Creating a Flatter World than Ever Before Existed

Remarks at the Opening Ceremony
(As Prepared)
The Centenary Conference
Electrical Engineering Department
Indian Institute of Science
Bangalore

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December 14, 2011

Thank you, Prof. Khincha. Director Balaram, Prof. Sastry, and Prof. Jenkins. It's a privilege to help open this conference celebrating a hundred years of Electrical Engineering at the Indian Institute of Science. I'm greatly honored by the invitation.

I've been looking forward to this trip for several months. I've had the good fortune to travel much of the world, but this is the first opportunity I've had to visit India. I am sorry that it has taken so long. I hope to return next year, during my term as IEEE President.

India is particularly important to the IEEE. About 9% of our members reside here. By country, that's the second largest, after the United States. About a third of our student members reside here. In fact, we have more than twice as many student members here as we have professional members. Soon all major universities in India will have access to IEEEXplore, our electronic library. Already 10% of the downloads from IEEEXplore are to addresses in India. And we are consulting with a variety of Indian organizations on education and standards.

My personal research interests are in photonics. I worked for many years on metrology associated with lasers and optical fiber. Of course, Indian scientists and engineers have contributed much to those fields. As a student, I studied the work of Satyendra Bose. Perhaps you know that colleagues of mine at the National Institute of Standards and Technology and the University of Colorado were the first to demonstrate Bose-Einstein condensation. And I am sure that I first became aware of the Indian Institute of Science through studying the work of C. V. Raman. He taught us important things about the properties of materials and, today, Raman amplification is seeing applications in optical communications.

Recently I've learned more about the history of IISc. I know that it was conceived as a research institute, the first research-focused institution in India. I know that, even as "science" became part of its name, applied science, what we might now call engineering or technology, was a part of the charter at the beginning. I understand that Applied Chemistry and Electro Technology were the first two research areas. I know that the Electrical Engineering Department here predates the other engineering departments by 30 to 40 years. I know that IISc played an important role in nurturing other universities in India, and that when the Indian Institutes of Technology were emerging, they drew heavily from IISc for their faculties. And I believe that it was the same for many of the Indian national laboratories.

A while back, I discovered an interview that Prof. Balaram did with Outlook Magazine, a couple of years ago. It was a good interview; I hope you have not forgotten it. In it, you talked about some of the points I just made, and you also offered some very thoughtful reflections on the relationships between science and engineering, or technology.

I'd like to take a few minutes to explore that distinction, the distinction between science and engineering, a little further.

First of all, I'd like to introduce you to Theodore von Kármán. Von Kármán was a Hungarian mathematician and a mechanical engineer in the first part of the 20th century. Educated in Hungary and Germany. Immigrated to the United States in the 1930s. Helped develop the field of aeronautics. Professor at the California Institute of Technology. Co-founder of Aerojet Corporation and the Jet Propulsion Laboratory. And famous enough that he appeared on a U.S. postage stamp. Not many engineers are so-honored.

If you read his autobiography, you'll see that he was also a keen observer of how technology develops, and the distinction between science and engineering. And he made a helpful observation about that.

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

Let me repeat that ….

Think about the first part of that sentence, the part about scientists. What do you see? A lot of famous people. Just in our areas, people like Faraday, Maxwell, Einstein, Bardeen, Bose, and Raman, just to name a few. You see Nobel Prize winners. You see people who dramatically expanded our understanding of the world, and who became famous for their work.

Early in my career, I was part of a team working on laser frequency measurements. The others were physicists. We were trying to measure the absolute frequency of a stabilized laser in terms of the primary standard for frequency. It was a huge undertaking, using large gas lasers, some of them eight meters long. And it involved generating 10,000 harmonics of a microwave signal to reach the infrared part of the spectrum…something that had not been done before.

Eventually, the experiments worked. We determined the frequency of a He-Ne laser in terms of the Cesium frequency standard. While we were doing that, some other colleagues were determining the wavelength of an identical laser in terms of what was then the primary standard for length. We then had both the frequency and wavelength of a very stable source. And you all know what that means. We multiplied the two numbers together and had a 100-fold better value for the speed of light. And as a direct consequence of that, ten years later, the meter, the standard of length, was redefined based on the speed of light. It means that the value of c in text books today is now exact. You can't measure it anymore. One of my colleagues in that work later won the Nobel Prize in Physics. It was a very important science experiment.

I am proud of that experience. I tell you the story to show that I have highest regard for scientists who spend their lives exploring “the world as it exists.”

But now I want to talk to you about the importance of engineering.

Think back to the second half of the von Kármán quotation. “…engineers work to create a world that never before existed.” Now, what do you see in that statement?

More famous people, and now famous companies, too. In our field we see Marconi, Edison, Westinghouse, Bell, Siemans, Toyota, Tata and the companies that took their names. We see Steinmetz and GE, Grove and Intel, Gates and Microsoft, and many others, including a very large number of small companies. I’m sure I could add more Indian companies and names to those lists. We see people and companies that dramatically changed our lives. We see enormous advances in quality-of-life. And we see millions of jobs and great prosperity created.

For me, and I think for many people who have worked in both science and engineering, von Kármán makes an accurate and respectful distinction.

Henry Petroski, who is a professor of civil engineering at Duke University, says it should be much more than that. He says it should be a roadmap for our future.

Petroski often writes about the engineering profession. You may have read his column in last December’s issue of Spectrum Magazine. Petroski builds on von Kármán’s ideas, and he points out that engineering achievements are sometimes accomplished without, or maybe even in spite of, advances in science.

For example, the steam engine preceded the science of thermodynamics by a century. The Wright brothers flew before the science of aerodynamics was developed. Marconi’s radio transmission across the Atlantic defied the scientific understanding of the time. And so did Ted Maiman’s ruby laser. The US space program and the internet were primarily triumphs of engineering, of designing and building things.

So Petroski says that von Kármán was right, and if we are to change the world, to create a new and better world, we need to focus at least as much on engineering as on basic science.

That’s us he is talking about. That’s the engineering profession.

I invite you to think back over the history of the 20th century, over the history of the Indian Institute of Science.

Start with electricity, which began to reach homes and businesses at the beginning of the century.   Electric lights replaced kerosene lamps. Refrigerators replaced ice boxes. Electric pumps brought better and safer water supplies. Washing machines, electric irons, sewing machines, vacuum cleaners, and other labor saving devices appeared. Electricity made life easier, safer, and more pleasant.

Then think about how the limits of time and distance diminished with advances in transportation, advances that made it possible for people and things to move quickly around the globe.

Think about how communications technologies – telephones, data communications, radio and television – increased the velocity of information to the fundamental limit, while expanding our access to knowledge, education and entertainment, building businesses and communities, and improving safety and security.

Think about how computers process vast amounts of information and control complex systems, and how microprocessors are now ubiquitous, present in even the most mundane products.

And think about health care. Recognize that most diagnostic procedures are enabled by electronics, that drugs and other therapies are developed using electronic instrumentation and computers, and that advanced prostheses are electronic and mechanical marvels.

Those are just parts of the story of technology in the 20th century, but they are enough to claim, without much exaggeration, that quality-of-life in the last century was ***defined*** by the creativity and ingenuity of engineers.

And in front of this audience, I'll claim that more of the quality-of-life enhancements in the 20th century were created by electrical, electronics, and computer engineers than by engineers of any other discipline.

Where are the students in the audience? Please raise your hands. I want to say this to you boldly. Your predecessors defined quality-of-life in the 20th century. The 21st century is **your** responsibility. What will you do with it?"

When I share these ideas with other student groups, I find that very few have thought about their future careers in this way. After a bit, they start talking about applying technology to health care….to diagnostics, therapeutics, and prosthetics…..and to sustainable energy….and to environmental concerns. I commend them for that. These are very important challenges, and engineers who make significant advances in those areas will be greatly honored. But I also encourage them to search for even bigger ideas….bigger opportunities. And I hope that you will also promote this idea of tackling big ideas, especially those of you who work with students and early career engineers.

Our profession has proven that it can take on the big challenges. To the students in the audience, I say please do not think small. To the faculty and others here today, I say, please do not let the next generation of engineers think small.

Now I want to talk about what our profession did not accomplish in the 20th century, the unfinished business of my generation of engineers.

Many of you probably know the work of Thomas Friedman, the foreign affairs correspondent for the New York Times. He often visits and writes about India. He's most famous for four words that formed the title of one of his books: "The World is Flat."

At least initially, Friedman spoke about flatness in a narrow sense. He spoke about the possibility of doing many jobs, including engineering, wherever there's access to high speed data, for example, at the end of any optical fiber connected to the internet.

Friedman saw that as an opportunity for workers in remote parts of the world and a threat to workers in more developed and affluent parts of the world.

With high speed data connections, jobs can move easily to countries where labor costs are lower. And we've seen that happen, as multinational companies have established R&D and manufacturing facilities around the world.

And I'll be honest. Friedman was thinking, at least in part, about India as a lower cost labor market.

But in a broader economic sense, the world is not nearly as flat as Friedman suggests.

Pankaj Ghemawat, an Indian, was for many years a professor at the Harvard Business School. He's now at a university in Spain, and he's written a new book called World 3.0. He says that if the earth *were* flat, certain things would flow between countries as though they were water on a flat surface – communications, information, investments, people, and goods should flow freely across national borders. And he proceeds to show that they don't, for whole variety of reasons, legal, cultural, and geographic, among others. In this view the world is not flat.

Joseph Stiglitz, the Nobel Prize winning economist from Columbia University, has a different view of flatness. He says that it should be associated with equality of income. He says, and I quote, "Not only is the world not flat, but also there is growing inequality around the world, and there is a growing gap between the rich and the poor. The world is becoming less flat as that inequity grows."

Some argue for a third definition, that flatness should be related to the subjective concept of quality-of-life. Perhaps to income we should add health considerations, literacy and education, political freedom, maybe something about a sense of community.

Then there's still another view of the "un-flatness" of the world, one that I particularly like. Shortly after "The World is Flat" was published, sociologist Richard Florida published a paper in *The Atlantic Monthly*, in which he said "The world is not flat, it's spiky." He plotted population as the vertical dimension on a flat map of the world. I think you can visualize that as a spiky picture. And then he took one of those pictures of the world from space at night – I'm sure you've seen them, spots of light – and plotted the light intensity on a similar map. Light intensity is a surrogate for economic activity. That's spiky, too.

I particularly like Florida's analysis because it gives us a visual impression of where the needs are and how large they are. There are huge parts of the world, where there are many people and there is no light.

<u>The greatest piece of unfinished business that my generation of engineers leaves behind is our failure to achieve universal access to the advanced technologies that we created and deployed in the 20^{th} century</u>. We have not created light in those dark spaces.

More than half a century after electricity, clean water, modern sanitation, airports, and fast highways reached the last corners of developed countries, these things are still rare in many parts of the world. Twenty percent of the world's population, 1.4 billion people, do not have electricity in their homes. The numbers for clean water and modern sanitation are similar or worse. In these respects, and in income and other aspects of quality-of-life, the world is ***not*** flat.

Perhaps better than any other profession, we as engineers can make the world flatter. Data on telephone penetration in developing countries shows that it can be done. The number of landlines in developing countries never rose above about 12% of the population. But in just the past decade, the number of cell phone subscriptions across the developing world has risen from 8% of the population to 80%; in some countries the growth is even more dramatic. In India, between 2000 and 2010, penetration grew from a third of a percent to over 60%, and the curve is steep so I'm sure it is well above that, a year later. It's happening everywhere because high tech businesses see the opportunities, and it can happen with other technologies.

And we need to do more than just play catch up. As technologists, we understand that innovation is the path to prosperity, everywhere. So, while we address the overdue challenges of universal access to technology, we should also help build long term capacity to innovate, everywhere.

That may be easier said than done, because in most countries, today, resources are a limitation. So we must think carefully about what can be done.

Start with this idea: Countries, companies, and universities can develop fertile environments for innovation, but innovation comes from people – talented, well educated, and creative people. Without a strong, creative workforce, no other strategies for stimulating innovation matter.

There's no shortage of people who have a talent for innovation. Innovation is creative problem solving. And it doesn't matter whether you look in the prosperous cities and suburbs of developed countries, or the rural areas of developing countries, or anywhere else, people are creatively solving the problems they encounter every day. I often reflect on the fact that my father, a farmer, was also my first engineering teacher. He was a reliant, self sufficient, innovative problem solver. One of his favorite sayings was "Necessity is the mother of invention."

So perhaps the greatest opportunity for governments is to make sure that creative young people have access to an education that can nurture their talents. Here at IISc, you have a history of educating outstanding faculty for other universities in India. I hope that will continue to be an important part of your contribution to the advancement of your country.

At IEEE, it's our purpose and our opportunity to support the global high tech workforce. We should work harder to attract young people into our profession, and support the schools and universities that educate them. And we must continue to improve the tools and resources we provide to help technologists thrive throughout their careers.

Once again, I thank you for the invitation to participate in this celebration. I've enjoyed it greatly, and I look forward to talking with many of you individually this evening.