The Importance of Diversity in Engineering

William A. Wulf

President

National Academy of Engineering

I want to share some thoughts with you from a talk I gave to the NAE Annual Meeting about two years ago, in which I tried to explain why I believe we should be deeply concerned about diversity in the engineering workforce. I feel very, very deeply about this issue because I believe diversity in the engineering workforce is an absolute necessity. It's not just that it would be nice if we were more diverse; the issue is much more important than that. I believe it is an issue of absolute necessity.

Many people talk about the need for diversity as an issue of equity, in terms of fairness, and that is a potent argument. Americans are very sensitive to issues of equity and fairness, so the fairness argument resonates with many people. But I will make a different argument today.

A second argument for diversity has to do with numbers, the fact that white males are becoming a minority in the population of the United States and that, unless we include more women and underrepresented minorities in the engineering workforce, we are simply not going to have the number of engineers we need to continue to enjoy the wonderful lifestyle we have had for the last century or so. This, too, is a potent argument, but it is not the one I am going to present today.

My argument is essentially that the quality of engineering is affected by diversity (or the lack of it). To make that argument, I am going to share with you some

very deep beliefs about the nature of engineering some of which run counter to stereotypes of engineers and engineering.

The whole argument in a nutshell is this. It hinges on the notion that engineering is a profoundly creative profession—not the stereotype, I know, but something I believe deeply. The psychological literature tells us that creativity is not something that just happens.   It is the result of making unexpected connections between things we already know. Hence, creativity depends on our life experiences. Without diversity, the life experiences we bring to an engineering problem are limited. As a consequence, we may not find the best engineering solution. We may not find the *elegant* engineering solution.

As a consequence of a lack of diversity, we pay an opportunity cost, a cost in designs not thought of, in solutions not produced. Opportunity costs are very real but very hard to measure. The stereotype of engineering in this country does not include a notion of creativity. Engineers are dull. They are nerds. Unfortunately, I think that is part of the reason we have not achieved the level of diversity in our profession that we have in the population. We need to break this negative feedback cycle. When I speak of diversity, I mean the kind of inclusion you probably thought of instantly, that is, appropriate representation of women and underrepresented minorities. But my idea of diversity also includes the notion of "individual diversity", that is, the breadth of experience of a single individual.

When I made this argument to the NAE members a couple of years ago, I had just seen some numbers about engineering enrollments. Undergraduate enrollment in engineering has been dropping since the mid-1980s. It is down about 20 percent from

that peak, and down about 3 percent since 1992. Graduate enrollment has been growing,
but largely because of an influx of non-U.S. students. In fact, the U.S. student
component of graduate enrollment is dropping, in spite of the fact that starting salaries for
engineering graduates are 50 to 100 percent higher than those of students graduating with
bachelor of arts degrees.

My friends who are economists keep telling me that this disparity in
salaries will eventually motivate more students to go into engineering. But that is not
what the data show. We need to stand back and ask ourselves why, in a society that is *so*
dependent on technology, in fact, in some ways is *addicted* to technological change, and
in a society with 50 to 100 percent disparities in salaries, engineering is not an *attractive*
discipline. Specifically, we must ask why it isn't attractive to underrepresented
minorities and women. Traditionally, engineering was thought of as a way to higher
economic status. That was certainly true in my generation, but it seems not to be the case
now. We need to stand back and ask ourselves why.

Even more disturbing than the overall numbers are the numbers for
underrepresented minorities and women. I told you that overall enrollment has dropped 3
percent since 1992, but minority enrollment has dropped 9 percent! African-American
enrollment has dropped 17 percent!

The percentage of women has held steady, just a tad under 20 percent of
the entering freshman class, but those numbers, bad as they are, don't tell the full story.
At the same time the number of engineering students has been going down or holding
steady, the number of minorities entering universities has been going up, and the number

of women entering universities has been going up. That means engineering is capturing a smaller and smaller "market share" of the total enrollment.

The situation is different elsewhere in the world. There is something uniquely Western (except for France) about these numbers. A few years ago I toured Taiwanese universities, where 35 percent of the undergraduates are in engineering. Forty-six percent of mainland Chinese undergraduates are engineers. At the ministerial level in Taiwan, half have degrees in engineering. In this country, only a handful of people in Congress are engineers.

Now let's return to my argument, starting with creativity. My favorite quick definition of engineering is "design under constraint." We design solutions to human problems, but not just any old solution will do. Our solutions have to satisfy the constraints of cost, weight, size, ergonomics, environmental impact, reliability, safety, manufacturability, repairability, power consumption, heat dissipation—the list goes on and on. Finding an elegant solution that satisfies those constraints is one of the most creative acts I know of. Let me dwell on the word "elegant" for just a minute. I believe that all great engineering achievements, from the Golden Gate Bridge to Post-It notes, are elegant. They are spare. To use Einstein's words, they are "as simple as possible, but no simpler." They are aesthetically pleasing. They appeal to our humanity. They are humane.

Let me tell you a personal story about creativity and elegance. My father and my uncles were engineers. So, in a sense, I was programmed to become an engineer. I never seriously thought of pursuing anything else when I went to college. However, I can tell you the exact moment I got "hooked" on engineering. Between my sophomore

and junior years at the University of Illinois, Chicago, I was working for Teletype Corporation as a draftsman. My job was doing inking on vellum, the most awful job in the entire world! If there is any job that was designed specifically to turn people off to engineering, it is inking on vellum. The team I was attached to, among other things, was designing an automatic telephone dialing device. A little punched plastic card was inserted into the phone with little mechanical feelers that came out and sensed where the holes were and dialed a telephone number. Occasionally, when these cards went through the reader the little fingers broke off.

I was hooked on engineering the moment I looked up from my drafting table at the dialer and saw what the problem was. I suddenly understood, and I understood the elegant solution to the problem. I mean, *really, really* elegant! I made a mock up of the solution with a bit of cardboard and drafting tape, and it worked!

My boss then had some metal parts made, for a total cost of pennies. It was really exciting. A bunch of more senior engineers who had been fiddling with this problem for a long time praised me and I got a bonus in my paycheck. For years, I thought about the fact that thousands of people around the world were using this dialer with no problem with binding. They may have had other problems, but they didn't have a problem with binding. That was all neat!

But what *hooked* me was the moment I looked up and saw the elegant solution, that moment of creativity. Looking back on my career, I have been fortunate to have had that experience a number of times. I can vividly recall each and every one of them because that is what engineering is all about.

Sam Florman, a member of the NAE, wrote a book called *The Existential Pleasures of Engineering* (St. Martin's Press, 1976) that makes this same point. Florman talks about the *joy* of creation, about the fact that creativity is what makes engineering an *interesting* profession. He cites a psychological study that had been done a number of years earlier that describes engineers as "intelligent, energetic, unassuming people who seek interesting work." Note that they seek "interesting work," not dull, pocket-protector stuff; interesting work, work that in some ways is more closely related to the work of our colleagues in the arts than of our colleagues in the sciences. As Florman says, "The artist is our cousin, our fellow creator." Bob Frosh, another NAE member and a former administrator of NASA, sent me a quote from the editor of the codices of Leonard da Vinci. Talking about the impact of editing the codices, he said, "At last people will start believing me. da Vinci was an engineer who occasionally painted pictures when he was broke."

The point is that engineering and art are not opposite ends of a spectrum. They are, in fact, closely related to each other. Indeed, a defining aspect of human beings is the use of tools to modify the environment. That is what distinguishes us from the great apes. So, in fact, engineering is the most humanistic of all activities. Obviously, engineering also has an analytic side, maybe even a dull side that comes from an innate conservatism. Just like medical doctors, the rule is "first, do no harm." Our conservatism and our creativity are always in tension. Indeed, the most original, most creative design is the one about which we are the most skeptical. If you make small incremental changes from previous designs, you don't meet much resistance. But the really creative, far-out designs arouse the great concerns. That is why, immediately after

our most creative moments, we always begin looking for flaws. We put on our skeptics'

hats and subject our idea to careful scrutiny, trying to ferret out the possible downsides,

all of the ways the design might fail.

In short, instead of celebrating our creation, we try to find its flaws. To

meet our responsibilities, that is exactly what we ought to do. Unfortunately, that is the

only side of engineering the public sees. To quote Florman again, "it is especially

dismaying to see engineers contributing to their own caricature." I can easily get a laugh

out of an audience of engineers by describing them as white-socks, pocket-protector,

cubicle folks. It is unfortunate. I think that caricature is one of the biggest problems

keeping young people from pursuing careers in engineering, despite the fact that study

after study after study has shown that both women and underrepresented minorities are

attracted to professions in which they can contribute directly to the welfare of others.

That is why we find more parity in the legal profession and in the life

sciences. But, in *fact*, engineers have contributed more to the quality of life than any of

those other professions. No one seems to think of painters or artists as dull people. Think

about how long Michelangelo laid on his back painting the ceiling of the Sistine Chapel,

the brute strength it took to plaster that ceiling while lying down—not a very exciting

activity.

A friend of mine who is an Emmy award-winning director set up a

weekend for me with a group of Hollywood film makers to see if we could convince

them to produce a show called "L.A. Engineer." It turned out we could not, but one of

the things that I learned that weekend was just how dull it is to make movies! The actual

shooting time of the movie is very brief; but months and months are then spent in a dark

studio editing this film. It is really, really dull. Every profession, whether painting the Sistine Chapel or making "L.A. Law" or being an engineer, has its creative side and its dull side. To increase our diversity we must make young people want to be engineers, and to do that we must address the stereotype.

Now I want to turn to my second theme, diversity. I repeat the simple truth that creativity is bounded by life experiences. The psychological literature is very clear about this. Creativity is simply making unexpected connections between things we already know. If engineers were as dull as they are in the popular stereotype, they wouldn't be good engineers. They wouldn't have the life experiences they need to come up with creative solutions to human problems. Let me repeat. If engineers were really as dull as the stereotype, they wouldn't be good engineers!

As president of the NAE, whose members are among the most creative engineers in the world, I can tell you they are *really* interesting and that is not a happenstance. Collective diversity, what people usually mean by diversity, is essential to good engineering at a very fundamental level. Men, women, people from different ethnic backgrounds, the handicapped—each of them experiences a different world. Each of them has had different life experiences.

I think of these life experiences as the "gene pool" out of which creativity comes, out of which elegant engineering solutions come. The quality of engineering is affected directly by the degree of diversity in the engineering team for that project. It doesn't take a genius to see that, in a world of global commerce, we must design products that are sensitive to many cultural taboos and for very different customers. But the need is deeper than that. The range of possible solutions to an engineering problem will be

smaller from a nondiverse design team, and the *elegant* solution to a human problem may not be among them. That limitation can have substantial economic costs, but they are opportunity costs, costs measured in terms of designs not considered.

Opportunity costs are very hard to measure, but they are very real. To illustrate the problem, let me tell you something from my own experience. One of my interests over the years has been computer security and until fairly recently, I still had two graduate students at the University of Virginia. One of my students came to me with a problem she wanted to solve. I told her not to waste her time, that it was an impossible problem.

I will describe the problem very quickly. She wanted to be able to run an application program and to know that either (1) the application had not been compromised, and was, therefore, working correctly or (2) that it had been compromised and should be ignored. But she wanted to run this program on a computer belonging to the bad guys who own the computer and have access to everything, can pull the plug out of the wall, can examine all of the software including the software my student wanted to run, can make arbitrary modifications to the underlying operating system, can make arbitrary modifications to the hardware, can modify the application my student wrote, and so on. In addition, because the application has to run virtually forever, the bad guy has all the time in the world to analyze the situation. I looked at that problem, and I said, "No way. You can't do that!"

Well, my student found a solution; not just any old solution but a truly *elegant* solution. I don't know whether it was because she is a woman or because of her Chinese background, but her life experiences enabled her to see a solution I would never

have seen. Once she explained it to me, I understood it, of course. In fact, I was able to build a proof that it would work—a nice linear, male, left-brain proof.

Now let me bring the themes of creativity and diversity together. I believe that a central factor in the declining enrollment in engineering, especially the declining enrollment among women and underrepresented minorities, is the stereotypical image of engineers. We know about a lot of other problems, of course—the need for mentoring, the lack of family support, the absence of role models. We know about a long list of problems. But to my mind, they don't explain the declining enrollment. It must be that these kids don't want to be engineers! There is something about engineering that is vaguely repugnant to them, and we need to understand what that is. There may be several things, but one of them is certainly the image. What really bothers me is that the image is incorrect! Engineering is *not* dull. Engineering, in fact, is an enormously fun, creative, rewarding profession that has had a profound impact on the quality of human life.

The image of engineers is very different in some other places, in France, for example, and China, both Taiwan and mainland China. In fact, the image is as different in this country from the early nineteenth to the mid-twentieth century, when engineers were celebrated as heroes in film, in poetry. Consider a few of the many quotations about engineers: Walt Whitman, "Singing the great achievements of today, singing the strong light works of engineers," or Robert Louis Stevenson who wrote about the engineering of the transcontinental railroad, "If it be romance, if it be contrast, if it be heroism we require, what was Troy to this?" I could cite dozens of other examples.

The nerdy image of engineers is not ordained. It is not ordained that the contributions of engineers to our society will be discounted. It is not ordained that our image will remain repulsive to the diverse students we must reach for excellence in engineering.   The NAE has initiated a number of programs to address these issues, and this workshop is an essential component of those programs.

To sum up, I believe that diversity is essential to good engineering! In addition to the issue of fairness and equity, in addition to the issue of numbers, there is an issue of quality. For good engineering, we *require* a diverse engineering team. But for some reason, engineering has become repugnant to young people. We need to face that fact and try to change it. There is no silver bullet to fix the image. We are going to have to work on it over a long period of time. But if we don't start working on it, we're never going to break out of this destructive, negative feedback cycle.

In the meantime, as we try to change the stereotype, we can do a great deal. The organizations you represent have taken aggressive and visible taken actions to address this problem. I believe we can make a start by sharing your experiences with each other and with us.