“The Nation’s Research Agenda at a Crossroads”
Georgia Tech President G. Wayne Clough
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(TITLE SLIDE)
Thank you, Dean Tumay, for that kind introduction and for inviting me to be here today. It is an honor and a pleasure to be at LSU and to participate in the Chancellor’s Distinguished Lectureship Series.

Mehmet Tumay is a fellow geotechnical engineer and an old friend. We are both fellows in the American Society of Civil Engineers and have been active in many of the same professional organizations, including the U.S. Universities’ Council on Geotechnical Engineering Research. I am honored to be here as his guest, and I hope to return the favor and invite Dr. Tumay to visit Georgia Tech if he is coming to Atlanta for the Council’s annual meeting next month.

My talk today is entitled “The Nation’s Research Agenda at a Crossroads,” and before I describe that crossroads, I want to set the context for the challenges we face.

(WILLIAM CLARK QUOTE)
At the 1999 annual meeting of the European engineering education society, Juergen Mittelstrass gave a talk that he called “Technology and Responsibility.” He said that over the course of history, we have gone from living with a little technology in the midst of a large natural world, to living in a vast labyrinth of technology in an ever-smaller natural world. He called this technological world of today a “Leonardo-World” after Leonardo da Vinci.

The “Leonardo-World” is not a natural system, but an artifact. Over the course of human history, we have increasingly used science and technology to take the natural world into our own hands and make it our own work. As a result, the problems confronting society are increasingly likely to be the consequences of our own inventions, rather than simply arising from natural causes. These consequences fall into two categories – the obvious and the unexpected.

(KOFI ANNAN QUOTE)
The first group is fundamental, powerful, and staring us in the face. We know we have to address these problems, and the timeframe for doing so keeps getting shorter. For

example, a major United Nations report released about a year ago entitled "Global Change, Global Opportunity" indicates that 40 percent of the world's population faces water shortages and a billion people lack safe drinking water.

Climate changes and the continuing destruction of wildlife habitat are creating new health problems. Drought, for example, favors the species of mosquito that spreads West Nile virus, while diminishing the dragonflies and amphibians that help keep the mosquito population in check. And as people encroach on wildlife habitat, diseases are increasingly making the jump from animals to humans. AIDS jumped from chimpanzees to humans. In sub-Sahara Africa, it has spread to the point where it has lowered the average life expectancy by up to 30 years, and it is expected to kill 150 million in China and India.

We know our well-being as humans depends on addressing problems like these that lie directly in front of us, and we can focus our research efforts very specifically on providing solutions.

(GROUND ZERO)
Other consequences are not so obvious. Events sometimes take us by surprise, and we scramble to adapt the technology we already have to meet new needs. The terrorist attacks of September 11, 2001, are certainly a good example, and we are still trying to organize our response to that new reality. In this case, it is not only new technology that is required, but also new approaches to security and communications.

(MRI PHOTO)
In other cases, something that has seemed unimportant or esoteric takes on new significance because of an unexpected shift in the paradigm. We tend to predict the future by projecting the present forward in a straight line, but in reality the path is full of twists and turns, often caused by the emergence of a new technology.

Back in 1950, *Popular Mechanics* magazine printed an article predicting what life would be like in the year 2000 by extrapolating 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 the microchip, which sent technology in 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.

(QUOTE)
The unforeseen events and unexpected twists of technology are reminders of the message on a plaque outside the National Archives in Washington, D.C. It says, "The heritage of the past is the seed corn that brings forth the harvest of the future." We cannot predict the future accurately, but we can make a careful investment in fundamental science and technology research that sets a positive course for the future and provides generations to come with the foundation they will need to solve the unknown challenges they face.

(KEYSTROKE: KRUSHCHEV FLIES IN) The strong economy we enjoyed during the 1990s was not so much due to Alan Greenspan or Bill Clinton or even Bill Gates as it was to Nikita Khrushchev. He challenged us to an arms race and a space race, stimulating the federal government to invest seriously in fundamental research in critical fields like physics, chemistry, and electrical, computing and mechanical engineering. Yes, it was largely for defense, but the spin-off effects of those investments generated inventions like semiconductors and the Internet that continue to drive our economy today.

(FEYNMAN AND PRODUCTS)
The time span from the basic research to the working implementation of a technological application is often decades, and it is not always clear in the early stages who will benefit from fundamental discoveries. When physicist Richard Feynman introduced the new field of nanotechnology to the American Physical Society in 1959 in a lecture entitled, "There's Plenty of Room at the Bottom," I doubt that anyone present in their wildest imaginations envisioned the commercial applications that are emerging today. They include, for example, stain-resistant clothing, self-cleaning windows, women's cosmetics, and running boards for vans. By the same token, I doubt that General Motors, Eddie Bauer, or Revlon Cosmetics, in their wildest imaginations ever thought of investing in the frontier research that generated the nanotechnology from which they are now profiting.

The new products and services we see are just the eddies that swirl around on the surface. They are driven by deep, steady currents of frontier research and knowledge that often have been flowing for decades before the surface eddies appear. So, one of the issues facing us at the crossroads is the balance between the "R" and the "D" of R&D. And through the years, that balance has been leaning toward the "D."

(LINE GRAPH: SOURCE OF RESEARCH)
As you can see here, over the past 40 years, the federal government and private industry have switched places in the proportion of our national R&D that each

conducts. Back in the early 60s, the federal government funded about two-thirds of R&D and private industry conducted about one-third. The two lines crossed around 1980, and today industry conducts almost 70 percent of the nation's R&D, while the federal government drives less than 30 percent. However, this is not a quid-pro-quo exchange.

(2 BAR GRAPHS)
Increased competition has intensified industry focus on the bottom line. As a result, industry, which is indicated here by the gray bars, is heavily vested in development and application. According to the National Research Council, the computer and semiconductor industries, for example, allocate less than 5 percent of their research expenditures to basic research.

Looking at basic research on the right side of each graph, you can see that federal government, indicated in bright blue, is the primary funder and that universities, indicated in light blue, are the primary performer based on federal grants and contracts. So, when the federal government and private industry changed places in the proportion of the R & D portfolio that each funded, that also indicated a portfolio shift away from basic, fundamental research toward application and development.

A similar shift is reflected in the federal defense portfolio. In decades past, fundamental defense research was a driving force for technology development in the broader economy. Today, that is pretty much reversed. It is more a case of beating plowshares into swords, as innovations created by the private sector are adapted for military use.

We are clearly enjoying the harvest from the fundamental research of prior decades. But are we fulfilling our responsibility to plant the seed by conducting the fundamental research the next generation will need to generate prosperity and address the dilemmas of its world?

(BAR GRAPH: COMPOUND R&D RATES)
Another important consideration is how we stack up in the international arena. The United States spends more money than any other nation on R&D, and President Bush has seen to it that our total outlay now exceeds $100 billion for the first time. However, our R&D expenditures are heavily focused on defense-related activities, while other nations focus a much larger portion of their R&D activities on basic, long-term knowledge discovery.

We also are not increasing our R&D expenditures as rapidly as a number of other nations. In the longer term, I would suggest it is wise to ask ourselves how this pattern affects our ability to be a leader in developing the knowledge that will lead to the next generation of new technologies and drive future economic miracles.

(LINE GRAPH: HEALTH LEADS)
A second challenge we face has to do with the balance of federal funding across the various disciplines. When the Cold War ended, the pressure to fund defense research eased, and Congress and the White House shifted the research emphasis toward health. The new goal was to double the budget of the National Institutes of Health over a five-year period. In fact, NIH went from receiving 32 percent of federal research funds in 1993 to receiving 40.4 percent in 2000. No one disputes that this increase will have tremendous benefits, but it behooves us to look at the question of balance, or lack thereof, in federal funding of research.

(YELLOW/BLUE BAR GRAPH)
While research funding for NIH was increasing, federal funds for the physical sciences and engineering were not doing too well. The problem with advancing some disciplines at the expense of others is that both the most important problems and the hot-beds of discovery and innovation are in the gaps between the traditional disciplines. This convergence of knowledge across the disciplines requires that they all move forward together.

Advances in biomedical research, for example, are grounded in fundamental research not just in biology, but also in chemistry and physics, and in electrical and mechanical engineering, which provide insight into the operation of living systems. Yet these disciplines have seen a declining level of federal support over the past decade. University faculty in these areas have compensated by being more aggressive in seeking and obtaining research contracts from private industry. But, as I noted a moment ago, this supplants long-term research with short-term application and development.

(4 PICTURES & QUOTE)
Congress is presently seeking to correct this imbalance by shifting its attention to increasing the budget of the National Science Foundation, which is laudable, but setting things to right will not be that neat and tidy. Research in the physical sciences and engineering is spread across a number of agencies. The single largest supporter of basic research in the physical sciences, for example, is not the NSF, but the Department of Energy, which provides more than 40 percent of the funding.

Congress organizes the federal budget according to 20 different functions or missions, and research expenditures occur in 15 of the 20. They are spread across about a dozen appropriation bills, which are handled by as many different congressional committees.

At the administrative end, 28 federal departments fund science and technology research. No single federal agency serves as a "fly-wheel" to provide balance and make sure all disciplines are in a position to contribute fully to the growing interdisciplinary mix. It is difficult not only to balance resources among scientific and engineering fields and disciplines, but also to insure that our national priorities are being addressed in a coordinated way.

The questions facing us at the crossroads include: How can we structure governmental bureaucratic procedures to allow for the dynamic nature of the research enterprise to drive the decisions? And who will be tasked with seeing that federal research investments taken as a whole are serving our national expectations and goals?

(ENGINEERING ENROLLMENT)
In addition to financial capital, research also requires human capital. Even as our Leonardo-World offers a growing number of virtual experiences, research is still very much a hands-on endeavor. Without warm bodies in the lab, we are unlikely to get very far. Unfortunately, the United States has been falling behind in graduating scientists and engineers. We now rank 14th in the world in the proportion of 24-year-olds who have a bachelor's degree in science or engineering, down from second in 1975. Engineering enrollments especially have suffered. China now produces twice as many mechanical engineers as the United States.

(3 LINE GRAPHS)
We also have issues with women and minorities. The social, behavioral, and life sciences do a much better job of attracting women and minorities than engineering and the hard sciences. However, workforce growth during the 90s consisted largely of women and minorities. The fastest growing sector of the population is now Hispanics, who are the least likely to be proportionately represented among the nation's scientists and engineers. The second-fastest growing sector is African Americans, who are the second least likely to be proportionately represented among scientists and engineers. White males, who have shrunk to just 40 percent of the overall workforce, still comprise nearly 70 percent of the engineering, science, and technology workforce. The new demographics are clearly out of synch with the new economics.

(S&E DOCTORATES)
At the doctoral level, the number of PhDs awarded in the sciences peaked in 1998, then declined 3.6 percent in 1999. PhDs in engineering peaked earlier, in 1996, and had declined by more than 15 percent by 1999. The enrollment of white males is flat, and we are only seeing slight increases in women and minorities.

(QUOTE: "WITH A DROP…")

This problem of human capital is closely linked to research funding. Fields in which federal funding for university research declined during the 90s also experienced declines in graduate enrollments and doctoral degree recipients. From 1993 to 2000, the number of full-time graduate students in physics declined by more than 20 percent, for example, and the number in chemistry declined by almost 10 percent. This trend is not simply an expression of a decline in federal fellowships. It is evident in the broader graduate student body and is, in fact, strongest among students who are not receiving any federal assistance at all. Graduate students view levels of federal funding for research as a broad bell-weather for career opportunities, and if the research money isn't there, neither are they.

(S&E DOCTORATES)

If we return to that graph on doctoral degrees in science and engineering for just a moment, you can see that the largest enrollment increase has been in international students. Over the past several decades the United States has become increasingly reliant on international talent in its science and engineering research. By the late 1990s, almost half of the PhD students in disciplines like engineering, computer science, and math at American universities were from other countries. However, that cannot be a long-term solution, and you can see that the trend line is already indicating that it has run its course.

(US, EUROPE, ASIA GRAPH)

The Immigration and Naturalization Service has been cracking down on student visas since 9-11, making it more difficult for students to come here. At the same time, however, the students are discovering that they don't really need to come. Other countries increasingly offer quality PhD programs in science and engineering. Europe passed the United States back in the late 80s in the number of doctorates it awards in science and engineering, and if you extrapolate the line for Asia, you can see that they have passed us as well.

(GRAPH: STUDENTS REMAIN IN US)

What's more, the international doctoral students that we still have are showing an increasing tendency to return home. This reflects the fact that white-collar jobs have begun to flow out of the United States to countries like India, China, Russia, Costa Rica, and the Philippines. These countries offer an increasing pool of educated workers who are fluent in English and will work for a fraction of an American salary.

We weren't too worried when textile, steel, and other low-skill manufacturing jobs left our shores for Asia and Latin America two decades ago. But the other shoe has now dropped. Higher-end, white-collar work in information technology, accounting, engineering, and human resources is now flowing overseas. And it has happened much more quickly than with manufacturing. After all, manufacturing demands large physical facilities and expensive equipment, while IT and helpdesk jobs only require a desk, a computer, and an Internet hookup.

(GARTNER, FORRESTER)
Over the summer, research and consulting companies like Gartner, Forrester Research, A.T. Kearney and Deloitte Consulting issued high-profile reports warning about the increasing migration of high-quality jobs. The primary reason for the exodus is cost. The $5,000-a-year computer software programmer has become the newest global economic reality.

Boeing laid off 5,000 American engineers and simultaneously hired replacements in Russia with salaries as low as $5,400 a year. The union at their home base in Washington state threatened to walk, forcing the company to scale back its Moscow operations – for the time being.

Microsoft, Intel, Hewlett-Packard, Proctor & Gamble, Eastman Kodak, American Express, and AT&T all have been moving their call centers and other tech services to the Philippines. The world's 100 largest financial companies plan to move a million back-office jobs to India during the next five years. Oracle has already moved 2,000 software development jobs to India. General Electric has a workforce of 20,000 there.

Microsoft recently announced a $400 million investment in India. The company is already investing $750 million over three years in China. Microsoft's Beijing lab has 180 programmers, one third of whom hold PhDs from American universities. They were instrumental in developing the "digital ink" that makes handwriting show up on the new tablet PCs.

Companies are also moving jobs offshore to facilitate round-the-clock operations. One of the most entrenched benefits of a white-collar job is that you don't have to work the night shift. A global workforce enables companies to parlay the nine-to-five workday into a 24-hour operation. In fact, IBM squeezes 32 hours of software writing into a 24-hour day by relaying the work around the globe in tandem with the time zones from the United States to Latvia to India to China and around to the U.S. again for the start of the next workday,

(INDIA)
The rise of an integrated, global knowledge-based economy is clearly a blessing for developing countries, where it will do more and do it quicker than economic hand-out programs ever could. India is attracting Western jobs because it has 520,000 IT engineers with entry-level salaries of $5,000 a year. That salary may sound appalling low to us, but it is a princely sum in a country where the average capita income is only $500 a year.

It is less clear what this shift in high-skill jobs portends for the United States. For the moment, it has made the recent economic recovery an anomaly, with jobs continuing to disappear even as economists claimed the recovery was well underway. It is also depressing wages for tech jobs, which had soared during the 90s. In 2000, senior software engineers could command $130,000; today they average only $100,000. Average salaries for entry-level helpdesk staff have dropped from $55,000 to $35,000.

(BUS WEEK QUOTE)
The United States has managed to realize a net gain from previous waves of economic globalization. Strong economic growth and innovation enabled us to replace lost auto and textile manufacturing jobs with more and better job opportunities. Can we do it again as job migration moves up the food chain to skilled mid-level professional positions?

We clearly cannot compete on a cost or price basis. If we were to take a brute force approach and try to stop American companies from outsourcing overseas, it would only undermine their competitiveness. If the United States is to maintain its economic leadership and sustain its share of high-end technology jobs, we must prepare for this new wave of change. While there is no consensus on exactly what to do at this stage, it is agreed that innovation is the key. Our goal must be to compete on a higher level with innovation and cutting-edge job expertise. To maintain our position, we must keep on innovating and creating the next generation of leading-edge industries and high-paying jobs.

(CROSSROADS CONCERNS)
Which brings me back to the place where I began. Nobody knows exactly where the next big innovation will come from. But we can be the ones who discover it and take competitive advantage of it. We can continue to be the master of innovation, the leader in developing the next generation of tools and products in emerging fields like nanotechnology. But to do that, we must be willing to address the issues facing us at the crossroads. If we are to drive significant advances in products, services, defense, and

health 20 years from now, we need to achieve appropriate balances between the "R" and the "D" of R&D and across the various science and engineering disciplines.

If we are to be effective in supplying the nation with the workforce it needs to compete, we must revitalize our education programs and attract increasing numbers of students to science and engineering, especially women and minorities. If we are to survive this latest realignment of the global workforce and continue to thrive economically, we must focus on developing our ability to innovate.

(BEYOND CROSSROADS)
If we meet these three challenges, we can continue to lead the global economy into the future. If we are willing to give focused and balanced attention to research, we can develop the next generation of products that will take time to reach the commodity stage where others can build them more cheaply than we can. We can also reconstitute more traditional industries and give them a new competitive edge with innovations in fields like logistics. And we can capitalize on the cheaper products coming from other countries, using them in innovative ways to improve the productivity of our existing industries.

If we are willing to make our educational experience proactive rather than reactive, we can prepare our students to be the workforce for the world as it will be in the future rather than as it is today. Even though the jobs that are being outsourced are skilled, they still are not leaving our shores until they reach the point where they have been made routine. We must break away from the idea that education is pouring information into our students like tea into a cup. Our goal must be to educate workers who are prepared to embrace rapid change and to model the next generation of jobs.

We are still the technological leader of the world, but we are no longer unassailable. All of the positive outcomes we would like to see require us to maintain our long-term capacity for innovation. Our most competitive and innovative industries of today were built on the discoveries of yesterday's research, and it is up to us to sustain the vision and conduct the research that will make prosperity possible for our children and grandchildren.