young people, their parents, counselors, mentors, and the public at large.

By 2020, we aspire to a public that will understand and appreciate the profound impact of the engineering profession on sociocultural systems, the full spectrum of career opportunities accessible through an engineering education, and the value of an engineering education to engineers working successfully in nonengineering jobs.

While engineering is a rapidly evolving field that adapts to new knowledge, new technology, and the needs of society, it also draws on distinct roots that go back to the origins of civilization. Maintaining a linkage of the past with the future is fundamental to the rational and fact-based approaches that engineers use in identifying and confronting the most difficult issues.

We aspire to a public that will recognize the union of professionalism, technical knowledge, social and historical awareness, and traditions that serve to make engineers competent to address the world's complex and changing challenges.

Engineering must be grounded in the fundamental principles of science and mathematics. This foundation supports the development of new knowledge and the creation of safe, reliable, and innovative technologies that advance society and the human condition. Solutions of societal problems require that these technologies be applied in innovative ways with consideration of cultural differences, historical perspectives, and legal and economic constraints, among other issues.

We aspire to engineers in 2020 who will remain well grounded in the basics of mathematics and science, and who will expand their vision of design through a solid grounding in the humanities, social sciences, and economics. Emphasis on the creative process will allow more effective leadership in the development and application of next-generation technologies to problems of the future.

Engineering Without Boundaries

Engineering has shown itself to be responsive to technological breakthroughs from within engineering and from other fields, although not always in the most timely fashion. From its first two subbranches, military and civil, it expanded early on in recognition of developments that led to mining, mechanical, chemical, electrical, and industrial engineering. This process has continued and is evidenced recently by the introduction of biomedical and computer engineering.

We aspire to an engineering profession that will rapidly embrace the potentialities offered by creativity, invention, and cross-disciplinary fertilization to create and accommodate new fields of endeavor, including those that require openness to interdisciplinary efforts with nonengineering disciplines such as science, social science, and business.

With technology becoming ever more pervasive in society, it is incumbent on the engineering profession to lead in shaping the ultimate use of technology and the government processes that control, regulate, or encourage its use.

By 2020 we aspire to engineers who will assume leadership positions from which they can serve as positive influences in the making of public policy and in the administration of government and industry.

The success of engineering is based on a deep reservoir of talented people. In the United States this wellspring has been nourished principally by drawing from a white male population.

We aspire to an engineering profession that will effectively recruit, nurture, and welcome underrepresented groups to its ranks.

Engineering a Sustainable Society and World

The world faces significant environmental challenges in the future. At the same time there is great opportunity for engineering to serve as a force to help society solve the problems associated with these challenges. This requires a holistic understanding of economic growth and development in terms of the principles of sustainability. The present generation has the obligation to leave a legacy to those who follow so they can have the opportunity to appreciate the unrestrained beauty of nature, the full diversity of the world's flora and fauna, and ancient and modern cultures and their artifacts.

It is our aspiration that engineers will continue to be leaders in the movement toward use of wise, informed, and economical sustainable development. This should begin in our educational institutions and be founded in the basic tenets of the engineering profession and its actions.

Advances in communications, travel, and economics have created a world where no country is untouched by any other. In the United States the oceans that bound our coasts no longer insulate us from other nations. In this dynamic global economy and political environment, engineering must adjust to a new world view.

We aspire to a future where engineers are prepared to adapt to changes in global forces and trends and to ethically assist the world in creating a balance in the standard of living for developing and developed countries alike.

Education of the Engineer of 2020

Engineering education and its nature have been debated for many years. Change typically comes in waves, often following from forces outside the education establishment. Fallout from the surprising success of the launch of the Russian satellite *Sputnik* led to reinforcement of the "engineering science" paradigm. The impacts of the recession of the early 1980s and subsequent reconstitution of the competitiveness of American industry and the dramatic failure of the space shuttle *Challenger* in the mid-1980s aided the movement toward more attention to quality principles and communication and teamwork skills. Presently, it is important that engineering education be reconsidered in a futures-based approach driven from within engineering.

It is our aspiration that engineering educators and practicing engineers together undertake a proactive effort to prepare engineering education to address the technology and societal challenges and opportunities of the future. With appropriate thought and consideration, and using new strategic planning tools, we should reconstitute engineering curricula and related educational programs to prepare today's engineers for the careers of the future, with due recognition of the rapid pace of change in the world and its intrinsic lack of predictability.

It is appropriate that engineers are educated to understand and appreciate history, philosophy, culture, and the arts, along with the creative elements of all of these disciplines. The balanced inclusion of these important aspects in an engineering education leads to men and women who can bridge the "two cultures" cited by the author C.P. Snow (1998). In our increasingly technological society, this is more important now than in the 1950s when Snow identified the issue. The case can be made that an appropriately designed engineering curriculum today offers an education that is more well rounded than that obtained by students majoring in classical liberal arts, where technology is conspicuously absent from the field of study.

Our aspiration is to shape the engineering curriculum for 2020 so as to be responsive to the disparate learning styles of different student populations and attractive for all those seeking a full and well-rounded education that prepares a person for a creative and productive life and positions of leadership.

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Attributes of Engineers in 2020

We complete our discussion of the engineer of 2020 by reviewing the key attributes that will support the success and relevance of the engineering profession in 2020 and beyond. Our discussion is framed by certain guiding principles that will shape engineering activities, as follows:

- The pace of technological innovation will continue to be rapid (most likely accelerating).
- The world in which technology will be deployed will be intensely globally interconnected.
- The population of individuals who are involved with or affected by technology (e.g., designers, manufacturers, distributors, users) will be increasingly diverse and multidisciplinary.
- Social, cultural, political, and economic forces will continue to shape and affect the success of technological innovation.
- The presence of technology in our everyday lives will be seamless, transparent, and more significant than ever.

CONNECTIONS BETWEEN ENGINEERING PAST, PRESENT, AND FUTURE

Many of the key attributes of engineers in 2020 will be similar to those of today but made more complex by the impact of new tech-

nology. In reviewing these enduring attributes for engineers, we also identify the essential characteristics that connect engineering's past, present, and future. As with any profession, we also recognize the imperative to remain flexible and to embrace necessary changes that allow for constant success. These new-century reflections on engineers in 2020 are outlined below.

The word *engineer* has its roots in the Latin word *ingeniator*, which means ingenious, to devise in the sense of construct, or craftsmanship. Several other words are related to ingeniator, including *ingenuity*.

Engineers in 2020, like engineers of yesterday and today, will possess **strong analytical skills**. At its core, engineering employs principles of science, mathematics, and domains of discovery and design to a particular challenge and for a practical purpose. This will not change as we move forward. It has been stated in earlier sections that the core knowledge base on which engineers develop products and services may shift as technologies involving the life sciences, nanoscience, optical science, materials science, and complex systems become more prevalent. Also, information and communications technologies will be ubiquitous—embedded into virtually every structure and process and vital to the success and usefulness of all engineered products. Just as important will be the imperative to expand the engineering design space such that the impacts of social systems and their associated constraints are afforded as much attention as economic, legal, and political constraints (e.g., resource management, standards, accountability requirements). Engineers will also concentrate on systemic outcomes in the same ways that focused outcomes are considered. Even though the scientific knowledge that defines operating principles is expected to be more fluid and more complex, the core analysis activities of engineering design—establishing structure, planning, evaluating performance, and aligning outcomes to a desired objective—will continue.

Engineers in 2020 will exhibit **practical ingenuity**. The word *engineering* derives from *ingeniator* (Johnston et al., 2000). Yesterday, today, and forever, engineering will be synonymous with ingenuity—skill in planning, combining, and adapting. Using science and practical

ingenuity, engineers identify problems and find solutions. This will continue to be a mainstay of engineering. But as technology continues to increase in complexity and the world becomes ever more dependent on technology, the magnitude, scope, and impact of the challenges society will face in the future are likely to change. For example, issues related to climate change, the environment, and the intersections between technology and social/public policies are becoming increasingly important. By 2020 the need for practical solutions will be at or near critical stage, and engineers, and their ingenuity, will become ever more important.

Creativity (invention, innovation, thinking outside the box, art) is an indispensable quality for engineering, and given the growing scope of the challenges ahead and the complexity and diversity of the technologies of the 21st century, creativity will grow in importance. The creativity requisite for engineering will change only in the sense that the problems to be solved may require synthesis of a broader range of interdisciplinary knowledge and a greater focus on systemic constructs and outcomes.

As always, good engineering will require good **communication**. Engineering has always engaged multiple stakeholders—government, private industry, and the public. In the new century the parties that engineering ties together will increasingly involve interdisciplinary teams, globally diverse team members, public officials, and a global customer base. We envision a world where communication is enabled by an ability to listen effectively as well as to communicate through oral, visual, and written mechanisms. Modern advances in technology will necessitate the effective use of virtual communication tools. The increasing imperative for accountability will necessitate an ability to communicate convincingly and to shape the opinions and attitudes of other engineers and the public.

In the past those engineers who mastered the principles of **business and management** were rewarded with leadership roles. This will be no different in the future. However, with the growing interdependence between technology and the economic and social foundations of modern society, there will be an increasing number of opportunities for engineers to exercise their potential as leaders, not only in business but also in the nonprofit and government sectors. Policy decisions in technological societies will demand the attention of leaders who understand the strengths and limitations of science and technology. New levels of sophistication will be needed as choices that affect physical, human,

and political infrastructures and decisions that define priorities and objectives for a community, region, or nation are made.

In preparation for this opportunity, engineers must understand the principles of **leadership** and be able to practice them in growing proportions as their careers advance. They must also be willing to acknowledge the significance and importance of public service and its place in society, stretching their traditional comfort zone and accepting the challenge of bridging public policy and technology well beyond the roles accepted in the past.

Complementary to the necessity for strong leadership ability is the need to also possess a working framework upon which **high ethical standards** and a strong sense of **professionalism** can be developed. These are supported by boldness and courage. Many of the challenges of the new century are complex and interdependent and have significant implications for the technologies intended to address them and the ways in which those technologies affect the planet and the people that live here. Effective and wise management of technological resources is integral to engineering work. The choices will be gray in nature, balancing (for example) economic, social, environmental, and military factors. Leaders, and those who influence these choices, will benefit from a sense of purpose and clarity. Successful engineers in 2020 will, as they always have, recognize the broader contexts that are intertwined in technology and its application in society.

Given the uncertain and changing character of the world in which 2020 engineers will work, engineers will need something that cannot be described in a single word. It involves **dynamism, agility, resilience,** and **flexibility**. Not only will technology change quickly, the social-political-economic world in which engineers work will change continuously. In this context it will not be this or that particular knowledge that engineers will need but rather the ability to learn new things quickly and the ability to apply knowledge to new problems and new contexts.

Encompassed in this theme is the imperative for engineers to be **lifelong learners**. They will need this not only because technology will change quickly but also because the career trajectories of engineers will take on many more directions—directions that include different parts of the world and different types of challenges and that engage different types of people and objectives. Hence, to be individually/personally successful, the engineer of 2020 will learn continuously throughout his

or her career, not just about engineering but also about history, politics, business, and so forth.

What attributes will the engineer of 2020 have? He or she will aspire to have the ingenuity of Lillian Gilbreth, the problem-solving capabilities of Gordon Moore, the scientific insight of Albert Einstein, the creativity of Pablo Picasso, the determination of the Wright brothers, the leadership abilities of Bill Gates, the conscience of Eleanor Roosevelt, the vision of Martin Luther King, and the curiosity and wonder of our grandchildren.

Lillian Gilbreth is known as the Mother of Ergonomics, a branch of engineering devoted to fitting the workplace to the worker. Ergonomics involves the application of knowledge about human capacities and limitations to the design of workplaces, jobs, tasks, tools, equipment, and the environment. Gilbreth's approach transformed the engineering activity by introducing a primary focus on human needs and capacities. She was recognized for her contributions by being the first woman elected to the National Academy of Engineering in 1966.

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Epilogue

The engineer of 2020 and beyond will face a bewildering array of new technologies, appearing at a rate that will bring his or her professional qualifications constantly near obsolescence. The engineering community will face a world which is more connected than today, requiring both social and political acumen to navigate the changing world conditions. The particular factors that will dominate engineering practice and require reform of engineering education are not predictable, although an array of possible factors is already evident. This report lays out those factors the committee deemed most plausible to have an impact and thus creates a framework of issues that it believes must be considered in a discussion of the action steps for engineering education. That discussion is the subject of Phase II of this project.

A vision of the future engineer is provided by the aspirations and attributes listed in Chapters 3 and 4. These aspirations describe engineers who are broadly educated, see themselves as global citizens, can lead in business and public service, as well as in research, development and design, are ethical and inclusive of all segments of society. The attributes include strong analytical skills, creativity, ingenuity, professionalism, and leadership. We believe that engineers meet these aspirations and evidence these attributes today. The issue is how we can ensure that the engineering profession and engineering education adopt a collective vision including these aspirations and encouraging creation of an environment that promotes these attributes and aspirations in the future.