

Eric Walker Distinguished Lecture on the Advancement of Research  
Georgia Tech President G. Wayne Clough  
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(TITLE SLIDE)

Thank you for that kind introduction. It is an honor and a pleasure to participate in the 55<sup>th</sup> National Conference on the Advancement of Research, and I want to recognize and thank Greg Schuckman and the University of Central Florida for all of their hard work in hosting an outstanding event. I would like to offer my congratulations to Greg and his colleagues for arranging for this lecture to be delivered on the set of “Who Wants to be a Millionaire.” I read the other day that there are fewer millionaires this year than last year so, I guess between the economy and loss of the show, it is harder to move up these days. I can promise you that I am not going to try to replace Regis this evening, but I will talk about money – not millions, but the billions that are presently being spent on our national research and development agenda, and how we need to critically assess this investment if it is to best serve the national benefit.

(PHOTO OF WALKER)

It is a distinct pleasure to be with you under the auspices of the first Eric Walker Distinguished Lecture. Way back in 1947, the first NCAR meeting was held at Penn State University, which is appropriate to this evening since this is when Eric Walker began his remarkable academic career at Penn State. He went on to become an outstanding model for all of us who engage in research in a university setting.

As a teenager in York County, Pennsylvania, Eric Walker excelled in science and math, and also in track and field. Penn State offered him a \$100 athletic scholarship; Harvard offered him a \$500 academic scholarship. So he went to Harvard, and earned his bachelor's, master's, and doctoral degrees there.

But he didn't hold a grudge against Penn State for failing to recognize his intellectual potential. He arrived on the Penn State campus in 1945 to direct the Ordnance Research Laboratory, and after serving as chair of the Department of Electrical Engineering and as dean of engineering, he became president in 1956 and served in this role for 14 years. His friend, Vannevar Bush, advised him that there were three possible routes to success as a university president – build buildings, build the faculty, or build a football team. Eric Walker replied that he intended to do all three, and he did with great success. Personally, I would like to think in my own career I have covered two of these three, but I have to confess that the football team is still a work in progress.

Dr. Walker was also a great national leader and statesman in science and engineering. Among the many national science, engineering, and military organizations he served were the National Science Board, which he chaired, and the National Academy of Engineering, of which he was a founding member and president.

If Dr. Walker were here, and joined us in reflecting on the past fifty years, I am sure he would remark on the dramatic growth of the influence of technology on our lives, and how this depended so significantly on the research investments made in his day. He might also observe that predicting the exact nature of the future would have been difficult for anyone, and that the only certainty was that the unexpected is to be expected. However, it would not surprise me if he pointed out that no matter how things ricocheted, research shaped the end result, and when it was done well, and with the proper motivations, it served to improve our lives.

And this is what it is all about – not attempting to predict what the future will be, but following the path that was blazed by pioneers like Eric Walker. They were bold enough to know that careful investment in the appropriate research and human resources would help in setting a positive course for the future, and I would suggest this is our challenge today. Insuring our R&D investments are structured as wisely as those who went before us. I would like to address this by considering three topics: the length of the picture, the breadth of the picture, and who is in the picture. First, some preliminaries are useful to set the context for the challenges facing us.

#### (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 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. 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 us are increasingly likely to be the consequences of our own inventions as well as from natural causes.

#### (KOFI ANNAN QUOTE)

Some of these consequences are fundamental, powerful, and staring us in the face. We know that we have to address them, and the timeframe for doing so is getting shorter.

A United Nations report released last summer 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. The “Asian brown cloud,” a haze two miles thick that hovers over all of southeast Asia, is blamed for reducing agricultural output by blocking sunlight and for hundreds of thousands of deaths from respiratory disease.

#### (FLEA PICTURE)

Climate changes and the continuing destruction of wildlife habitat are also creating new health problems. Drought favors the species of mosquito that spreads West Nile virus, while wiping out the dragonflies and amphibians that help keep the mosquito population under control. And as humans encroach on wildlife habitat, diseases are increasingly making the jump from animals to humans. AIDS, for example, made the jump from chimpanzees to humans. In sub-Saharan Africa, AIDS has now lowered the average life expectancy by up to 30 years, reducing it to as little as 36 years in Botswana, and it is reasonably predicted that 150 million people will die of this deadly disease in China and India alone. These are examples of major problems that lie directly in front of us. We know our well-being as humans depends on addressing them, and we can direct our research efforts accordingly to provide solutions.

#### (GROUND ZERO)

Other events, however, take us by surprise, and we scramble to adapt the technology we already have to meet new needs. The terrorist attacks of September 11 were certainly a good example, and we are still trying to organize our technology and our response to that new reality. Former U.S. Senator Sam Nunn, who co-founded and now co-chairs the Nuclear Threat Initiative, has been participating in simulated terrorist response scenarios conducted at Andrews Air Force Base. They are the homeland security version of war games. He was recently at Georgia Tech and described a terrorist war game in which he played the role of the President of the United States and had to deal with a small pox attack that had been made simultaneously at three locations. Based on that experience, he concluded that we are ill prepared to deal with the challenge of biological terrorism. As he stated, we not only do not have the technological tools to address this eventuality, but we also do not yet know how to communicate with the public about such ominous threats.

#### (COMET PHOTO)

In still other cases, something that has seemed unimportant or esoteric takes on new significance because the paradigm has shifted in an unexpected way as the result of an event or a new technology. The anthrax attacks of a year ago were one such event. After the attacks, three decades of genetic research suddenly took on new significance,

because it enabled scientists to quickly develop the microbial gene sequence of the anthrax that was used and trace it to a lab in Fort Detrick, Maryland. Similarly, physicist Buford Price from the University of California at Berkeley developed a filter to study cosmic rays above Antarctica. It is now being turned toward the study of anthrax.

**(QUOTE ON RIGHT)**

These examples of unforeseen events and unexpected twists of technology are reminders of the message of a plaque outside the National Archives in Washington, D.C. It says, “The heritage of the past is the seed that brings forth the harvest of all the future.” It is critical that we take the long view of research in science and technology and continue to develop the seed through research that takes place on the frontier of knowledge discovery.

**(KEYSTROKE: PICTURE 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 Krushchev. He challenged us to an arms race and a space race, stimulating the federal government to invest seriously in the fundamental research across an array of agencies. The vast majority of early federally funded research at universities was ostensibly for defense. And over time this source of funding accounted for the majority of support for critical fields like physics, chemistry and electrical, computing and mechanical engineering. The spin off effects of the investments made of this type continues to help drive our economy to this day.

**(QUOTE: “FOR INVESTIGATORS”)**

Today’s semiconductors emerged from federally funded university research in quantum mechanics conducted during the 1940s. The Advanced Research Projects Agency, known as ARPA, and the National Science Foundation provided the funding in the 60s and 70s to develop the Internet, which has become a force in so many aspects of our economy and our lives today. Many think of research in mathematics as being highly abstract and of mathematicians tucked away in dusty corners pondering unsolved theoretical problems that hardly seem relevant to real life. Yet mathematics is at the core of many diverse and practical applications, from aircraft design and computing to the prediction of climate change.

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 fundamental research that the next generation will need to provide prosperity and address the dilemmas of its world? Are we investing in a way to protect our strategic advantages and to remain competitive in a global economy? Is the future workforce being educated

to power a technology driven economy? There are reasons why these questions ought to be niggling in the back of our minds.

#### (BAR GRAPH: COMPARING INTERNATIONAL R&D)

Internationally, the U.S. spends more money than any other nation on R&D, and President Bush has seen to it that our totals now exceed \$100 billion for the first time. However, the patterns of our investment differ markedly from others and have changed over time. Not surprisingly, ours is more heavily invested in defense related activities, and increasing this funding is directed at “D” not “R.” Other nations are spending a much larger percentage of their R&D budgets on basic, or long term, research and focusing on issues not related to defense. In the long term I would suggest it is wise to ask ourselves how this pattern affects our ability to be a leader in the development of new knowledge that will lead to the next generation of technologies that will drive future economic miracles.

#### (LINE GRAPH: SOURCE OF RESEARCH)

Another pattern of significance is that over the past 40 years, the federal government and private industry have switched places in terms of who conducts what portion of our national research and development. Back in the early sixties, the federal government was the source of about two-thirds of R&D and industry was the source of about one-third. The two lines crossed around 1980, and have gotten farther apart ever since, with industry conducting almost 70 percent of the nation’s research, while the federal government now drives less than 30 percent. However, this is not a quid-pro-quo exchange.

#### (2 BAR GRAPHS)

The focus on U.S. industry today is on the development portion of R&D as is seen in these charts. In the interest of maintaining the bottom line for investors, industry laboratories that conducted long term research have largely disappeared. On the other hand, funding from the federal government historically has been more focused on fundamental, frontier research, for which research universities act as the largest provider based on federal grants and contracts. For many years this formula has worked to the advantage of our economy.

#### (FEYNMAN PHOTO)

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 research that generated the nanotechnology from which they are now profiting. And, much more is yet to come from this rich vein of technology, including the vast potential that will lie in quantum computing.

(QUOTE: "From the funder's")

In the dog-eat-dog competition of today's global marketplace, it is difficult for private industry to justify investments in frontier research. The National Research Council's publication *Trends in Federal Support of Research and Graduate Education* indicates, for example, that the computer and semi-conductor industries allocate less than 5 percent of their research expenditures to fundamental research.

I am privileged to serve on the executive committee of the U.S. Council on Competitiveness, and we track patents as a measure of innovation. The Council's 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.

(COSEPUP GOALS)

Given these circumstances, how do we insure that we are appropriately investing in our future? The National Academies' Committee on Science, Engineering, and Public Policy identified two national goals for science and technology: First, that the United States should be among the world leaders in all areas of science, and second, that the United States should seek to maintain clear dominance in specific fields that contribute substantially to important economic, social, or cultural objectives. I suspect that we can all agree to these general goals, but as is often the case, the implementation of such goals gets you to the "devil's in the details" state of affairs that requires we understand where we are and where we are headed.

(AAAS LINE GRAPH)

With the end of the Cold War as a driver for federal investment in research, the tendency has been to shuffle the priorities for R&D spending. With the federal Fiscal Year 2003 budget, we are coming to the end of a five-year period in which Congress focused on doubling the budget of the National Institutes of Health, and you can see that the lion's share of increases in research funding has been going to NIH in recent years. As a result, NIH went from 32.1 percent of federal research expenditures in 1993 to 40.4 percent in 2000. No one disputes that this increase will have tremendous



benefits, but it behooves us to look to the question of balance, or lack thereof, in federal funding of research.

#### (YELLOW/BLUE BAR GRAPH)

While research funding for NIH was increasing during the 90s, 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. A consequence of this trend is that university faculty in these areas have aggressively sought, and obtained, industry support. However, as noted, this tends to supplant long term research in the interest of short term research.

#### (4 PICTURES+QUOTE)

Recently, Congress announced that it is considering doubling budget of the National Science Foundation. While no one doubts that this will have a positive byproduct, neither NSF or any other single federal agency serves as a “fly-wheel” to provide the balance that will make sure all disciplines move forward together and are in a position to contribute fully to the growing interdisciplinary mix. For example, as I noted earlier, the largest base for funding of long term research in electrical and mechanical engineering is the Department of Defense.

I serve as chair the panel on federal investment in science and technology and its national benefits for the President’s Council of Science and Technology Advisors, known as PCAST. We recently commissioned a RAND study on federal investment in research and development. The study reported that 28 federal departments and agencies fund science and technology research. The federal budget classifies expenditures according to 20 different functions or missions, and research expenditures occur in 15 of them. They are spread across about a dozen appropriations bills, which are handled by 13 different congressional committees.

These circumstances make it difficult to coordinate priorities across agencies and across congressional committees and to coordinate a balance of resources across scientific and engineering fields and disciplines. It is difficult to insure that our national priorities are

being met with so many diverse entities involved. The question is, how can we structure governmental bureaucratic procedures to allow for the dynamic nature of the enterprise to drive the decisions? Some one has to be tasked with seeing that federal investments meet the expectations of our goals.

### (First UNIVERSITY DEGREES)

The third aspect of the bird's-eye view of the advancement of research is the question of who is in the picture. 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. So far this evening we've been focused on financial capital, but the more critical need for the advancement of research may be human capital. The first step, obviously, is a bachelor's degree in science and engineering, and if we look at what proportion of 24-year-olds have earned bachelor's degrees in science and engineering in the United State, we can see that we are falling behind. We have increased that number since 1975, but we have not done as well as many other nations. Back in 1975, we were second only to Japan in the number of 24-year-olds with bachelor's degrees per 100,000 population. We now rank 14<sup>th</sup>.

### (ENGINEERING ENROLLMENT)

Five years out of college, engineering is one of the top 10 professions for earnings. So, if the workforce marketplace operated in a purely rational fashion, you would expect high school graduates to be flocking in droves to engineering schools. But they're not.

MIT economist Lester Thurow does a survey called the Lemelson-MIT Invention Index, and the results are 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. Only journalists and politicians rank lower than inventors on the list of careers that teens aspire to. 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.

### (S&E DOCTORATES)

At the graduate level, the number of Ph.D.s awarded in the sciences peaked in 1998, then declined 3.6 percent in 1999. The number of Ph.D.s in engineering peaked earlier, in 1996, and had declined by more than 15 percent by 1999. The enrollment of white males, the group that has traditionally dominated science and engineering, is flat, and we are only seeing slight increases in women and minorities. The largest enrollment increase has been in international students. By the late 1990s, almost half of the Ph.D. students in engineering, computer science, and math at American universities were from other countries. About a third of the students in the life sciences were



international. But, as the trends show, enrollments of international students has begun to decline as they find jobs are as readily available at home as here in the U.S with the migration of manufacturing and research and development facilities overseas.

#### (U.S., EUROPE, ASIA GRAPH)

Beyond the change in the job market, the decline in international Ph.D.s is also happening because other countries are now helping their universities increasingly offering quality Ph.D. 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 Asia is probably passing us right now, even as I am speaking.

#### (GRAPH: STUDENTS REMAIN IN US)

What's more, the international doctoral students we still have are showing an increasing tendency to return home, reflecting the trends I have already mentioned. So we are now swimming in a sea of new and dangerous currents. Adding to the urgency is the knowledge that a generation of technologically proficient employees are aging and will reach retirement within a few years of each other. Who will be there to replace them?

One of the reasons why it is difficult to get students to pursue graduate studies is that the average annual stipend for graduate students in science and engineering is about half of the average wage of bachelor's degree recipients. Our bright students understand this well and go directly into the workforce.

#### (QUOTE: "TRENDS IN")

When we look more closely at graduate stipends, a second pattern emerges. In its study, "Trends in Federal Support of Research and Graduate Education," the National Research Council found that fields in which federal funding for university research declined during the 1990s also experienced declines in both graduate enrollments and doctoral degree recipients. While some of this may be attributed to the job market, it is clear that given a choice of a graduate career with ambiguous prospects for support, or taking a job with a salary at twice the likely graduate stipend even if support is forthcoming, then the incentive lies towards taking a job and forgetting about graduate study.

It works in the opposite direction as well. From 1993 to 1999, for example, federal funding for research in medical science increased by 20.5 percent, and graduate school enrollment increased by 41.5 percent. We know that graduate students view federal funding for university research as a bellweather, and they simply do not invest their own funds in fields that are not perceived as important to the future.

So, that is the bird's eye view of today's research from the perspective of the length and the breadth of the picture, and who is in the picture. While much of what we see is desirable, there are growing cracks in the façade that portend problems in not addressed. I suspect if our friend Eric Walker were here today, he might ask us why we have been complacent about allowing troubling trends to develop without addressing them, particularly in a time of plenty? In his day when a shortage of critical personnel was identified, the National Defense Education Act was passed to provide scholarships and fellowships to support young people who were motivated to undertake studies in a variety of important fields. Funding to support research was forthcoming for a spectrum of fields deemed important to the future, including those mainly seen as involved in basic research like physics and mathematics. And the nation's research agenda was more coordinated and less a matter of partisan interest.

Fortunately, there is a growing recognition among industry, government and academia about the issues and what needs to be done to redress them. PCAST has reported on these matters, and to their credit, the Bush administration, OMB, and OSTP have indicated a willingness to tackle them. However, as has been demonstrated in the past, building a common agenda between the public/private sectors is the best way to make progress on such a wide front. It will be up to all of us to create the coalition needed to develop a consensus approach to finding the right working solution and maintaining interest long enough to change course. I am optimistic we can work together to make it happen.

**(QUOTE: "THE OPEN SOCIETY")**

Earlier this fall, NSF Director Rita Colwell told the U.S. House of Representatives that "our future economic strength will come almost entirely from the technologies emerging from our laboratories today." The tremendous expansion of science and technology over the past two centuries has not only created the "Leonardo World," but it has also brought wealth and strength to the nations who engaged in it. The wealth in our global economy is increasingly vested in knowledge and technology rather than the traditional measures of land and minerals. Today, nations that are "science-poor" are also poor in economic terms. They need the scientific and technological expertise that provides appropriate tools for rapid economic development.

Maintaining our own quality of life and competitiveness in the world economy and helping to solve global problems like the ones I described at the beginning of this talk will require us to be more strategic in our discovery of knowledge and creation of technology. Fortunately, knowledge is not finite like land and minerals. We have an

infinite capacity to discover new knowledge and put it to work to solve the problems we face, “transforming our world through research and imagination.”