Thank you, Dean Baum.

It is great to be back in New York again. Atlanta is a wonderful city, but there is no place quite like New York, and I always look forward to coming here, especially when I have time to enjoy the outstanding theater and other cultural amenities.

As Dean Baum indicated, she has asked me to give you my take on the National Academy of Engineering’s “Engineer of 2020” initiative, which I am privileged to chair. The National Academy of Engineering is made up of the nation’s most eminent engineers, and its mission is to marshal and leverage their knowledge and insights to promote the technological well-being of the nation. The Engineer of 2020 initiative is a good example of one way that can happen. It involves a core group of 18 people, that includes professors and presidents of universities like George Campbell from Cooper Union and myself, as well as engineers from private companies and national laboratories. It even includes a journalist – Peggy Girsham from National Public Radio.

Our work involves two stages: First, to envision the future and anticipate what engineering’s role as a profession might be in that future, and then second, to suggest how engineering education could prepare its graduates for the vision. Our report for the first stage is being finalized, and we are going to start the second stage this summer. The report has not yet been released, so I’m not in a position to say much about the specifics of it. But what I can do is give you my own take on the ideas that come into play in a discussion of the future of engineering, and then look with you at some of the questions and topics that are likely to shape the upcoming discussions on engineering education.

Beginning an exercise by trying to predict the future is no easy task and the Engineer of 2020 participants have had robust debates about it. Of course, some of the realities of the future are already staring us in the face. Over the next 50 years or so, the United Nations projects that the world’s population will increase from 6 billion people to 10 billion people before it levels off. We are faced with the challenge of accommodating an additional 4 billion people without totally destroying the natural resources that sustain life. Within the next two decades, global per capita forest area is projected to fall to one-third of its 1990 value; global warming will bring new threats to coastal lands and to our ecosystems; and virtually every nation in the world will face some type of fresh water supply problem.

Similarly, old problems do no fade away if we ignore them; the timeframe for addressing them just gets shorter. For example, the United States has not kept up with the infrastructure needs of our existing population. The 2003 report card of the American Society of Civil Engineers gave our nation’s present physical infrastructure an overall grade of D+ and estimated that $1.6 trillion would be needed to restore it to health.
One third of our roads are in poor or mediocre condition. Airport capacity has increased by only 1 percent during the past decade, while air traffic has increased by 37 percent, causing dramatic growth in what the aviation industry calls “runway incidents,” which is to say near-misses. New air traffic control technologies are being developed to handle the increasing traffic, but it is hard to install them in a system that can never shut down.

It is estimated that an investment of $11 billion annually is needed to bring the nation’s water systems into compliance with federal water regulations. And when it comes to our sewer systems, some of which are 100 years old, the money we have been investing to upgrade them is falling short by $12 billion a year.

Challenges like these represent the know-able part of the future for engineering, and we can make reliable predictions by looking at the present and projecting it forward. But many other aspects of the future are less certain, and are likely to cause a number of unexpected twists and turns in our path. Events like the terrorist attacks on the World Trade Center take us by surprise, and two and a-half years later, we are still not sure whether we have done all the right things in response or whether we are any safer than we were before. There is clearly an important role for engineering and technology in homeland security, but we’re still grappling with exactly what form it might take.

In other cases, it is technology itself that shifts the paradigm in unexpected ways. Back in 1950, Popular Mechanics magazine printed an article predicting what life would be like in the year 2000 based on what was happening in research labs at the time. It accurately anticipated a few things, like fax machines, teleconferencing, and automated manufacturing plants. But the writer failed to foresee one small invention – the microchip – which sent technology in many new directions. Personal computers and cell phones are nowhere to be found in that article, and instead of e-mail and the Internet, the article imagined the postal service zipping paper mail around in rocket-propelled airplanes. Today we are in the early stages of new developments in biotechnology and nanotechnology, and it is difficult to tell what new discovery or invention might have an impact similar to the microchip and change the effect technology has on our lives in far-reaching ways.

So, to help us get a better sense of what might lie beyond the bend in the road, the Engineer of 2020 group used what is known as “scenario-based strategic planning.” Basically, you identify larger trends and events that could dramatically affect the way the future unfolds, and then you start asking, “What if…?” We explored several possible wide-ranging scenarios, and recognized that the year 2020 might actually reflect any one of them, or a combination of more than one of them… or none of them. At the same time, however, this exercise made it clear to us that the future is not random, nor is it the statistical compilation of a bunch of accidents. Even the unpredictable parts of the future often have a basis in the choices we make today.

So, what are the trends we can see in engineering, and what are the choices we can make to help shape the future? Engineers have been around a long time. They were involved in the creation of the remarkable roads and water systems in ancient Egypt, Greece, Rome, and China. But it was not until the 1700s that civil engineering was formalized as a discipline distinct from military engineering. In those days, it was possible for a single individual to have a grasp of most, if not
all of the scientific knowledge that existed. So it was eminently do-able to have all of engineering contained within one discipline, and for many years all engineers were civil engineers.

Since that time, however, the pace of discovery has been accelerating. Today, the volume of scientific and engineering knowledge is doubling every 10 years, and this, along with workforce needs for new job skills, has driven the emergence of a variety of engineering disciplines with their own distinct identities. *U.S. News & World Report* now ranks more than a dozen different engineering disciplines.

The development of new engineering disciplines has been rapidly followed by the emergence of interdisciplinary fields like biotechnology and nanotechnology. And as the lines between disciplines become increasingly interwoven, the time-honored understanding of engineering as a whole is becoming less distinct. To many it is no longer clear where science stops and engineering starts, or even where engineering stops and business begins. It is enough to make a person wonder if the traditional engineer as a species will even exist 50 years from now, or whether engineering will become indistinguishable among the many overlapping disciplines and interdisciplinary combinations.

Way back when I was a student, you could always tell the engineers by the way they looked – crew cut, pocket protector full of pens and a slide rule hanging from the belt. And they argued for an hour over what the result was going to be of a test they could have run in five minutes. In those days, American companies had no peers, and the largest market for engineers was right here in the United States. So, engineering graduates sought out a job at a great company right here in the U.S. and worked for that company their entire career.

Today, an ocean on each flank no longer holds competition from the rest of the world at bay. We live in a global economy where careers can shift with short notice, and where rapid-fire Internet linkages and growing international talent pools are loosening engineering jobs from their local moorings and moving them to nations like Russia, China, and India. Even after we have pared our costs to the bone, nations like these can still offer a cheaper alternative. Our solutions must not only be cost effective, but they must also be creative and innovative to win in the competitive circumstances we face today.

India and China are emerging as economic powers in part because they have done what our nation is not doing – steadfastly investing in building world-class education systems that produce skilled technology workers like engineers. *BusinessWeek* recently reported that India’s schools are pumping out 260,000 engineers a year who will work for salaries much lower than in this country. China is graduating more engineers than any other country in the world – more than twice as many as the United States – and Russia has a large number of high quality engineers who are welcoming U.S. companies to open shop there.

In stark contrast on the home front, the number of American students earning engineering degrees has been declining since the early 1980s. For a while, we were fortunate to be able to offset that decline by attracting outstanding foreign students to fill our classrooms, and many of them stayed to take jobs in our workforce. However, this trend line has now turned downward, as
other nations improve the quality of their education programs. And those international students who still come are much more likely to return home, because good jobs are now waiting for them in their own countries.

Much about the future is uncertain, but these trends are pretty clear and they are not very encouraging. U.S. engineering stands to be marginalized if we are passive. So, instead of standing on the deck pulling on life preservers as we watch the ship of engineering veer dangerously close to shore, the Engineer of 2020 initiative is an attempt to take control of the helm and steer a course of our liking. We may still hit the rocks, but at least we will try to do it on our own terms.

I believe that if we act, we can provide an exciting new face for engineering and attract our share of the talent pool we need for the future. I even go so far as to believe we have an opportunity to help build a strong future for a long while, IF we are willing to prepare for it.

I’ve already mentioned that the world needs to find a way to accommodate an additional 4 billion people during the next 50 years, and that here in the United States we find ourselves in a veritable pothole for not having addressed the infrastructure needs for our existing population. Embedded in problems and challenges like these are incredible opportunities for engineers to develop new technology and new solutions.

But we must be open to developing and adopting new technologies and new strategies. Why is this important? First, the expectations of the world for engineers are higher than in the past and skilled engineers are emerging in other places. If we offer the same old solutions, decision makers will go elsewhere for better answers. Second, in a world where foreign competition will offer a cheaper alternative to anything we can do, our solutions must be innovative. They must be cost effective not because they are cheap, but because they offer additional value to customers that make them worth the money. The United States is not going to have a competitive advantage among those who provide what is needed at the low end of the economic spectrum. We are at the high end of the spectrum, and our success will be based on our ability to compete with high-end products and services.

So, we need to redefine the traditional economic lingo, images, and perceptions that pertain to low-skill pursuits and refocus them on the high-level, leading edge of the economic spectrum. We have traditionally thought of factories as dusty, greasy, and full of rows of people operating clanking machinery. And while manufacturing of that sort may still be needed to make some products, it will fall at the lower end of the economic spectrum, which we will cede to others to do. American manufacturing of the future will be focused on the highest-possible leading-edge precision technological work that it is not possible to do in other parts of the world. It will involve sophisticated, complex equipment, and American manufacturers are already starting to raise their qualifications for employees. For example, technology and processes at the Timken Company, which is the world’s leading manufacturer of roller bearings, have become so sophisticated that it now looks for workers with bachelor’s degrees for many of its entry level positions.
Our traditional economic lingo also connects the world “services” with low-skill jobs like the typing pool or the cleaning crew. While those tasks will still need to be done, we need to expand our concept of services to reflect the most sophisticated level of business operations. The letters in IBM, for example, stand for International Business Machines, and for many years all IBM did was manufacture office equipment. Today only one-third of IBM’s business is in hardware. Two-thirds of it is providing the software and the ongoing business services that put the hardware into a context that enables its use to be maximized.

Engineering reflects this broader trend. Of course we still need technical, hands-on engineers, just like IBM still manufactures computers. But at the high end of the engineering spectrum, we are seeing the increasing emergence of engineering consulting companies that provide sophisticated services. Instead of physical products and infrastructure, they deal in concepts and ideas. And then they manage and orchestrate a bevy of sub-contractors who do the actual hands-on work.

If we want to maintain our standard of living here in the United States, we need to lead the way at the high end of the economic spectrum, providing sophisticated manufacturing and services that are a step ahead of the rest of the world. To do that, we have to build an economy that is based on innovation. The formula for innovation is invention plus insight. It begins with targeted investment in fundamental research that is balanced across the science and engineering disciplines that are increasingly interacting to produce new knowledge. Then, innovation takes the new knowledge we discover and the new technology we invent and applies them in imaginative ways that create new solutions and new opportunities. Innovation emerges at the intersection of technology with business and the marketplace. It requires not only that we are the first to invent leading-edge technology, but also that we are the first to develop new ideas and new ways to put that technology to work to address needs and solve problems.

About two weeks ago, Georgia Tech was the launch site for the National Innovation Initiative, which is being sponsored by the U.S. Council on Competitiveness. I am privileged to be co-chairing it, together with the CEO and Chairman of IBM, Sam Palmisano – and your president George Campbell is a member of one of our working groups who are at the heart of this endeavor. The purpose of the National Innovation Initiative is to understand and harness the factors and dynamics that promote innovation, so that the United States can take deliberate actions to create a fertile environment for innovation and build an innovation-based economy. We cannot fault other nations for wanting to make themselves more competitive in the global economy. But if we focus on innovation, we can assure our own position and help to create more wealth for the benefit of everyone.

The innovation economy of the future will require engineers who are not only on top of the latest technology, but who are also much more collaborative. Engineers need stronger teamwork skills than ever, and the collaboration that they are a part of will increasingly take place in a virtual environment rather than face-to-face. The Boeing 777, for example, has 132,000 uniquely engineered parts that were designed by hundreds of suppliers in a dozen different countries. Yet no model of the plane was ever assembled to make sure they fit together and worked. The plane was simply manufactured and flown. The design of its parts was coordinated across company
lines and national boundaries using compatible software on networked computers. Parts and systems were pre-assembled and tested at computer work stations.

In today’s economy, speed has become more critical, and the Internet also gives companies an opportunity to speed up the pace without violating one of the most entrenched perks of skilled, professional jobs – the eight-to-five workday. Companies are increasingly using the capabilities of the Internet to in effect create a night shift and get the work done faster. At Bechtel, for example, an engineer in the United States who is finishing work for the day on the design of a power plant, sends his work over the Internet to a colleague in New Delhi, India, who is just arriving at the office to begin the workday and who picks up where the American engineer left off.

Some see this as a trend that will lead to a reduction in U.S. engineering jobs, while others feel it offers U.S. companies the opportunity to compete more readily for global projects. Because this trend will happen regardless of our opinion about it, we need to ensure that we develop the optimal advantages for both large and small engineering firms in the U.S. We need to understand that there are niches in the global economy where our engineering services are highly desired and as a result, will open business opportunities for us.

The engineers of 2020 will also need to be much more aware of the larger context of their work, and more customer focused. We can no longer simply invent technology in a vacuum and put it on the shelf without concerning ourselves about who might use it or what they might do with it. The key question for us as engineers is not merely how can we make a piece of technology better, but rather what can we make it do for our customers that will make life better for them, and for society at large that will make the world a better place.

Let’s think back for a minute to those additional 4 billion people the world will have to accommodate over the next 50 years or so. The pressure points for that population growth will not be in our own developed part of the world, but in less developed parts of the world that lack the basic infrastructure that provides the foundation for the health and gainful employment of their people. In the global environment that now characterizes our world, this is a problem that should concern us. What happens in these nations has consequences for all of us.

The developing world offers engineers a unique opportunity to leapfrog older technologies and bring new technology to the fore quickly. For example, the huge power grids that we have here in the developed world are expensive to maintain and vulnerable to terrorism. But it is very difficult for us to abandon that infrastructure. In the developing world where no such large-scale infrastructure exits, it will be easier to test use new approaches such as hydrogen fuel cells to generate power with small units that are easy to replace, and have the added advantage of generating water as a by-product. If we take the lead in developing such approaches, it will lead to the creation of new business opportunities here at home.

Our future value as a profession will be measured by how indispensable we are in solving the problems society faces. But we have something of a PR problem here. In many respects, engineering is a “stealth” profession that operates below the public’s radar screen. For example, public perception surveys for engineering show that while 85 percent of the general public
believe scientists can help solve our environmental problems, only 5 percent believe engineers have a role to play.

Engineering has always created the technology that enabled humans to prosper, but we have often been behind the curve in foreseeing and understanding the human aspects of technological change. Over the course of the past century engineers invented and put to use a wide range of incredible technology, but we did it in a rather decentralized, disjointed fashion. Now we are taking a look around us and realizing that all of those many disparate engineering efforts have converged to form a world in which technology is pervasive in every aspect of life. And the engineering decisions we used to regard as unrelated to social, political, and economic concerns have in fact become tightly interwoven with them. Technology and social change have become a double helix – two strands that are inextricably interwoven.

Engineers have always been “doers.” But the presence of technology in every aspect of life now calls for us to become “deciders” as well. Joe Bordogna, deputy director of the National Science Foundation, says, “I like to think of the engineer as someone who now only knows how to do things right, but also knows the right thing to do.” The skills and perceptions of engineers make us well suited to play a broader leadership role in today’s technological world, and our challenge is to prepare ourselves and our profession for that responsibility. We need a better understanding of the larger social context and the larger, human dimensions and implications of what we are doing. We must learn to see ourselves as global citizens and our technology as a tool to solve intricate social problems.

For example, global environmental conferences like the ones in Rio and Kyoto make clear the difficulty of finding political solutions to environmental problems. Political solutions invariably call for someone to give up something, and no one wants to volunteer. Engineers can step into the breach created by political stand-offs and offer solutions based on sustainable approaches and innovative technology, enabling economic development and prosperity without jeopardizing the environment.

As technology becomes ever more pervasive in all areas of our lives, the link between engineering and public policy should grow. Now, by public policy I do not mean partisan politics. Public policy involves establishing the legal and regulatory framework within which society operates. Of course, public policy can be driven by partisan politics, and when that happens without the tempering influence of objective technological expertise, the results can be disastrous. Engineers can often do much public good by working to help the public and elected officials understand complex issues. This role cannot be under-estimated and this is true at the most local level as well as at the national or global level.

The opportunity clearly exists for engineering to play a much broader and more significant role in society. But engineering is going to have to position itself to take advantage of that opportunity. Our future success will be rooted in the decisions of today. Part of that positioning process depends on the quality of the engineering graduates we produce, and that, in turn, depends on our education programs and our ability to draw our share of the brightest and best students.
So, let’s turn to the second stage of the Engineer of 2020 initiative, which looks at the future of engineering education. This summer we will tackle this phase by holding a conference of invitees who will examine the question of how we should educate engineers to prepare them for the year 2020 and beyond.

The basic idea is to step beyond the traditional paradigm in which we engineering educators change things after-the-fact in response to an event or a development in society. In my time as a student, for example, the Soviet Union launched Sputnik, and engineering education responded by adding more science-based material to the curriculum. We want to turn that process on its head. We are going to examine bold and innovative ideas in engineering education and think creatively about the coming challenges we identified in the first stage of the process. There is no question that this second phase of this project is going to be as interesting as the first. So, let me give you a little preview.

First, it is important to understand what NOT to expect from this process. Do not look for us to propose a specific engineering curriculum that everyone should be required to follow. If anything, we will probably move in the opposition direction to release engineering education from the constraints of a set, standardized curriculum, so that individual institutions can be more creative in developing unique programs that fit their own missions and their own students.

The same size does not fit all. And rather than one standard curriculum coming from this exercise, I think it is more likely to produce several models that can serve as a framework for education reform. They will probably evolve along a spectrum that ranges from ways to update and energize the standard curriculum at the conservative end, to a radical new approach at the other end.

Engineering educators have not been sitting on their hands. There are already some interesting new models out there, and one of our goals for the Engineer of 2020 initiative is to take a close look at them. Dartmouth University and Smith College are pioneering a curriculum with a humanities focus, for example. The military academies offer a model that incorporates strong leadership training into the engineering curriculum. Institutions like Drexel, Northeastern, Kettering, and my own of Georgia Tech offer models that incorporate a strong cooperative education component. There are also several newly created engineering schools, like Olin, Smith, and UC-Merced, who don’t have to overcome any historical baggage. And we want to see what they are doing with the opportunity to make a fresh start.

We are too early in the process of this phase of the Engineer of 2020 for me to have much to say about it. But I can tell you some of the issues that I think are important from my own experience and that I expect to be on the table for discussion. One of the first questions that always comes up in every discussion of engineering education reform is this: How it can be even remotely possible to incorporate new developments into engineering curricula that are already stuffed full? The answer is only with great difficulty, and probably too slowly, if we continue to think only in terms of what goes on in within the conventional classroom in the course of a conventional four year curriculum.
Of course, new developments can replace old ones, or at least be offered as options to adventurous students. But even if you don’t want to change your curriculum, leadership and communication skills can be taught outside of the classroom or during summer internships. At Georgia Tech, for example, we offer students the opportunity to participate in an identified range of co-curricular leadership development activities, and then we provide them with a co-curricular transcript to go along with their academic transcript.

Engineering educators can also be more vigorous and systematic about building a solid foundation in the social sciences and humanities rather than simply offering the opportunity for a haphazard selection of electives. And we can approach environmental sustainability as a mindset rather than a problem set. Rather than requiring additional courses in sustainability, Georgia Tech permeates our engineering curriculum with an awareness and understanding of the environmental ramifications of decisions and actions, so that our students see their discipline through a prism of sustainability. These are some examples of ways to enrich the existing curriculum without overloading it.

We also need to think about how we can make engineering students citizens of the world. The international collaboration that is increasingly characterizing engineering work will require them to be more knowledgeable and sensitive to broader differences in culture, custom, and the way business is conducted around the world. It has always been difficult to fit traditional study abroad experiences into a curriculum so full of required courses. But we must become more creative with international internships, co-op assignments, and exchange programs with high-quality international engineering schools.

One way to address the challenges facing engineering educators is to develop multiple tracks within our curricula, so that students choose a direction that fits their abilities and goals. We could maintain the standard curriculum as a straight technological track – as I noted earlier, such engineers will always be needed – and develop alternative tracks that offer a stronger focus in other areas.

Another idea that is sure to generate discussion is to follow the trail already blazed before us by professions like architecture, business, and law of making the master’s degree the first professional degree. This would provide more time for the educational process, making room to add in important new elements and skills.

Finally, we need to think broadly about lifelong learning. I believe we should consider placing greater emphasis on a coherent approach to the use of continuing or professional education programs to serve engineers as their careers advance. The most obvious reason to strengthen our professional education programs is that the shelf-life of technological information has grown pretty short, and engineers are finding that their technological knowledge and skills need continual updating.

But it is also clear that as engineers move through their careers and assume greater levels of leadership in business and in society, their educational needs continue to evolve. Surveys of recent graduates from engineering schools indicate that they wish they had taken more technical courses. But by the time they are ten years into their careers, engineers wish they had taken more
courses in business and management. And 20 years after graduation, engineers say they wish they had studied more literature, history, art, and philosophy. A well-structured professional education program can address those changing needs that come with career advancement.

We also need to ask what our responsibility is as engineering educators to help address the abysmal level of technological literacy in the general public. We have become a people with no clue about the workings of the technology we use, and we are not good at anticipating how it might be abused to harm us. Even those with college degrees who use technology often do not understand how it works.

Those are some of the topics that will be discussed in the coming months as the Engineer of 2020 initiative moves into its second phase. Will our efforts to make engineering and engineering education more proactive be successful? I don’t know, but it is exciting to try this new high-risk, but high-pay-off approach as opposed to sticking with a reactive method that will likely cause us to lose valuable time by trying to respond after the fact to a rapidly changing landscape for engineering.