DIVERSITY IN ENGINEERING

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Every time an engineering problem is approached with a pale, male design team, it may be difficult to find the best solution, understand the design options, or know how to evaluate the constraints.

Two years ago, my topic for this talk was change. I had just become the president of the National Academy of Engineering (NAE), and it seemed appropriate. Last year, I talked about the challenges that I saw facing this Academy. I was sorely tempted to go back to those two topics today; I've spent a lot of time talking to members this year, and I have a strong sense of additional challenges and needed changes. But I decided I would defer that until next year, after we have completed our strategic planning.

Instead, I'm going to tackle a subject that is quite different. It's a subject that I approach with a bit of trepidationnot because of the substance of the subject, but because of the nature of the argument that I want to make. It's an argument that requires me to talk about some of my deep beliefs about the nature of engineering and the implications of those beliefs.

The subject is the absolute necessity for diversity in the engineering work force. A lot of people argue for diversity in terms of fairness. We Americans are very sensitive to issues of fairness, but that's not my argument. Others argue in terms of simple numerics: Male Caucasians will be the minority in the 21st century, and so to meet the need for engineers we will have to attract women and underrepresented minorities. That's true too, but that's not my argument, either.

I believe there is a far deeper reason why we require a diverse work force. Let me give you the argument in a nutshell, and then I'll try to draw it out more carefully.

First, engineering is a very creative profession. That is not the way it is usually described, but down to my toes I believe that engineering is profoundly creative. Second, as in any

creative profession, what comes out is a function of the life experiences of the people who do it. Finally, sans diversity, we limit the set of life experiences that are applied, and as a result, we pay an opportunity costa cost in products not built, in designs not considered, in constraints not understood, in processes not invented.

DEFINING DIVERSITY

When I say diversity, by the way, I do mean what most people assume: the representation of women and underrepresented minorities. But I also mean "individual diversity," the breadth of experience of an individual engineer. Both, I believe, are critical.

Four things came to my attention this spring and summer that made me want to bring the issue of diversity before you today. The first was a clear message from the members of the Academy that we need to fix the poor public understanding of engineering.

The second was the results of a Harris poll commissioned by the American Association of Engineering Societies that confirmed our intuitions about the public's perceptions of engineering. The full results can be found on our website, but the one result that really bothered me related to a word-association exercise. Only 2 percent of the public associate the word "invents" with engineering; only 3 percent associate the word "creative" with engineering. Five percent said "train operator." That's funny, but it's not funny, really. As I said, I believe that engineering is a profoundly creative activity, yet more of the public associate us with operating trains than with this quintessential dimension of engineering.

The third was new data on engineering enrollment. Enrollment continues to drop. It has been dropping since 1983, but it's dropping especially rapidly among some underrepresented groups. Since 1992, overall enrollment has fallen 3 percent; for minorities, it has dropped 9 percent; for African Americans, the dip is 17 percent. Enrollment of women has stayed relatively flat, just under 20 percent of the total, but it is certainly not growing. This downward trend exists despite the fact that starting salaries for newly minted engineers are averaging $40,000. We need to understand why in a society so dependent on technology, a society that benefits so richly from the results of engineering, a society that rewards engineers so well, engineering isn't perceived as an desirable occupation.

The fourth was the palpable contrast between the situation here in the United States and some other parts of the world. My wife and I visited Taiwan at the invitation of the minister of education. We toured engineering schools there. Thirty-five percent of the undergraduates in Taiwan are engineering students35 percent! The top levels of government are riddled with engineers.

I think these four things are "of a piece." How could we expect young people to go into engineering if the general population has an image of engineering that is so different from

reality, and so wrong? So, what do we do? Let me start by talking about creativity, and why I believe engineering is a profoundly creative activity.

As many of you know, my favorite quick definition of engineering is "design under constraint." We design things to solve problems, but not just any design will do. The design must satisfy a long list of constraints related to cost, size, weight, manufacturability, reliability, ergonomics, environmental impact, reliability, repairability, and so on.

Designing a solution that elegantly solves the problem and satisfies the constraints is one of the most creative activities I know. By the way, I really bristle when people talk about engineering as "just applied science." Engineering is not just applied science. Yes, we need to understand nature, which is what science tells us about, and we apply that knowledge, but nature is only one of the constraints that we must live with. In my experience, it's usually neither the hardest nor the limiting constraint.

Let me tell you something rather personal that perhaps explains what makes me feel so passionately about this. My father and uncle were both engineers. I suppose I was programmed to be one, too, and hence engineering was my initial major in college. But one year I had a summer job at Teletype Corp. I was a draftsman. I was doing inking on velum. For those of you who have done it, you know what an awful job that is. It might have easily turned me off engineering.

Instead, I can remember the exact moment when I got hooked on engineering. I was working in a group that was designing an automated phone dialer. The dialer consisted of a set of mechanical fingers that read punched plastic cards with the phone number encoded on them. These cards were occasionally binding as they went through the reader. The team was stumped by the problem for several weeks, but, then, it wasn't their highest priority either.

One day I looked at the reader and saw what was wrong and how to fix it, elegantly! It was an incredibly creative moment. I have been lucky enough in my career to have a number of them, but that first one was when I got hooked. I'm sure all of you have similar experiences and know exactly what I mean.

I got a lot of praise from my fellow workers, all much more senior engineers. They gave me a small bonus in my paycheck. I still think about the thousands of people who use that darn dialer in which those little plastic cards didn't bind. But the thing that hooked me was that moment of creation, of seeing the elegant solution.

Sam Florman, one of our members who unfortunately couldn't be here today, wrote a book in 1976 called The Existential Pleasures of Engineering. He talks about the joy of engineering and the joy of creation, and that's what makes engineering an interesting profession.

Sam also cites a psychological profile of engineers that had been done in the sixties. The profile stated that "Engineers are intelligent, energetic, unassuming people [who] seek interesting work." Interesting worknot pocket protector stuff, not cubical stuff, but interesting, creative work. Work that, in some ways, I claim has more in common with art than science.

In one of my travels this spring, I encountered a professor at a midwestern university. He was a chemical engineer who as an undergraduate was a music major. He said that it was in classic composition that he learned how to build systems, how to engineer. Florman talks about the artist as "our cousin, our fellow creator."

NAE member Bob Frosh sent me a quote from Ladislao Reti, the editor of the Codices of Leonard da Vinci. In talking about these codices, and what he hoped they would achieve, Reti said, "At last people will start believing me . . . da Vinci was an engineer who occasionally painted a picture when he was broke" (Gies and Gies, 1994).

Now, obviously, there is also an analytic side to engineering. There is an innate conservatism in engineering arising from our responsibilities to the public. Much like the physician, our role is "first, do no harm." That conservatism is always in tension with our creative side. The most original, the most innovative designs are also the most suspect!

PUTTING ON THE SKEPTIC'S HAT

So, following that flash of creativity, that wonderful feeling, that existential joy, what do we do? We turn around, put on our skeptic's hat, and start analyzing all of the ways that our design could possibly fail. Instead of celebrating our creativity, we try to find its flaws.

That's just what we should do, of course, but unfortunately, but that is the side of engineers that the public sees, rather than the creative side. Again let me quote Sam Florman: "It's especially dismaying to see engineers contributing to their own caricature." In fact, I think that's the biggest single problem we have in attracting the best, the brightest, and the most diverse students to engineering. The worst of it is, it's an incorrect caricature.

Now, let me turn to my main topic, diversityindeed the absolute necessity of diversity in the engineering work force. My premise is a simple one: One's creativity is bounded by one's life experiences.

In case you're wondering whether the premise is correct, I checked. One of the nice things about my job is that we've got about 400 Ph.D.'s from many fields who work in the National Research Council, so I asked the social and behavioral scientists whether this is

true. I was inundated with a lot of information that seems to indicate the premise is on target: Life experiences do limit creativity.

Now, if I may be permitted to coin a phrase, I want to talk first about individual diversity, an individual's breadth of experience. I claim that breadth of experience in an individual is essential to creativity and hence to good engineering. If engineers were really as dull, as narrow, as society seems to think, they wouldn't be good engineers! They couldn't be creative because they wouldn't have the life experiences to draw on to be creative.

In my personal experience, engineers are immensely interesting people. Just look at the people sitting next to you. You are "interesting people" who sought out "interesting work," and you are at the top of the engineering profession. That's not an accidental correlation.

Collective diversity, or diversity of the groupthe kind of diversity that people usually talk aboutis just as essential to good engineering as individual diversity. At a fundamental level, men, women, ethnic minorities, racial minorities, and people with handicaps, experience the world differently. Those differences in experience are the "gene pool" from which creativity springs.

LIMITATIONS OF THE "MALE CAR"

Two years ago, we had a woman speaker at the Frontiers of Engineering symposium who is in charge of chassis design for the Ford Windstar. She gave an uproariously funny talk about the difficulty women have with a car that has been designed for the 50th-percentile male. Women have different needs, women carry purses, women use a vehicle differently, women are of a different size, etc., all of which make the "male car" difficult to use.

As I said, it was a very funny talk. However, when I mentioned this to my wife, who has a long involvement with the Defense Department, she said, "Yes, and it's just as true of fighter planes where it's not funny; it's a life and death matter."

Our profession is diminished and impoverished by a lack of diversity. It doesn't take a genius to see that in a world whose commerce is globalized, engineering designs must reflect the culture and taboos of a diverse customer base. Absent a diverse engineering team, those sensitivities may not be reflected. But it's deeper than that. It's not just that Asians are a different size or that women have different needs than the 50th-percentile U.S. male. Marketing can tell you that.

Rather, it is that the range of design options considered in a team lacking diversity will be smaller. It's that the constraints on the design will not be properly interpreted. It's that the product that serves a broader international customer base, or a segment of this nation's melting pot, or our handicapped, may not be found. It is that the most elegant solution may never be pursued.

There is a real economic cost to that. Unfortunately, it is an opportunity cost. It is measured in design options not considered, in needs unsatisfied and hence unfulfilled. It is measured in "might have beens," and those kinds of costs are very hard to measure. That doesn't change the fact that they are very real and very important.

Every time we approach an engineering problem with a pale, male design team, we may not find the best solution. We may not understand the design options or know how to evaluate the constraints; we may not even understand the full dimension of the problem.

Let me pull together the threads of creativity and diversity. I believe that the central problem of our declining enrollments, particularly among women and minorities, is our dull image, an incorrect imagean image that ignores the existential joys of engineering. At the same time, by failing to attract a diverse engineering work force, we diminish what engineering can contribute to society, and society pays an opportunity cost.

The issue of the negative image of engineering seems at the base of the problem. Why do we have that image? There are lots of reasons. Let me mention just a few. It clearly starts in college. We work our engineering students through an initial 2 years of dull math and science courses before we let them do the "interesting stuff." Is anybody surprised that we lose 40 percent of those who enroll?

I already mentioned that there is an intrinsic tension between our creativity and our conservatism, and that in terms of time measured, we spend more of it on the analytical side than the creative side. We also talk more about the analytical side than the creative side. Perhaps we are trying to convince people that the designs are safe and environmentally sound. Perhaps there is also a collective false modesty about our creativity. Whatever the reason, I seldom hear engineers talk as I have today about the joy of engineering creativity or associate themselves more with the creative arts than the sciences.

I also think that around the end of World War II, we let our hype get ahead of reality. Look back at the Popular Mechanics of the 1950s, with its helicopter in every garage, you see how we encouraged the idea that "technology will solve all social problems." In reality, society became aware of concerns such as environmental pollution, and we began to be perceived as part of the problem rather than part of the solution.

Whatever the reason, we got our dull image. It is worth noting again: It doesn't have to be that way! It isn't that way now in other parts of the world, and it's not always been that way in this country. Between 1850 and roughly 1950 in the United States, you find engineers portrayed as heroes in poetry, film, novels, and plays. None less than Walt Whitman wrote, "Singing the great achievements of today, singing the strong light works of engineers."

Robert Louis Stevenson wrote about the engineering of the transcontinental railroad, "If it be romance, if it be contrast, if it be heroism required, what was Troy to this?" I could have found dozens more examples. The point is, it is not ordained that engineers have to have that dull, narrow, pocket-protector image.

Finally, what are we, the NAE, going to do about all of this? What do we do to encourage the diversity that I believe we need to engineer well? If I knew the answer of course, I would be out doing it, not just talking about it.

That said, it seems to me there is a class of things that we should not do: One more fellowship program, one more mentorship program, and so on, is not going to make a fundamental difference. There are lots of people working on these kinds of approaches to the diversity problem. The special advantage that this Academy has is its members, their reputation, and the positions they hold. We need to figure out how to exploit the imprimatur that the Academy inherits because of its membership.

Central to whatever we do should be to give the public a true image of what engineers do, including the existential joy of creativity. Equally central should be the notion of using our special value added, our imprimatur, to do what others simply cannotand often that will be to leverage their efforts.

For example, we have under way a project to celebrate women engineers. We have created a website <http://www.nae.edu/cwe>, and we're planning a summit meeting next spring of other organizations working on this problem. We are cooperating with professional societies and women's organizations, leveraging their efforts and using our prestige to underscore the seriousness of the issue. That's the kind of thing we should do. We should not duplicate the kinds of things others are doing.

A ROLE FOR TELEVISION ADS

Here's another idea that we might try. I have been particularly taken by two television ads recently. One is by a Swedish company; it focuses on a young elementary school student, who is excited about the possibilities of affecting the world through engineering. He is so excited that he gets up on his desk and tells his fellow students about the possibilities. The teacher finally says, "Where are you going to do all of this?" The boy answers with the name of the sponsoring company. It's the only mention of the company in the whole ad.

The other is a series of ads by a paper company. It features the children of their employees talking about what their parents have created that make life better for everyone. The ones I remember are coatings on cardboard to allow for fresh-tasting milk and fresh-tasting orange juice.

It seems to me that those ads are good both for the companies and for engineering. Can we challenge NAE members who are senior executives in their companies to think about that kind of institutional advertising as well?

In closing, let me just repeat my essential point. Engineering has contributed so much to the welfare of our society. To continue to do that well we require a diverse work force. We and our output are both impoverished without that diversity. Clearly, if monetary incentives were enough, current starting salaries would have already fixed the problem. They haven't, and so we need to look deeper, at what it is about the perception of engineering that repels young people in the face of these high salaries. I believe it is what they believe engineers do, what they think they would be doing, what they feel their life would be like if they became engineers. We know their perceptions are wrong. They are especially wrong about engineering being dull and uncreative. We need to fix that; no one will do it for us.

REFERENCES

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