

REMARKS BY GEORGIA TECH PRESIDENT G. WAYNE CLOUGH
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It is a pleasure to be with you and to have an opportunity to spend a few moments talking about the opportunities and challenges facing the nation's research enterprise and our research universities. Let me first thank all of you for serving on the National Science Board, since your role is crucial at this time.

We live in an era of contradictions about science and technology and about the role of our nation's research universities, and we are reminded of them almost daily by the media. Technology is seen by many as a threat to the existence of the natural world, but at the same time it also is understood to be one of the great hopes for the survival of the natural world. Research universities are criticized for their impersonal approach to education, but they are highly sought out by prospective students and their parents. University faculty for years have been called unresponsive to the needs of society and industry, but recently they are seen as too driven by interests in commercial ventures. These are but of the few issues that reflect the growing interest, for better or worse, in the role of science and technology and research universities in society. Expectations have never been higher, but there are challenges in terms of the choices we have to make, how we insure they work to the good of the Earth, and how we manage the public perception that goes with them.

At the 1999 annual meeting of the European engineering education society SEFI, Juergen Mittelstrass gave a talk that he called "Technology and Responsibility." He said that over the course of history, we have gone from having 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. We have used science and technology to take the natural world into our own hands and make it our own work, and the problems confronting us are increasingly likely to be the consequences of our own inventions rather than natural forces. The science and engineering decisions we used to regard as unrelated to social, political, and economic concerns have now become tightly interwoven with them. Technology and social change have become a double helix – two strands that are inextricably intertwined.

It is worth our time to consider some of the daunting changes we face. The world's population passed 6 billion in 1999, and the United Nations projects it will reach 10 billion later this century before it levels off and begins to decline. These new residents will require two billion new jobs to support themselves, requiring job creation at a pace equaling our best rate in the past. So far we have managed to increase the food supply as the population has grown, but that effort is now depleting water supplies faster than they are renewed. By the year 2025, 3 billion of the world's people are expected to live in places where fresh water resources have fallen below sustainable levels.

More than a third of the Earth's land mass has been degraded beyond recovery on a human time scale and we have destroyed 55 percent of our tropical forests, which serve as habitat for half of

the Earth's biological species. Over half of the U.S. population now lives in areas where air pollution is significant enough to aggravate respiratory problems and cause long-term lung damage.

In December of 1999, the chief meteorologists of Great Britain and the United States issued a rare joint statement indicating that the 90s were the hottest decade of the past 1,000 years, that global warming is now changing the world's climate rapidly. As if to add an exclamation point to this statement, a piece of ice the size of Rhode Island broke off of the Antarctic Larsen B ice shelf this spring.

Every society since the beginning of time has had its rich and its poor, but today the gap is widening. The prospect of a quantum leap into the age of technology is particularly formidable for societies that are closed and repressive. The openness of Internet communications and e-commerce has given an economic edge to countries with democratic forms of government. Radical groups in the closed societies that are being left behind are feeling the tide turn against them, and they are lashing out with terrorist attacks with huge consequences for developed nations and the U.S. in particular as was shown on 9-11. While technology may help us defend ourselves militarily, we have to look for broader solutions in the long run.

As we make decisions about the research we advocate to address the issues our society and world face, we need to take a view that is both long and broad. There is a plaque in front of the National Archives that says, "The heritage of the past is the seed that brings forth the harvest of all the future." The long view of research in science and technology provides a powerful illustration of this statement.

A case can be made that the strong economy we enjoyed during the 90s was not so much due to Alan Greenspan or Bill Clinton or even Bill Gates as it was to Nikita Krushchev. When he challenged us to an arms race and a space race, he stimulated the federal government to invest seriously in fundamental research at universities, and that research proved to be the seed for the harvest of today, especially in the fields of physics and electrical and computer engineering.

The U.S. Council on Competitiveness, on whose executive committee I serve, tracks patents as a measure of innovation. Their research shows that nearly three-quarters of industrial patents cite publicly funded research as the basis for their invention. Under the surface eddies that swirl around the issuance of patents and licenses for new products and services, there are deep, steady currents of frontier research and knowledge discovery that run through decade after decade and feed the commercialization that takes place up on the surface.

We are enjoying the harvest from the fundamental research of prior decades, but are we fulfilling our responsibility to develop and plant the seed that the next generation will need to maintain economic strength? To answer that question, we need to take the broad view, and look at changes and trends across funding sources and types of research.

If you took a snapshot of research funding back in the mid-60s, it would show the federal government providing two-thirds, while industry contributed less than one-third. If you take the same snapshot today, you will find that these two entities have switched places. The federal

government now provides less than 30 percent of our research funding, while industry provides almost 70 percent.

However, this is not a quid-pro-quo exchange. The federal government is the largest provider of funds for fundamental, frontier research and the work of social scientists, while industry-funded research tends to focus on applications and product development. The NSF Science and Engineering Indicators for 2002 indicate that over 70 percent of industry's funds go for the "D" in R&D – the development of marketable products – leaving less than 30 percent for research. And most of that is for applied research rather than fundamental, frontier discovery. The computer and semiconductor industries, for example, spend less than 5 percent of their R&D budget on fundamental, frontier research.

When the commercial pay-offs are in the distant future, it is hard to know when and where discoveries will appear and who, exactly, will benefit from them. For example, when physicist Richard Feynman introduced the new field of nanotechnology to the American Physical Society in 1959 in a lecture entitled "There is Plenty of Room at the Bottom," I doubt that anyone there in their wildest imaginations envisioned the products that are emerging today as a result. They include, for example, stain-resistant khaki pants, 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 physics research that generated the nanotechnology from which they are now profiting.

If we do not keep a healthy balance of federally funded frontier research with industry-funded applications and product development, we will undermine our ability to achieve the sustained innovation that will enable us to continue as an economic leader without destroying the planet in the process.

In a technology-based economy, science and engineering research play an important role in stoking economic growth and productivity, which is measured by our Gross Domestic Product. The federal investment in research and development in the United States was 1.5 percent of the GDP in 1987 but declined to about six-tenths of one percent in 1999 – a decrease of almost two-thirds relative to the size of the GDP it is supposed to be driving. We are also losing ground relative to other nations. Sweden, Japan and South Korea now invest more in R&D relative to the size of their Gross Domestic Products than the United States.

A second question of balance that emerges when we look across the breadth of our research endeavors is among disciplines. Federal investments in life sciences and computing have increased over the past 15 years, and the R&D budget for the National Institutes of Health is in the fourth year of a commitment to double it over five years.

At the same time, however, support for research in the physical sciences and engineering has decreased, and not just relative to the size of the GDP. In Fiscal Year 1999, chemistry, physics, and chemical, electrical, and mechanical engineering were down by 20 percent or more compared to FY 1993, according to the National Research Council. There have been similar declines in support for research in social and political sciences, and because of the critical issues

related to social and political context related to our decisions in the future, this is of great concern.

And, there is more to discovering knowledge and generating innovation than simply funding the research itself. You also have to have a lab to work in, and our physical research infrastructure is falling behind. As a growing number of funding agencies have required ever-larger matches for research grants, universities have adjusted by deferring construction and maintenance on research facilities. The Council on Competitiveness reports that from 1990 to 1997, the amount of federal funding going into lab infrastructure dropped from \$610 million to \$390 million. And in 1998, research institutions around the nation reported about \$11 billion in deferred construction and maintenance.

In addition to the funding and the lab, you also have to have scientists and engineers to do the research, plus an educated workforce that can literally make something of the ideas the research produces. This is yet another area of growing concern for the United States.

We just had commencement exercises at Georgia Tech on Saturday, and a record number of engineers and scientists graduated. But we run against the grain and national trends. MIT economist Lester Thurow does a survey called the Lemelson-MIT Invention Index, and the results for 2001 were not encouraging. Teenagers recognize the importance of invention – 46 percent of them chose an inventor as the best person to be stranded with on a desert island – but they don't want to be inventors. They don't even want to know an inventor. Only 8 percent of teens would actually like to meet one – dead last among the career categories from which teens would like to meet an important person.

Their attitudes are reflected in the declining number of students at both the undergraduate and the graduate levels who sought degrees in engineering, the physical sciences, math, and computer science during the 90s. In a clear demonstration of the connection between research funding and warm bodies, graduate enrollments were down in fields that have experienced cuts in federal research funds and up in the life sciences where research funding has increased. To quote NCR's recent report, "Trends in Federal Support of Research and Graduate Education," "The effect of cutting research is both direct, in reducing the number of research assistant positions, and indirect, in signaling to prospective graduate students that some fields offer poor career opportunities."

We're not doing very well on demographics, either. Workforce growth during the 90s consisted largely of women and minorities, who do not tend to gravitate toward science and engineering. 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 fastest growing sector of the population is Hispanics, and they are the least likely to hold college degrees or to be proportionately represented among the nation's scientists and engineers. The second-fastest growing sector is African Americans, and they are the second least likely to hold college degrees or be proportionately represented among scientists and engineers. Women are going to college in record numbers, but they are seeking liberal arts degrees. The number

going into fields like engineering and computer science is stagnating at levels that are far too low, or even declining.

The new demographics are clearly out of sync with the new economics. If we can't get more young women and minorities in the door and through four years to a bachelor's degree in science or engineering, we certainly don't have much chance of getting them into graduate school or the research lab.

Student enrollment in science and engineering is another issue that takes on more dramatic proportions if we put it in a worldwide context. A year or so ago, the *Wall Street Journal* had a front-page chart showing that while the number of American students enrolled in graduate programs in science and engineering has been declining, the number of international students in those programs has been increasing. International students, who are increasingly likely to return home after graduation, now comprise over 40 percent of Ph.D. Students in science and engineering at American universities.

Yet another issue in the context that surrounds our decisions about science and engineering is providing appropriate channels and incentives for the commercialization of research. The Bayh-Dole Act, passed in 1980, gave universities the right to take title to discoveries from federally funded research, assuming they would commercialize them. And organizations like the Council on Governmental Relations and the Association of University Technology Managers have been keeping up with the changes in commercialization of university discoveries since then. This is what they report:

- The number of universities engaged in patenting and licensing has increased by tenfold from about two dozen to more than 2,000.
- Over 2,200 new companies have been formed based on the licensing of university innovations.
- Technology commercialized from university research now generates about \$41 billion in economic activity a year, accounts for 270,000 jobs, and generates about \$5 billion in tax revenues, all without any government expenditures.

Of course, not all of this ramp up in activity can be attributed exclusively to Bayh-Dole, but it is certain that this legislation has had a profound influence on improving the climate for technology transfer without requiring a government bureaucracy to achieve it.

From the perspective of research universities, our growing participation in technology transfer is a two-edged sword. On the one hand, it provides a very tangible demonstration of the benefits that derive from our research endeavors, and allows us to commercialize technology that otherwise would have sat idle on government shelves. On the other hand, our success has attracted attention, especially to those few universities who earn large royalties for pharmaceutical discoveries. We are now faced with reconciling conflicts of interest and answering criticism that we are more interested in making money than in educational pursuits.

Such criticism questions whether allowing universities to take title to intellectual capital serves the public good. However, making it difficult or cumbersome for university knowledge to go through technology transfer into the private sector clearly doesn't serve the public interest either.

Between 1950, when the Congress appropriated \$15 million for NSF to begin funding university research and 1980, when the Bayh-Dole Act was passed, the federal government retained ownership of the intellectual capital that universities produced. There were no incentives and no mechanism for effective technology transfer other than what made its way into the private sector through publications and direct interactions between university faculty and industry. Before 1980, barely 10 percent of government patents were licensed to industry for commercialization. The slow moving federal government bureaucracy is simply not up to the task of moving ideas to the commercial sector.

The attention drawn by a handful of universities with successful pharmaceutical royalties obscures the fact that for the vast majority of us, gross revenues from technology transfer activities generally account for less than 3 percent of our research dollars. As the examples I cited earlier in my talk demonstrate, it often takes decades before fundamental university research yields commercial products, which means that no more than a third of university patents are producing revenues at any given time.

Universities as a group earn upwards of \$900 million a year in royalty income, but that is gross income. At the front end of the process, virtually all research agencies require us to put up large sums of matching funds in order to obtain research grants. At the back end is the cost of operating intellectual property offices and maintaining patents. As a result, it is a struggle for most universities to break even on the bottom line.

Still, we have to recognize that we are faced with a growing chorus of criticism. Universities need to take the initiative to justify our position based on a sound rationale that works for today and the future. Otherwise the commercialization of university research might be altered in fundamental ways to the detriment of innovation and entrepreneurship in the American economy.

The most valuable economic development tools we can have in the 21st century are a platform for research and innovation that will drive leading-edge technology, and a skilled workforce. Universities are the source of both of these tools. But to develop and use them well, a closer and more complex relationship is essential among universities, government, and private industry.

In conclusion I would like to suggest that the opportunities have never been greater for science and technology and our great research universities. There are serious challenges that desperately need our attention, but we are fortunate that our system is not broken. Rather it needs careful attention by thoughtful people to make it a success for future generations.

Some of the challenges I believe we need to address include:

- 1) Attracting more students to science and technology, particularly women and minorities.
- 2) Helping the public understand and appreciate the role of science and technology in shaping society and helping scientists and engineers understand and appreciate their role in society.
- 3) Developing a means to help restore the health of research facility infrastructure at universities.

- 4) Addressing the issue of balance in funding – in research vs. development; in long-term vs. short-term research objectives; in coordinating across federal agencies with different missions; and in coordinating across disciplines.
- 5) Developing a strategy to help elected officials appreciate the need for research and for a balanced research portfolio.
- 6) Sorting out the issues associated with commercialization of university research.
- 7) Helping the nation develop a coherent strategy to defend itself against terrorism while working on the root causes of terrorism.