Emerging Technology and its Broad Implications

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When we moved into the 21st century we entered an altogether new world, a world propelled by technology. This is leading to major disruptions in everyone's life, some for the better and some for the worse. For example, the average American's lifespan has vastly improved in the past century, but terrorists acting alone can now profoundly impact the lives of very large groups.

Much of the change that is occurring is attributable to developments in science and engineering. Two advancements especially contributed to globalization, the most profound change of all. I refer to jet aircraft that make it possible to move "things" including people around the planet at nearly the speed of sound, and to information systems that move ideas and information around the world literally at the speed of light.

The result is that, according to Francis Cairncross writing in *The Economist,* distance is dead.

*This version is an abridged version of the full lecture by Mr. Augustine. The full version is available at: **www.stevens.edu/lecture,** where a video of the talk is also available.

In order to fully appreciate the implications of this notion, let's turn the clock back in time 200 million years. Geologists tell us that something over 200 million years ago many of what today are the earth's major continents were joined together in a single "supercontinent" which slowly broke up and the pieces drifted apart. As they did so, their influence on each other diminished correspondingly.

According to economists, in just a few decades globalization has suddenly brought these pieces crashing back together. As Tom Friedman put it in his remarkable book, *The World is Flat*, "Globalization has accidentally made Beijing, Bangalore and Bethesda next door neighbors."

Change comes rapidly in the Global Village. One of the more profound consequences of globalization is that Americans no longer compete for jobs simply with their neighbors down the street…rather, they must now compete with highly motivated and increasingly well educated neighbors all around the globe.

There are already numerous real-world examples of the Death of Distance to be found in our daily lives:

- To repair a problem with the television receiver in our cabin in Colorado, I spoke with customer service experts in Denver, Jamaica, Indonesia and India.

- To better prepare students for jobs in call-centers in India, courses are offered on how to speak with a mid-western accent and some workers are encouraged to adopt a pseudonym that will make American callers more comfortable.

- Visitors to a firm's offices in Washington, D.C. are greeted by a receptionist whose image–live from Pakistan–appears on a flat-screen display mounted on the wall.

- The C-T scans of patients in a number of U.S. hospitals are now read in near real-time by radiologists in Australia or India.

- "Pilots" at consoles in Nevada fly unmanned aerial vehicles that attack targets in Afghanistan, then drive home in time for dinner.

- And a patient in France had his gallbladder removed by a surgeon in New York using a remotely controlled robot.

Ironically, in this new world order, it will be the "established" nations that are most challenged. Why? Well, for starters, nine factory workers can be hired in Mexico for the cost of one in the United States. Likewise, five Chinese chemists and eight Indian engineers cost the same as one of their counterparts in the U.S. Over time, wages will rise in the developing countries, but because of the sheer size of their potential workforces it will take decades to approach equilibrium, particularly for the less-skilled portion of the workforce.

Since the year 2000, *one-third* of all U.S. manufacturing jobs—5.5 million jobs—disappeared. Forty-two thousand factories closed. It isn't only factory workers who are being affected . This is a "full-spectrum problem," impacting accountants, dentists, radiologists, architects, professors, scientists, engineers, and even basketball and baseball players. In addition to the factories that are moving abroad, the list now includes research laboratories, administrative offices, financial centers, prototype shops, and more.

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A job is the foundation of an individual's standard of living as well as of the nation's tax base that enables our government to provide the many services to which we have become accustomed, ranging from national defense to healthcare and from education to social security.

We may be entering an era of sustained unemployment because of enduring structural flaws in our economy. The future real unemployment rate may well be closer to today's than to that of the historical past.

Concerned over this prospect, the U.S. House and Senate seven years ago asked the National Academies of Science, Engineering and Medicine to examine what will be required if America is to be competitive in the new global marketplace. In search of an answer, the Academies formed a 20-member committee composed of individuals with highly diverse professional backgrounds that included public and private university presidents, Nobel Laureates, CEOs of Fortune 100 companies, former presidential appointees, and the head of a state public school system. Upon completion of our work, two of our members took positions in President Obama's cabinet, one as Secretary of Energy and the other as Secretary of Defense.

The committee, which became known as the Gathering Storm Committee after the title of our report, concluded that the only reasonable answer to the global competitiveness challenge facing America is through leadership in *innovation*. That is, creating new knowledge through leading-edge research; applying that knowledge to produce new products and services through world-class engineering; and being first to market with the resulting products and services through extraordinary entrepreneurship.

The Academies' conclusion was strongly influenced by the substantial number of studies, one of which was the basis of a Nobel Prize, that demonstrate that over the past half-century 50 to 85 percent of the increase in the nation's GDP has been attributable to advancements in science and engineering. So too is two-thirds of the nation's increase in productivity—both strong indicators of the creation of jobs and improvement in the standard of living.

While the Gathering Storm report emphasized the importance of science and engineering, it did not focus, *per se*, on jobs for scientists and engineers. Scientists and engineers now comprise less than five percent of the nation's workforce, but the work performed by that five percent disproportionately creates jobs for the other 95 percent.

For example, the invention of the iPad, the Blackberry and the iPhone, all rooted in much earlier work performed in solid state physics and quantum mechanics, created jobs not only for scientists and engineers but also for factory workers, salespersons, advertisers and even musicians. A recent study reported in the Journal of International Commerce and Economics states that in 2006 the 700 engineers working on Apple's iPod were accompanied by 14,000 other workers in the U.S. and nearly 25,000 abroad. Meanwhile, Steve Jobs told the president of the United States that the reason Apple employs 700,000 workers abroad is because it can't find 30,000 engineers in the United States.

Other nations have not overlooked this proposition—for example, China, where as many as seven of its eight top leaders have held degrees in engineering. This is what Wen Jiabao, Premier of the State Council of the People's Republic of China, had to say on the subject: "The history of modernization is in essence a history of scientific and technological progress. Scientific discovery and technological inventions have brought about new civilizations, modern industries, and the rise and fall of nations…I firmly believe that science is the ultimate revolution."

Probably the greatest economic advantage the U.S. enjoys today, other than our democracy and free enterprise system, is the strength of our great universities. Many studies place the majority of the world's top universities within the U.S., but it is becoming more and more apparent that we are living off of past investments. Suddenly, and unexpectedly, as state and local tax revenues declined precipitously due to the economic downturn this past decade, U.S. institutions, particularly the public ones, find themselves facing severe budget shortfalls. Over the most recent decade our state research universities—that educate 70 percent of our scientific and technological degree recipients—have on average suffered a 24 percent budget cut, not including the effect of inflation. State funding for colleges and universities per student is now at a 25-year low.

If a developed nation is to create jobs for its citizens in an era of globalization it is clear that it will need a sizeable, world-class education system, particularly in science and engineering. But today, only 16 percent of U.S. Baccalaureate degrees are awarded in science and engineering, compared to 47 percent in China.

And that brings us to our elementary and secondary education system, the source of domestic science and engineering candidates. Despite our many outstanding schools, teachers and students, in international tests in math and science, U.S. K-12 students on average are firmly ensconced near the bottom of the global class.

You may recall how strongly Americans reacted when we discovered a few years ago that our Olympic

basketball team was no longer first in the world, yet we seem remarkably indifferent that we now rank:

6th in innovation-based competitiveness
10th in percent of adults with college degrees
16th in college completion rate
20th in high school completion rate
23rd in science proficiency of 15-year-olds
48th in the quality of overall K-12 math and science education

In most of these areas the U.S. ranked number one only a decade or two ago.

One thing that is not the problem is a lack of investment in K-12 education. The U.S. spends more per student, totaling 7.4 percent of the GDP, than any other country with the exception of Switzerland. The worst performing schools in the nation are in Washington, D.C.—which just happens to be where the most highly funded schools are to be found.

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Perhaps not surprisingly, the Hamilton Institute reports that the median real income of men in the U.S. between 25 and 64 years old fell 28 percent over the forty-year period prior to 2009. In the case of high school graduates who did not attend college, the drop was 47 percent.

McKinsey consultants linked GDP—a not unreasonable surrogate for the standard of living in a country with a relatively stable population—with K-12 educational achievement. It concluded that if U.S. youth could match the academic performance of students in Finland, our economy would be between 9 and 16 percent larger. That is about two trillion dollars—the equivalent of nearly three of the recent stimulus packages, *each and every year.*

The American Dream simply does not happen without quality education for all youth. During the 25-year period between 1979 and 2004, the real after-tax income of the poorest one-fifth of Americans rose by only 9 percent while that of the richest one-fifth rose by 69 percent—and that of the wealthiest one percent by 176 percent.

One must ask what kind of a nation it is if 34 percent of males between the ages of 16 and 24 having only a high school diploma are unemployed, with little hope of employment. And that does not include those who have given up looking for a job. Or when the one-quarter of students who drop out of high school have a 63 times greater chance of being incarcerated than those who

graduate from four-year colleges.

And, the requirement for higher education in the workforce is gaining momentum. A Georgetown University report states that in 1973, 72 percent of jobs were available to workers who had either a high school diploma or an incomplete high school education but some on-the-job training, whereas by 1992 this number was down to 44 percent, and by 2007 it reached 41 percent…and it is still declining.

Given the situation that exists in grades K-12, it is not surprising that the nation's supply of engineers and physical scientists has become a significant concern to most U.S. corporate executives. During the past two decades, part of an era that has been described as technology's greatest period of accomplishment, the number of engineers, mathematicians and physical scientists graduating in the U.S. with bachelor's degrees actually *fell* by over 20 percent until a very recent up-tick—the latter largely propelled by an increase in foreign students.

One popular misconception which prevents some young people from pursuing STEM education is that the STEM professions do not pay well…a conclusion often fueled by comparisons with the extraordinary compensation received by a comparatively few individuals working on Wall Street. Overall, STEM workers earn 26 percent more than their non-STEM counterparts, and earn more than the latter group even when employed in non-STEM occupations. The most common undergraduate degree among Fortune 500 CEO's is an engineering degree. Further, following the 2008 financial crisis, when overall unemployment exceeded 10 percent, it peaked at 5.5 percent in the STEM fields.

Exacerbating the dilemma we face in producing scientists and engineers is the enormous leakage in the talent pipeline. Consider the following scenario based upon a little arithmetic of my own. If you need one additional engineering researcher possessing a PhD in the year 2029; you will need to begin today with a pool of about 3,000 students in 8th grade in the U.S. public schools.

A strong case can be made that America's science and engineering enterprise would barely function were it not for the contribution of foreign-born individuals who have come to this country to study and elected to remain and contribute here. Immigrants make up 12 percent of the U.S. workforce, yet 52 percent of the PhD-holders under the age of 45 working in the "hard sciences" are foreign-born. Immigrants started one-fourth of all successful high tech companies in recent years, and 18 percent of the Fortune 500 were founded by immigrants. This latter figure grows to 40 percent if the children of immigrants are included.

Yet another problem is the lack of women in engineering. Women, comprising about half the nation's population and 58 percent of its undergraduate degree recipients, receive only 20 percent of the engineering bachelor's degrees and 19 percent of the engineering doctorates awarded by U.S. universities. In contrast, they now receive a majority of the degrees in law and medicine.

Members of minority groups receive even more disproportionate shares of science and engineering degrees. For example, African Americans and Hispanics, separately making up about 12 percent of the

total U.S. population, each receive fewer than five percent of the bachelor's and doctorates awarded in each of these fields.

What is critical is for the U.S. to produce and retain a cadre of engineers who are innovators, who are risk-takers and entrepreneurs—because these are the people who produce most of the new jobs.

Turning to the subject of research—the fount of knowledge—the total federal annual investment in research in the fields of mathematics, engineering and the physical sciences is about equal to the amount by which U.S. healthcare costs *increase* every ten weeks. In the case of granting U.S. patents, the number of domestic grantees has already been surpassed by foreign grantees. After decades of ranking first in research publication impact, the U.S. has fallen to third place.

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One might reasonably argue that investing in research should be the province of the nation's industrial sector, since industry is a major beneficiary of its results. But a survey conducted by the U.S. National Bureau of Economic Research reveals that 80 percent of the senior financial executives questioned said they would be willing to forgo funding research and development in order to meet their public projections of near-term profitability. Constructive or not, the reality of the financial markets is to emphasize short-term results at the expense of long-term, high-risk endeavors—such as research.

All of which is to say that our nation's future resides to an ever increasing extent upon our federal government providing the funds needed to support research that will largely be conducted in the nation's universities. The great industrial research institutions such as Bell Labs, home of the laser, the transistor and numerous Nobel Laureates, have seen their best days.

Lastly, let me briefly turn to the Innovation Ecosystem. The story here is no more pleasant than the previous two issues I have addressed, research and education. American firms now spend over twice as much on litigation as on research. General Motors spends more on healthcare than on steel. Starbucks spends more on healthcare than on coffee. The U.S. has the highest overall corporate tax rate of any industrialized nation, backed by a 3.7 million word, 17,000-page tax code that only a (well-paid) accountant can understand. And the U.S. patent system suffers flaws of such magnitude that many companies now deem seeking a U.S. patent to be a liability. The availability of venture capital, an important U.S. advantage in the past, is no longer a discriminator since that money is now being invested in promising new opportunities on a global basis. Then there is the matter of excessive regulation in some areas.

One of the first responsibilities of government in a free enterprise system is to conduct its own affairs in a responsible manner such that it creates an environment in which the private sector has the opportunity to contribute and prosper. However, letting market forces solve our problem, from a U.S. perspective, is the problem. Market forces *are* solving the competitiveness problem. Individual companies are doing so by creating jobs *outside* the United States.

The bottom line is that the path the U.S. is currently pursuing is likely to lead to prosperous U.S. companies with their research laboratories, engineering facilities, factories, customers—and jobs—largely located abroad.

Some months ago while I was testifying before a committee of the Congress in support of increased investment in education and research, a member asked, "Mr. Augustine, do you not understand that we have a budget crisis in this country?" I responded by saying that I was aware of that but I am an aeronautical engineer and during my career I have worked on a number of airplanes that during their development programs were too heavy to fly. Never once did we solve the problem by removing an engine.

In the case of creating jobs for Americans, it is research, education and entrepreneurialism that *are the engines* of in novation and the creation of jobs.

I am often asked if I am an optimist or a pessimist. I usually answer by quoting the old sage that says, "A pessimist is a person who wants to be an optimist but has a grasp of the facts."

On the other hand, Winston Churchill once said that you can always count on the Americans to do the right thing, after they have tried everything else.

In this case, we had better get it right…soon.

Thank you.