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LAST WORD

RE-ENGINEERING ENGINEERING

21st-century needs can't be met with just a four-year degree.

By Norman R. Augustine[1]

Distance is Dead.

So wrote Frances Cairncross in The Economist. One consequence is that routine engineering has become a commodity. There will never again be a shortage of engineers in America to perform routine engineering functions. Such work will simply be shipped abroad — at the speed of light — to the hordes of engineers now being produced in several other countries. China, for example, is now graduating more English-speaking engineers than America. One can hire a half-dozen engineers in India for the cost of one in America.

But there will always be demand for superbly educated engineers who are capable of performing in an innovative, creative, and entrepreneurial fashion. It is upon these individuals, together with those who create fundamental new knowledge, that 21st-century society will depend to a very large degree to solve looming problems in energy, the environment, national security, healthcare, and the economy. Although only 4 percent of today's U.S. workforce is composed of engineers and scientists, that 4 percent disproportionately creates jobs for the other 96 percent.

Unfortunately, the traditional engineering education is in some respects not well suited to the challenges of the 21st-century global economy. The highly compartmentalized, discipline-oriented, almost exclusively technical focus embraced by many 21st-century engineering schools served us extremely well in the past. This is in spite of the fact that nearly two thirds of those who pursued an engineering education abandoned the effort. Worse yet, women, making up well over half the college enrollment, produced only 20 percent of the engineers, with minority students even less well represented. But despite these major talent gaps, America's engineering schools were justifiably viewed as the best in the world. And therein lies the problem. As the provost of MIT once told me, speaking of making change in that institution, "You don't understand how difficult it is to overcome 100 years of excellence and success."

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But if change is in order, what might be some of the ingredients of a 21st-century engineering education? The following is the view of but one person, but one who not long ago had 62,000 engineers working for him:

Ingredients of a 21st-Century Engineering Education

- A solid understanding of the fundamental laws of nature — physics and chemistry — along with a corresponding understanding of the "language" of engineering and science: mathematics. These subjects are the sine qua non of a sound engineering education.
- Deep exposure to the concepts of design and analysis, especially the conduct of trade-offs. That is, a strong understanding of engineering itself.

Other nations will absorb routine engineering tasks. America's engineers must be superbly trained, innovative and entrepreneurial.

- Exposure to the actual practice of engineering in the freshman year, in part to reduce the number of students who abandon the field without ever having been exposed to engineering activities.
- Knowledge of lessons learned from real-world engineering projects of the past, especially those embodying failure. Call it "Scar Tissue 101"… without pain!
- Familiarity with at least the rudiments of systems engineering, both technical and nontechnical, including making trades that involve nonquantifiable aspects.
- Consideration of the techniques of operations analysis, underpinned by a grounding in probability and statistics.
- Exposure to modern biosciences, which increasingly permeate almost all fields of engineering.
- Understanding of the fundamentals of economics at both the macro and individual-business levels. Economic considerations play an ever increasing role in what engineers do — and what they don't do. The supersonic transport, the superconducting supercollider, and the mission to Mars are examples of the latter.
- A basic understanding of public policy, government, and history — without which tomorrow's engineers can expect to have little influence over the destiny of their profession. It is noteworthy that in China, eight of the top nine political leaders are engineers.
- An exposure to literature, art, and music, not simply for self-satisfaction — which is important — but also because not everyone in this world reads Popular Mechanics.
- Experience in writing and speaking effectively, so as to correct the greatest shortcoming of today's engineers. Somehow, (we) engineers have never quite accepted the notion that every sentence deserves a subject and a verb!
- Opportunity to work as a team. While there is still a role for the Edisons and Bells of the world, the great majority of 21st-century engineers will find themselves working as part of highly diverse teams.
- At least a semester of studying abroad, learning to become comfortable interacting with individuals from vastly different cultures.
- Opportunity to explore, challenge, and innovate. This has been a traditional strength of American engineering education and will become increasingly important. It is noteworthy that toleration of occasional failure, as long as it is not the result of negligence, incompetence, or ethical failings, is an essential companion to risk-taking.

- Regarding engineering faculty, increased emphasis on, and rewards for, teaching. Research is an important aspect of teaching, in addition to being a valuable end in itself; but it is the balanced combination of teaching and research that has made America's research universities great. A modest "rebalancing" seems to be in order. (The third rail!)
- An appreciation of the role of ethics in engineering. Not necessarily the teachings of Socrates, Kant, or St. Augustine, but rather, the day-to-day, tough ethical decisions that engineers encounter as they pursue their responsibilities.

How are students going to do all this in four years? The answer is that they are not.

The accumulation of newly generated knowledge, coupled with the broader societal demands on a 21st-century engineer, is such that the master's degree must become the primary degree of the engineering profession. It makes little sense that it takes more education to authorize my neighbor's cat's vaccination than it takes to design an aircraft or build a bridge or construct a nuclear power plant on which vast numbers of human lives will depend.

A few years ago, I was giving a lecture at a highly regarded U.S. "engineering" school and mentioned that I had been studying the requirements for a bachelor's degree in mechanical engineering stipulated in the catalogue. In addition to the conventional science, math, and engineering curriculum, the mandatory course work included six semesters of French or German, two semesters of English literature, and one semester each of rhetoric, English composition, U.S. history, European history, industrial history, political economics, business law, and the economics of corporations. I commended the school on this superb curriculum, and then pointed out that the catalogue I had been citing was for the year 1900! Perhaps if we want to leap forward, it is time to move backward.

Many countries are experimenting with new approaches to engineering education. In India, a private citizen is building a university offering a unique curriculum to support tens of thousands of students. The president of France has announced a major revamping of that country's institutions of higher education. Ireland has already fundamentally changed its long-enduring relationship — or should we say nonrelationship — between the economic sector and the academic community. China is building a large number of new, nontraditional institutions, mostly focused on science and engineering. Singapore and Korea are changing their educational systems to place more emphasis on innovation rather than rote. And Saudi Arabia recently announced a major new research university that will operate entirely at the graduate level and that will have, on opening day, an endowment equal to what it took MIT 142 years to accumulate.

Winston Churchill said that you can always count on the Americans to do the right thing … after they have tried everything else. When it comes to engineering education, it has never been more important that we get it right; that we preserve the many strengths of the past while adding those features that address the needs of the future. Only in this way can engineering remain the exciting, vital, contributing, and rewarding profession it has been in the past.