Round, Flat, or Spiky: The World Turns on an Axis

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Good morning everyone. I am pleased to join this talented, committed, and eclectic group of leaders, people who get things done. Your leadership generally for IEEE, and specifically at this Workshop for IEEE-USA, is enormously important for both individual IEEE members and for the betterment of society worldwide. Your Workshop Chair, Joey Duvall, and President, Ralph Wyndrum did a grand job last night setting forth the strategic base for IEEE-USA and this Workshop.

Flash! This just in - hot news of the moment from the National Science Board's *Science and Engineering Indicators:*

- U.S. patent applications from the Asia-8 nations (South Korea, Indonesia, India, Malaysia, Singapore, Philippines, Taiwan, and Thailand) are growing rapidly.

- International spending on research and development is growing rapidly.

- China is keeping pace with the U.S. in the growth of its high-technology production relative to its total manufacturing output.

Did you know that the RCA logo is owned by a Chinese manufacturing company? Gee whiz, to think that I started my engineering career as an RCA engineer in Camden, New Jersey, and Nipper now speaks Chinese. Well, as the saying goes, the world does turn and tomorrow's a new day.

No question – round, flat or spiky – our world is turning on its axis and each nation right along with it. What axis you ask? Hmmmm .... let's see.

What's happening in the world today is, well, happening. Since the dawn of civilization, forward thinkers have been essential to the progress of a nation. Visionary thinkers have been vital forces propelling progress. Vannevar Bush, an engineer and visionary who helped set the stage for the yeasty technological expansion of the past half century, described economic enterprise as "...the free

play of initiative of a vigorous people under democracy... [supported by] the advance of science and its application."

Today, at the dawning of this century, new paradigms of technology are disrupting the economic system we have come to know and which has served us well. The disruption is rather extraordinary, and simultaneously exciting and painful, but nonetheless, it is in our laps and needs our attention. In many ways engineers have set the base for the disruption and it is likely that Adam Smith and Joseph Schumpeter are pleased that we did so.

Contemporary thinkers look at the current scene and are expressing their views in a variety of ways:

In 2004, Tom Friedman published a book, *The World is Flat*, that has garnered much attention, including the title of this Workshop.

In 2005, the National Academies, prompted by Congress, released, *Rising Above the Gathering Storm*.

That same year the Council on Competitiveness, a private sector group, published *Innovate America!*

Also in 2005, Richard Florida wrote a provocative article in *The Atlantic Monthly*, suggesting that, *The World is Spiky*.

And just now the President of the United States announced the *American Competitiveness Initiative* in his State of the Union address.

Taken together, these documents express well what's going on in the world market of ideas, the economy, and the workforce. They all focus on *innovation*, that is, in the words of the late Peter Drucker, the process of creating new knowledge and applying it to things that are new and different.

Integrating the thoughts in these documents can help empower IEEE-USA leaders to be robustly effective. I recommend that you all go through them. I believe that they will convey to you what you already know: that the dynamic integration of *talent*, *investment*, and *infrastructure* is what it's all about, what makes the world turn on its axis.

The power of these documents is that they are all on the same wavelength, are produced by credible minds, everyone is discussing them, the private sector is lobbying for implementation of their recommendations, and both the White

House and Congress are using them for policy decisions, with nascent federal bills in play.

So, what may come out of all of this? Well, maybe these documents well define *innovation* as the axis around which the world is turning; maybe they integrate the separate notions that have compelled some minds to describe the world as either round, flat, or spiky.

In Friedman's book he points out that while Columbus argued that the world was not flat but round, its gotten flat again. Starting from the pre-1492 flat, Friedman walks the reader to the present, ultimately pointing out that, in addition to other reasons, the seamless integration of disparate networks into an Internet was "a huge flattener, because it enables so many more people to get connected with so many other people," or paraphrasing the words of Doug Engelbart, inventor of the mouse, we now have the capability to access the entire wisdom of the world.

Yet, Florida argues that the world is spiky. He writes, "In terms of both sheer economic horsepower and cutting-edge innovation, surprisingly few regions [of the world] truly matter in today's economy. What's more, the tallest [economic] peaks - the cities and regions that drive the world economy - are growing ever higher, while most of the valleys languish."

I have been asked to make some observations on all of this but, first, I want to share with you a poem by British poet, Wendy Cope, both for a bit of levity to set our compass, and also to focus on the importance of the whole being greater than the sum of the parts.

I was given this poem by a colleague of mine, Dan Hoffman, who studied engineering as an undergraduate, became an English professor, and crowned his career as Poet Laureate at the University of Pennsylvania. How's that for a career prepped by engineering studies?

Wendy Cope's poem plays on themes of function, beauty, and reward, and their integration in our culture. Titled "Engineer's Corner," it was composed as a response to a lament by a U.K. Engineers' Council letter posted in the London Times, to wit: "Why isn't there an Engineers' Corner in Westminster Abbey? In Britain we've always made more fuss of a ballad than a blueprint..."

The posting went on to suggest that sans recognition in the Abbey, engineers do not enjoy the presence in society enjoyed by other careers and are thus minimized. In response to the posting, Wendy, with lighthearted humor, wrote:

We make more fuss of ballads than of blueprints –
That's why so many poets end up rich,
While engineers scrape by in cheerless garrets.
Who needs a bridge or dam? Who needs a ditch?

Whereas the person who can write a sonnet
Has got it made. It's always been the way,
For everybody knows that we need poems
And everybody reads them every day.

Yes, life is hard if you choose engineering –
You're sure to need another job as well;
You'll have to plan your projects in the evenings
Instead of going out. (It isn't swell).

While well-heeled poets ride around in Daimler's,
You'll burn the midnight oil to earn a crust,
With no hope of a statue in the Abbey,
With no hope, even, of a modest bust.

No wonder small (tots) dream of writing couplets
And spurn the bike, the lorry and the train,
There's far too much encouragement for poets –
That's why this country's going down the drain.

Wendy's observations are astute. Notwithstanding the lack of recognition for engineers in the Abbey, both poets and engineers are creative and share common traits: they create lovely things that thrill our senses, enliven our souls, and add quality to our lives ... all for a "modest" fee of course. Both seek to improve the quality of life, make us see the world whole, and propel us to actions we otherwise would not take.

The poem also reveals that poets and engineers suffer misconceptions about each other, as do most specialized groups in our society. These misconceptions disrupt the lines of understanding and yield narrow vision, especially about societal trends. Examples of misinformed vision abound and illustrate how easy it is for a specialized person to miss something that might be obvious to someone with a more holistic understanding of the world and its parts.

For example, since we are engineers, let's play with the classic definition of what constitutes an *engine*. Our earliest dictionaries taught us: an engine is a device that converts energy to mechanical force and motion. The essence of that definition is *creative transformation* – energy to momentum.

That process – energy to momentum – which engineers certainly embrace, speaks directly to the excitement and inspiration of integrative 21st century science and engineering innovation at the frontier. Propelled by advances in genomics, materials, computer-communications, *and* advances in cognition, mathematics and social science, our profession is on the verge of new, exhilarating frontiers.

At those frontiers we look for the integration of vast computing power, massive data sets, and simulation science that will enable us to model, understand, and manage the most complex of systems – physical, biological, environmental, societal and virtual. Moreover, with emerging nanomanufacturing techniques, new materials and systems may be designed and constructed atom by atom.

And an integrated *cyberinfrastructure* is being born that will enrich and continue to revolutionize discovery, learning and innovation in all science and engineering domains. This distributed infrastructure will integrate a range of heterogeneous tools into a common, persistent and widely accessible national infrastructure, which would include advanced computing engines, federated data archives and digital libraries, observing and sensor systems, and other instrumentation.

And so on ... there is a lot of momentum here. These new capabilities promise to shape and benefit the way we live, work, and progress. The world is turning on its axis.

Putting ideas to work is a critical element for innovation if a nation aspires to continued success. The present competition from China and elsewhere is just the beginning of a global economic pattern that will become ubiquitous. To prosper on this playing field, leadership demands being a paradigm ahead, that is, to continually reach the next dimension of capacity to be competitive ... at least for some time to capture the wealth derived therefrom, since everything eventually becomes a commodity.

Constant change, accelerated progress, and increased expectations are emblematic of this new time. One thing is certain – this trend of scientific, technological, and societal transformation will escalate, and while much of what lies ahead is beyond predictability, we can, in the words of Peter Drucker, "look out the window and see what's visible but not yet seen." In other words, if we are astute we can anticipate well. This capability requires that we are well informed about what is, that we continually focus on what could be, and that we take entrepreneurial risk to bring ideas to fruition.

Of course, without a continually refreshed stack of ideas, there is nothing to bring to fruition. Thus, a symbiosis among the idea makers and *entrepreneurs* is an imperative.

Entrepreneurs, whether alone or in a corporate organization, are the bridges between the present and the future. The skills they bring to the melting pot of innovation include a comprehensive understanding of our society's structure, infrastructure and nuances; the present state and future potential of science and engineering; and the creativity and outlook to transform our current situation into the potential that awaits us. This is a formidable portfolio.

In a marketplace economy, entrepreneurs are the disruptive agents of Schumpeter's "creative destruction." Their putting new knowledge to use for things that are new and different literally defines innovation. Robust innovation lifts us to a dimension beyond competition, raising our prospects for an economy of great magnitude.

Innovation moves us forward earnestly, if hand-in-glove with fresh science and engineering knowledge. Discovery and innovation are the twin pillars of 21st century progress. Coupled together, they offer the potential for an era of breathtaking transformation.

Of course, this is a tall order and may feel daunting, but however elusive innovation may feel, it is not an abstract force. Rather, it's what people do to drive change. Innovators break the "rules." It may be a leap of faith to trust them, but trust them we must, or we suffer the quagmire of the status quo. Their, our, stretch to realize new ideas, like all revolutions, alters the fabric of society. Innovators apply knowledge to tasks that are new and different keeping us moving forward.

A nation's need for highest performance in every sector is expanding. U.S. citizens have watched with great satisfaction, the subsequent growth and development of the nation's science, engineering and technology (S, E & T) enterprise. The investment in research and development (R&D) of the past half-century gives ample testimony to the progress made in bringing benefits to society and its citizens.

Warmed by a genuine sense of satisfaction, we are in a position to look toward the future and ask, "What next for the world - how will it turn on its axis tomorrow?" In answering this question, we should be aware of two characteristics that will determine how well we are able to meet the challenge of innovation in our 21st century world: how adept we are in *anticipating the future*, and how wise we are in *shaping it to our ends*.

Looking back, we are struck above all by how startling and visionary the ideas were that shaped the nation's R&D enterprise – and equally by how much we take it for granted today! The new publications I noted are so steeped now in the rhetoric of "innovation" that it's something of a struggle just to imagine how little salience it had two decades ago.

That's an indication of the extraordinary transformations that have swept through our society and our lives during the past two decades. Changes that we scarcely could have imagined 20 years ago are now our common currency. Today, new technologies – and whole industries – emerge in what seems like the blink of an eye.

Many threads intertwined to produce the innovative tapestry that is our nation's S, E & T investment. I'll mention just three, perhaps the canonic three, that will be familiar to you all.

The first is the realization that universities and their science and engineering faculty and students are *critical resources* that can make a valuable contribution to economic development – much the same way that agricultural, industrial and natural resources did in the 19th and 20th centuries. New knowledge at the frontier is our new capital, our engine of innovation.

The second is the notion that *partnerships* – among academe, business and government – can speed the transformation of new knowledge into new products, processes and services, and in their wake produce new jobs, create wealth, and improve our social well being. The wise advice of Woodrow Wilson applies here. "I not only use all the brains that I have," he said, "but all the brains I can borrow."

Third, and perhaps the most radical of the three, is the idea that we can *design* partnerships and institutions to achieve common, long-term goals – in this instance, to bolster economic development and raise the standard of living and security of the nation. "Design," says the architect and ecologist William McDonough, "is the manifestation of human intent." As engineers, we are accustomed to thinking in terms of systems designed to meet specific ends. Applying this directly to the larger context of economic and social prosperity is the radical step.

These three *conceptual* innovation parameters – *knowledge as capital*, *partnerships as transformational*, and *design as intent* – are the heart and soul of what drives today's S, E & T investment.

In anticipating the future, we must recognize that civilization is on the brink of a new industrial world order. Success will not be garnered by those who simply make commodities faster and cheaper than the competition. They will be those who develop talent, techniques and tools so advanced that *competitive capability can be continually robust*.

How will we get from here to there? Standing at the nexus of accelerating scientific and technological change, engineers are expected to foster progress toward a daunting array of ends – creating new knowledge, products, and systems; stimulating economic development; creating wealth and jobs; sharpening the nation's competitive and leading edges; raising our prospects for more creative and satisfying lives; caring for the environment; and strengthening the security of the world and its myriad infrastructures.

With this as a backdrop, I would like to examine some important questions with you. What is the essence of innovation? What attributes do innovators and entrepreneurs exhibit? How do we encourage innovation?

Inspiration is a key characteristic of innovation. In the United States, we have admired and even been enchanted by inspired entrepreneurs. *Life* magazine cited our most famous inventor-entrepreneur, Thomas Alva Edison, as the peak achiever in the last millennium. This non-stop "idea-to-reality machine" beat out queens and kings, scientists and mathematicians, and writers and artists in the *Life* magazine competition. The "Wizard of Menlo Park" was number one in a list of a hundred leaders and thinkers that included Elisabeth I, Galileo, Pablo Picasso, Helen Keller, and Albert Einstein.

Born in 1847, Edison radically changed global society by transforming electricity from a novelty to a household and commercial necessity. Talk about entrepreneurial spirit, Edison cleverly garnered critical investment from a group of Manhattan "movers and shakers" by inviting them to his home and lab for a weekend to see "electric light" and buy into it even when his light bulb device operated for only a minute or so before burning out. Well, I guess they trusted him.

Despite his stellar record of over a thousand patents, Edison believed that, "Genius is one percent inspiration and 99 percent perspiration." In any large-scale societal change, there is a lot of perspiration in the carry-through, but the spark comes from the inspiration. Inspiration is that chaotic and complex moment where past and present knowledge combine to synthesize an idea that stands on the edge of the future. Imagining something is where it starts.

If our goal is to instill entrepreneurship in those we educate and mentor, and in the case of IEEE also serve, then encouraging them to use their imaginations, to be visionaries, and to think creatively is critical. We must teach them to think against the grain; swim upstream; violate the norm.

Albert Einstein believed that "imagination" was the key to *his* work. He said, "Imagination is more important than knowledge." Imagination in the hand of entrepreneurs brings the ability to connect the results of research to society, i.e., to envision. The ability to understand the larger context in which we work - the sector, the society, and even the time in history, the moment in civilization, is crucial to any form of entrepreneurial leadership. Learning to read the larger context provides a path for imagining the future.

Part of *our* task is to mentor others in scanning the big picture for the relevant signals. We must develop acumen for such thinking in our nation's students, beginning engineers and engineers in mid-career. We cannot graduate talented young professionals nor mentor new engineers with supremely specialized expertise that exists in a vacuum.

The ability to read the subtle signals will often make the difference between a nation being an industrial leader or laggard. Reading the tea leaves, so to speak, is not just for mystics anymore. It's a job for mentors, managers, entrepreneurs, and every kind of leader.

The astute "readers of the context" and "imaginers of possible futures" have proven to us that envisioning is a worthwhile endeavor. Envisioning combined with risk-taking is a supercharged combination on the personal level as well as on the level of the economy.

In 1999, the *Economist* highlighted Austrian economist Joseph Schumpeter, in an article on innovators. Schumpeter developed a rule-breaking theory of economics in the 1940s in which he described a "creative destruction" of industrial cycles. As Schumpeter described it, a normal healthy economy was not one in equilibrium, but one that was constantly being disrupted by technological innovation; that is, disruption is the normal state of a healthy, vibrant economy. *Technological innovation* is thus the axis on which our round, flat, spiky world turns. The trick to turning this process into success is having a rational hand on the rotation of that axis, with a capacity to perform no matter how the frontier may move.

Something new and exciting is happening in the 21st century that can help us foster this capability. The borders between discovery, learning, and innovation are blurring.

Increasingly, scientists and engineers, educators, and entrepreneurs are working across many different disciplines, fields and even sectors to make the connections that lead to deeper insights and more creative solutions. The IEEE would do well to emphasize its service to members by fostering ever more robust linkages among its many societies.

We look ahead to exquisite but practical improvements in everything from drug delivery systems to renewable energy resources. I like to think of this as *creative transformation* - the flip side of the coin of *creative destruction*. Focusing on creative transformation can help us act intelligently as we move ahead. It can cultivate a benevolent approach to robust change.

The question for us is: how do we mobilize such an effort? A critical founding stone is to ingrain early on in education that failure is a part of the learning process – if students fear failure they will surely avoid changing the status quo.

As students move on, we need to educate them beyond their technical expertise. The best technical training must be combined with understanding how that expertise fits into the larger societal environment, into overriding national goals, and indeed, into the goals of other nations. Engineers need a good bolt of policy savvy.

Today, the trend in science and engineering research, technology development, and business operations is much more cross-boundary centric. Many disciplines are converging in surprising ways to generate the new knowledge needed for the increasingly complex challenges we face as a society. Today's graduates must be capable of integrating knowledge from a variety of disciplines and working with industry partners to advance that knowledge into innovations.

Engineers, scientists, educators, entrepreneurs, and workers at every level must be able to see functionally beyond the boundaries of their own fields. In the past, when the tools for discovery and application were rudimentary, innovative progress across the frontier of science and engineering was possible only by parsing the frontier into doable pieces that we called disciplines. But today's increasingly exotic tools allow a more holistic attack along the frontier.

If we want to change the way the workforce thinks, and increase its creativity, innovation, and boundary-crossing abilities, we must ingrain these ideas, in partnership with business, while students and engineers are on the path to becoming the workforce we need them to be.

Together, we need to educate today's students and tomorrow's entrepreneurs to think strategically and holistically. They need to be able to read patterns and trends from the larger context to envision the future. And, in particular, integrative, cross-boundary-educated, visionary engineers and scientists are critical components to success in our age of complexity.

In the larger sense, innovation depends upon a synergistic set of interactions that includes not only science, engineering and technology, but social, political and economic interactions as well. We need new arrangements that foster the kind of integration that supports innovation, and the social and economic well being it enables.

If technological innovation is at the heart of progress, the engine turning the world's economic axis, then we need to understand the skills that foster the capacity for risk taking, for imagination, and a tolerance for unfamiliar and uncertain territory. That in turn will mean that our institutions, including the IEEE, must evolve to cultivate these skills.

Innovation and competitive entrepreneurship will always remain an enduring quest, an on-going process. There is no peak that we can reach that will assure continuing success. It is not a matter of sticking to the task for the long haul. It is the "haul."

We will always need to keep improving the process with fresh ideas and a fundamental commitment. We will need to break the right rules and take the right risks. It will be demanding, exciting, and a bit precarious, as the unknown always is.

Engineers will have to be effective collaborators, innovators, risk takers, and communicators, working across shifting boundaries, and embracing diversity. They will need to know the human and social dimensions of technology. Our social and economic progress depends upon it. All of you carry the excitement and the responsibility to make it happen. The contribution of entrepreneurial thinking is to tie the whole package of ideas, knowledge, workforce and institutions together into a productive engine of economic growth. That's not only a big job, but a worthy goal and I am certain that you here in St. Louis today can carry this through!

Today, when we look over the horizon – it's through a world-wide window. Mindful of Drucker's admonition to "look out the window and see what's visible but not yet seen," our view beyond the horizon intimates that the acceleration of our knowledge and its complexity, and the ever-growing appreciation for the interrelated nature of knowledge, already establishes the parameters of the next

revolution: that of the *Integration of Knowledge*. This is the universal window we are now knocking on.

In this quest, all partners must act as the true colleagues we are. We must approach our needs from a collective and integrated perspective. Argument that capitalizes on understanding and integrating our differences is of value; argument that enhances our division is not and works against the inherent unity of our enterprise.

Focusing on diversity of partners, I suggest our thoughts follow something that Bill Wulf asserted eloquently in a 1998 speech he gave during the National Academy of Engineering Annual Meeting: "... in any creative profession, what comes out is a function of the life experiences of the people who do it." Wulf continues: "... sans diversity, we limit the set of life experiences that are applied, and as a result we pay an opportunity cost, a cost in products not built, in designs not considered, in constraints not understood, in processes not invented."

In closing, as Friedman wisely says in his book evoking flatness, "the greatest challenge for our time will be to absorb these changes in ways that do not overwhelm people but also do not leave them behind. None of this will be easy. But it is our task. It is inevitable and unavoidable." As IEEE-USA leaders, this pretty much defines your task in service to IEEE members. Round, flat or spiky, the world is turning on its axis.