Thoughts for Young Engineers

Remarks Delivered to a Meeting of the IEEE Tokyo Section
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(As Prepared)

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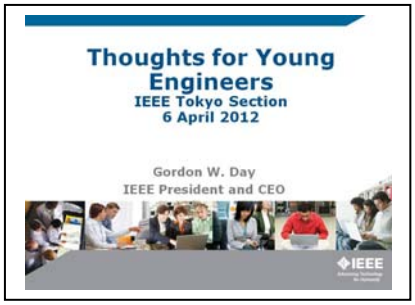


Thank you very much Prof. Aoyama. It's good to be back in Japan. I've been here many times and I always enjoy my trips.

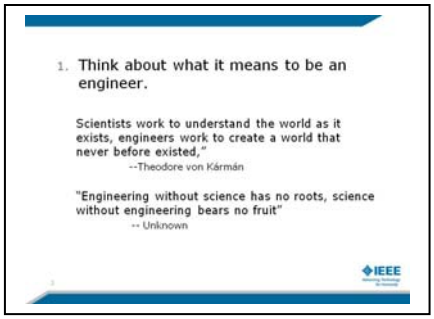
I came to Japan this week partly to help dedicate an IEEE Milestone for the development of the G3 Facsimile Standard. As you probably know, the history of the fax machine is very old, nearly 170 years old. But it was three decades or so ago that fax transmission became a very big part of our lives. That was, in large part, because of the G3 standard that we celebrated yesterday, a standard created jointly by NTT and KDDI. Bronze plaques will be placed at both laboratories to commemorate the achievement.

IEEE Milestones recognize very important events in the history of technology. There are currently 117 of them, starting in the 18th century with the work of Benjamin Franklin and Alessandra Volta. Others recognize the birth of telecommunications with the invention of the telegraph in the 1830s, Maxwell's equations in the 1860s, and many developments related electric power. Marconi's work on wireless and other developments related to communications are honored, as are several developments related to computing, the liquid crystal display, the cardiac pacemaker, and the

compact disc. With the one dedicated yesterday, there are now 17 milestones in Japan.

I'm very glad to see many students and young engineers here today. I talk to many student groups. I think it is important and I always enjoy it. I wish I had been able to spend more time talking with older engineers when I was your age.

I started as a university student 50 years ago this year. I will tell you some things that I've learned since then, but mostly I want to encourage you to do some thinking for yourselves. I have seven recommended topics.



First, I encourage you to think about what it means to be an engineer.

Start by thinking about the difference between science and engineering. Both are technical professions, but they are different. They're the ends of a spectrum, science at one end, engineering at the other, with mixtures in between.

I have worked at both ends of that spectrum. I started my career as part of a team that was making a more accurate measurement of the speed of light; that's pretty fundamental science. Later on, I worked on laser applications, standards, and some new ideas in instrumentation, some of which led to products – things engineers typically do.

Science and engineering are very different, but the same people can do both.

My favorite description of the difference between science and engineering comes from Theodore von Kármán. He was an early 20th

century mathematician, mechanical engineer, and aerospace pioneer, born in Hungary and a US immigrant. He said,

> "Scientists work to understand the world as it exists, engineers work to create a world that never before existed."

As one who has worked in both science and engineering, I think that statement is respectful of both disciplines, of both ends of the spectrum. Scientists teach us about the universe we live in. Faraday, Maxwell, Einstein, Shannon, Bardeen – pick your favorites – they and many others taught us what we need to know. Some scientists are highly honored and become very famous.

Engineers, on the other hand, design and build new things, things that change lives and create value and prosperity. Engineers start companies and create jobs. Think about the high tech companies that you know and about the jobs and wealth they created.

Most people seem to think that engineers create things using the principles that scientists taught them, and sometimes that's the case.

I heard another nice quote recently:

"Without science, engineering would have no roots; without engineering, science would bear no fruit."

But do not conclude that engineers just apply science, or only apply science. Sometimes engineering achievements come before related achievements in science.

The steam engine preceded the science of thermodynamics by a century. The Wright brothers flew long before the science of aerodynamics was established. In my own field, Ted Maiman demonstrated the first laser

using an approach that people working on the physics of stimulated emission said would never work. Superconductivity was well characterized experimentally, and its applications were well anticipated, before there was a theory to explain it. I encourage you to think up some other examples.

This brings me my second recommendation: I urge you to think about the important achievements of the engineering profession.

Creating a world that never before existed isn't an exaggeration.

Think back to what you know about the history of the 20th century, to what your parents and grandparents, and maybe even your great-grandparents, experienced. My own parents, who were born in 1906 and 1907, didn't have electricity in their homes until they were young adults. They could talk at length about how it changed their world: Electric lights replaced kerosene lamps, and provided a much better, cleaner, safer, and healthier environment. Refrigerators replaced ice boxes and freezers appeared. Food could be stored longer, and was safer. Electric pumps provided a better supply of water. Electric washing machines, sewing machines, and tools became available. Life became healthier, more comfortable, more productive, and far different.

Then there were the indirect applications of electricity.

Communications – telephones, radio, television, facsimile, data communications – it became possible to communicate at the speed of light, not at the speed of a horse.

Consumer electronics – audio, video and games – provided entertainment.

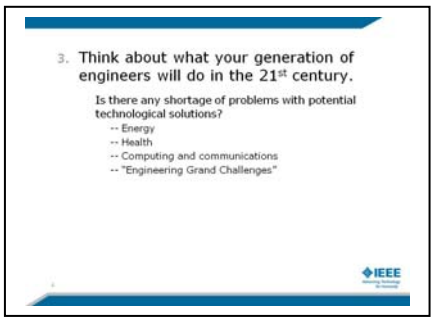
Computing – for computation and control; ubiquitous microprocessors.

Health technologies – most diagnostic and therapeutic techniques depend on electronics directly or indirectly.

The ability to control electrons created a new world. And that doesn't speak to the contributions of mechanical, civil, and chemical engineers, or all of the other kinds of engineers. They have their own lists.

It is not an exaggeration to claim that quality of life in the 20th century was defined by the creativity and dedication of engineers, by technological innovation.

That's our profession. I'm proud to call myself an engineer, I'm proud of what our profession has achieved over the past century or so. And I hope that you will develop that same pride in our history.



And now my third recommendation is obvious. This is the 21st century. It is the century in which **you and your successors** will define quality-of-life. Think about how you will fulfill that responsibility. We are expecting great things from you.

You may ask whether it is possible to achieve as much as your predecessors. To that, my answer is another question. Is there any shortage of problems that have technological solutions?

Energy may be the most fertile field for innovation in the 21st century. Perhaps you've already noticed the rate of growth in car ownership around

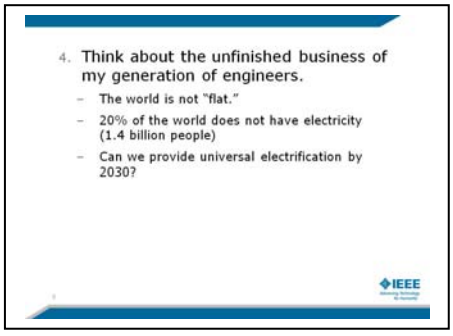
the world? In China the fleet doubled in the past three years. When per capita car ownership in India and China reach just a quarter or so of what it is in much of the developed world, where will we get the energy? How will we protect our environment and our climate as we use more energy? What other profession, but the engineering profession, is going to figure that out?

If you'd like to get excited about what engineers can do to help the handicapped, read the January and March issues of IEEE Spectrum, and look at some of the video. You'll see a paraplegic woman walking with an exoskeleton, and blind woman with an artificial retina who can see well enough with it navigate her way home. And you'll hear them talk about what those things mean to them. And looking further out, you'll learn about new ideas for interfaces between prostheses and the brain.

How can technology improve health care and extend life expectancy. Can engineers reverse engineer the brain? Can we provide smarter health care with sensors and computers?

What other new possibilities have not yet emerged from the convergence of computing and communications?

Try searching the web for "engineering grand challenges" for more ideas.



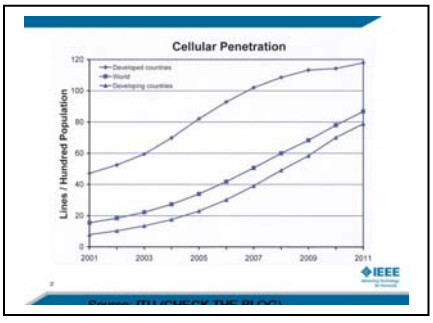
And after you've thought about the future for a while, may I suggest that you <u>think about the very important unfinished business that my generation of engineers is leaving behind for you to complete.</u>

New York Times Columnist Thomas Friedman famously said that the world is flat. By that, he meant that many jobs can be performed wherever there is access to a high speed internet connection. But we know that, in many respects, the world is not flat.

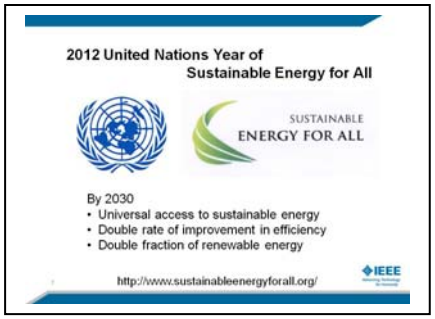
We know that the benefits of technology that my parents gained close to a century ago still haven't reached the 20% or so of the world that still doesn't have electricity.

We know about the disparity in quality-of-life and prosperity that exists, country to country, region to region. We know that the needs of many countries are substantial. And we know that those needs differ, country to country. They are local and one solution does not fit all.

But we also know that the engineering profession is the one perhaps most able to solve these local problems. We are the profession that can provide electricity where there is no grid. We can bring clean water, transportation, better health care and a better food supply to places where those things are desperately needed. And we have an example that demonstrates how these things can be done.

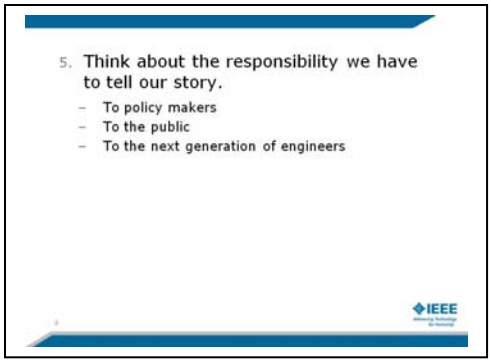


Telephone landlines never reached more than about 12% of people in developing countries. But over the past decade or so, cellular phones expanded from about 1% of the population in developing countries to nearly 80%. Cellular phones have now reached almost every corner of the earth.



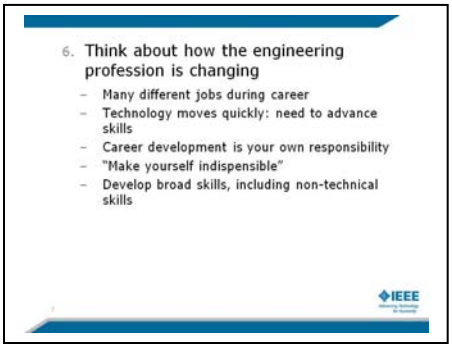
The UN has declared 2012 as the "Year of Sustainable Energy for All," and in Rio de Janeiro, in July, ministers from many countries will consider a specific goal of universal access to sustainable energy by 2030. Other goals to be considered are doubling the rate of improvement of energy efficiency and doubling the fraction of renewable energy in the world's energy supply, also by 2030.

We are the profession that can provide energy where it is not yet available and technology where its benefits are not yet known or understood. I believe that we have a responsibility to do so.



That brings me to my next suggestion. Think about the responsibility to we have to tell this story, the story of what technology can provide, the important roles that technologists play, and what technologists need to continue changing the world as we have in the past. Let us become activists on behalf of technology and technologists.

I believe that we should make it a priority to stay informed about national and international issues that affect the capacity of our profession to continue to innovate. We should explain our profession to others, especially to young people who are considering career decisions. We should to talk to opinion makers, thought leaders, and policy makers about technology and our profession.



Next, <u>think about how the engineering profession is changing</u>.

I realize that some things have not yet changed in Japan as much they have in other countries, but change is coming. Today, in the United States and some other countries, engineers will work for many companies during their careers. They must prepare for that.

We all know that technology is progressing faster and faster. Those who fail to keep their skills fresh will not be able to advance in their careers or find new opportunities. Organizations don't want to hire and train. They want people who can do the job, as quickly and inexpensively as possible.

Sam Palmisano was the CEO of IBM until a few months ago. And recently he was quoted in the New York Times recently as saying, "You need to have the advanced skills that the future requires. You need to move to the future from a skills perspective." But then he added, "We do a lot of retraining every year, and we still find ourselves in the situation where people can't move up the skill ladder. So we have to replace them with current skills."

He may be correct that some engineers of our profession haven't moved "up the skill ladder," but I won't accept the idea that they can't. We may lose the currency of our knowledge, but we don't lose our talents or our basic understanding of physical principles. If we, all of us, don't commit to a lifelong expansion of our skills, we'll be in trouble.

I was lucky enough to have an early boss who made it clear that my job opportunities were my own responsibility. My first job out of graduate

school was as a post doc at what was then called the National Bureau of Standards, in Boulder, Colorado. It didn't take me long to figure out that NBS was a great place to work and Boulder was a great place to live; it still is. So one day I asked him, my boss, about the chances of a permanent position. He looked me in the eye and said, *"Make yourself indispensable!"* and ended the conversation.

That message is even more important today than when I got it several decades ago.

Today, it may not be enough to try and stay at the leading edge of one technology. The engineers who will have the greatest impact are likely to be those whose skills are broadest.

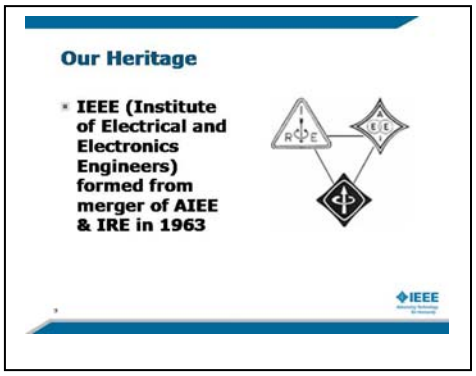
And it's not enough just to stay current technically. Whether today's engineers want to advance with their employers, or perhaps become entrepreneurs, they need a host of other knowledge and skills. They need skills in communications, business practices, negotiations, customer relations, marketing, accounting, intellectual property and more.

And that brings me to my final suggestion. Think about where your professional home should be. May I suggest that you become involved in a professional society?

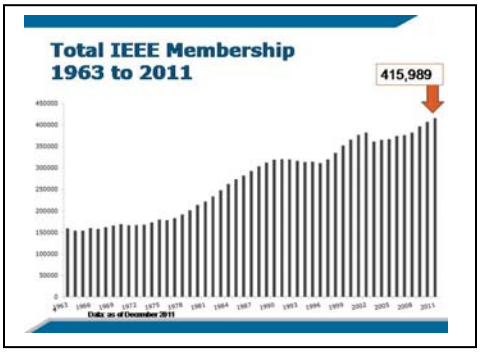
Getting help to move up the skills ladder is one of the greatest benefits of belonging to a professional society. Professional societies are about knowledge, about nurturing its creation, disseminating it, and thereby helping technologists thrive, helping innovators innovate. We're also about the non-technical aspects of being a

professional, through education, but at least as importantly through the opportunity to gain experience as a volunteer. We're a source of advice and information about career management. And all of that happens through a supportive community of peers and friends.

That's what IEEE has done for me, and what it's doing for more than 400,000 members all around the world, helping us move up the "skill ladder," a bit closer to becoming indispensable.



IEEE has deep roots. We were formed in 1963 through the merger of two very much older U.S. engineering societies. So this is our 50th year, and over those fifty years we have become a global organization. Today, about half of our members live outside of the United States.



Among our members, I think you will find more expertise, in more areas of electrical, electronics, and computer technology, than anywhere else. And I would add that we increasingly support the professional interests of applied technologists in other disciplines, including mechanical engineering, civil engineering, physics, and materials science.

We provide products and services to support our global members and other technologists.

We are a major publisher. There are 150 journals and magazines in our portfolio, many of them ranked very highly by impact factor. There are more than three million documents in IEEEXplore, our electronic library, including publications of IET and VDE, and more than 3400 technical standards. Each month almost 8 million documents are downloaded.

Through conferences, we bring individuals together into communities with shared interests. By enabling a culture of collaboration we can produce high quality resources that have a substantial global impact. Last year we sponsored, or co-sponsored, 1300 conferences, including 40 in Japan.

Countries, companies, and universities can develop fertile environments for innovation, but innovation comes from people – talented, well educated, and creative people. To support the high-tech workforce, we work with universities to accredit academic programs, and we provide a variety of programs in continuing education.

Those are the things I discuss with young engineers when I have a chance. They are some of the things I wish older engineers had discussed with me, when I was young. And I am delighted to have had the opportunity to share them with you today. Thank you..