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Divider Title: **Northwestern Univ.**

Remarks of
John H. Gibbons
Assistant to the President for Science and Technology

A National Strategy for Science and Technology Leadership
Northwestern University
Evanston, Illinois
April 7, 1997

Fifty years ago, Franklin Delano Roosevelt set out as powerful and as succinct an argument for public support of research as I have ever seen when he commissioned the work of Vannevar Bush whose ensuing report, *Science--The Endless Frontier*, gave birth to the golden age of public investment in science and most of our present scientific institutions. In President Roosevelt's words:

"New frontiers of the mind are before us, and if they are pioneered with the same vision, boldness, and drive with which we have waged this war we can create a fuller and more fruitful life."

Roosevelt spoke at a time of brimming confidence about the future and about our Nation's manifest destiny. We had in those days a strong sense of common purpose, a belief in community, a confidence in our capacity for joint enterprise, and a faith in the possibility and benefit of science.

Today we are still a nation of explorers, and, as Vannevar Bush pointed out, "Science offers a largely unexplored hinterland for the pioneer that has tools for his task."

I think President Clinton said it well in a recent State of the Union message, "we live in an age of possibility. A hundred years ago, we moved from farm to factory. Now we move to an age of technology, information, and global competition. These changes have opened vast new opportunities for our people, but they have also presented them with stiff challenges."

While some see this as a time of crisis with mostly negative connotations, I take the more optimistic view that this is an exciting time for productive change and progress in many dimensions.

This dichotomy of perspective is not new. I think this was best articulated by Gramsci when he wrote in his prison notebooks: "The crisis consists precisely in the fact that the old is dying and the new cannot be born. And into this interregnum a great variety of morbid symptoms appear."

Gramsci's observation is a fair characterization of how we find ourselves as we move to the millenennium, away from the Cold War, into an era of unprecedented competitiveness, economic integration, global environmental stress, and rapid technical and social change.

I reject the notion that science and technology are in a crisis, at least a crisis of impending disaster. A true crisis in science would correspond, for example, to an approach to the limits of knowledge itself, or to a massive retreat of support for research. And despite our extraordinary continuing adventure of discovery, I think we need not worry. John Horgan and *The End of Science* notwithstanding, we are still quite secure in our ignorance. Science still remains a most exciting territory to explore. Charles Vest, President of MIT, recently described some of the mysteries on the horizon. His list is too long to repeat here, but a few examples give a sense of it:

-- We do not know how the human mind thinks or remembers, or the relationship between language and thought.

-- We do not know, even in principle, what aspects of the climate are predictable.

-- We do not know how old the universe is, what it is made of, or what its fate will be.

-- We do not know the potential of the explosion in the networked electronic communications or its effects on society.

And the list goes on.

The elements of the rapid societal and institutional change the President highlights and Vest hints at are easily recognizable as we approach the twenty-first century. The end of the Cold War, the emergence of highly competitive economies in Europe and Asia, and the pervasive consequences of the information revolution have stimulated a significant ongoing reexamination of the scope and scale of government needed to address them. Our scientific investment portfolio must also adapt to this post-Cold War world if we are to march confidently into the future.

I share NSF Director Neal Lane's view that we will enter a "golden era of science in which the Federal government will be much more a partner with industry, academia, state governments, and other parts of society. And increasingly, the doers and users of science will be connected by yet to be established networks through collaborations as individuals, groups, and centers. And those doers and users will perhaps at times even switch roles."

This new engagement of scientists in the mainstream of society will not damage their creativity, dull their insight, or destroy their focus. On the contrary, I suspect it will have an energizing, invigorating effect. Science will be in the thick of the turmoil, in the forefront of seeing how societal problems evolve and escalate, and in the center of managing the dynamics of disparate forces. Granted, this vision is not a current reality, but it *is* a promising work-in-progress. We in Government cannot do it without you. We must work shoulder-to-shoulder. To paraphrase a familiar expression: "Now is the time for all good scientists to come to the aid of their country."

The Manhattan Project demonstrated in graphic terms the application of science and technology to critical national problems. With a shift in our national priorities, together we must seize the opportunity to reorient our national research agenda and use our considerable talents and resources to help the nation tackle other large, technologically complex problems such as energy, environment, education, economic competiveness, health care and human welfare, and space -- all of which are becoming increasing important to enhance our quality of life and our national security as viewed from today's perspective.

President Clinton, in his most recent State of the Union speech, emphasized the broader role for science in driving the nation's economic and national security, saying:

"To prepare America for the 21st century we must harness the powerful forces of science and technology to benefit all Americans." He continued, "we've only begun to spread the benefits of a technology revolution that should become the modern birthright of every citizen. The new promise of the global economy, the Information Age, unimagined new work, life-enhancing technology -- all of these are ours to seize. We must continue to explore the heavens. We must speed the remarkable advances in medical science. We must build the second generation of the Internet so that our leading universities and national laboratories can communicate in speeds 1,000 times faster than today, to develop new medical treatments, new sources of energy, new ways of working together."

Maintaining Our S&T Leadership

The knowledge-based society of the next century only increases the centrality of research, innovation, and human capital as our principal strengths, placing important continuing responsibilities on the Administration and Congress:

- America's world-leading science and technology enterprise must be sustained and nurtured.

- We must strengthen our science, mathematics, and engineering education and ensure their broad availability.

- The fiscal and regulatory environment for research and innovation must be sound and responsive to rapidly changing societal and business conditions.

- We must retain a long-term commitment to research, education, and innovation even in this period of budgetary constraint.

- The Federal government has an important role in each of these areas, but must be viewed only as one partner in the nation's effort.

These imperatives drive the Administration's strong commitment to an integrated investment agenda in scientific research, technological innovation, business environment, and education. Many elements of that agenda represent continuing commitments that have long enjoyed bipartisan support. However, the investment portfolio must also evolve in response to the knowledge-based, information- and technology-driven, globally competitive borderless economy. With knowledge as the key resource, there is a tremendous premium on human capital development and on new ways of doing business. With global linkages growing stronger, the rapid movement of people, goods, and information has permanently altered commerce, national security, demographics, and health.

Not surprisingly, the science and technology investments driven by these challenges to established societal structures are in many ways those that still lack bipartisan consensus. Achieving that consensus is an important element of this Administration's plan to take us to the threshold of a new century and enable a bright future in the decades beyond.

The Administration is unequivocally committed to maintaining leadership across the frontiers of scientific knowledge. The nation's prior investment has yielded a scientific and engineering enterprise without peer, whether measured in terms of discoveries, citations, awards and prizes, advanced education, or contributions to technological innovation. This scientific strength is a treasure that we must continue to build on. Thus, even as the Federal budget deficit is eliminated, the Administration has protected the level of investment in key Federal basic science programs, not only those in the National Science Foundation and the National Institutes of Health, but also those in numerous mission agencies, such as the Department of Energy, and the National Aeronautics and Space Administration.

Several factors have changed significantly over the past decade. Defense technologies depend increasingly on the commercial sector, both to make cutting-edge technologies available and to reduce the cost of defense procurements. In the commercial sector, the information revolution and globalization have irreversibly affected the nature of industrial research and development. Dramatically shortened product cycles, competition for customers and from companies everywhere, and the pressure for product quality improvements have, among several factors, focused commercial research and development on shorter-term business goals and away from exploratory research.

The appropriate Federal response to these changes must recognize that it is crucial to maintain our position at the forefront of technological innovation. The Administration response is multi-pronged: sustaining our research leadership position; strengthening a business environment that supports private sector research and development; investing in technological infrastructure; and advancing critical technologies, often in partnership with industry.

The Administration has advanced numerous initiatives to improve the business climate for technology development. Examples include telecommunications reform, open trade policies, intellectual property rights protection, regulatory reform at the FDA, procurement reform at the DOD, support for the research and experimentation tax credit, and cost-shared, industry-led research and development partnerships. However, the overarching priority, as expressed consistently by business, is deficit reduction. The annual deficit has been reduced from nearly $300 billion almost to $100 billion while preserving the research and education investments that underlie future technological innovation. The deficit reduction accomplishments play a significant role in sustaining today's healthy economy.

Above all, our S&T leadership strategy must be a national — not just a Federal — strategy. The benefits of research are not fashioned in Washington, they are forged in factories, laboratories, and universities and colleges across America. We need a national program to address these national goals. To do so:

From planning to execution to evaluation, we must bring to the table all the players in science and technology — the business community, research universities and institutions, educators, and state and federal governments.

We must foster international cooperation in science and technology, even as we compete with our global partners in an increasingly competitive world market. Such collaboration is critical, not only to share the burden of expensive programs, but to benefit from the expertise and know-how of others.

Strengthening partnerships among stakeholders in universities, industry, and the states is vital to such a national strategy. We have taken the initiative in a number of areas, all of which will be key to forging the effective partnerships we need. Let me give you a few examples:

Over the past year, the President has listened carefully to leaders in government, universities, and industry, as well as the nation's governors, who have warned that the nation's universities are under stress. The President asked me to review the government-university partnership. Our principal goals are to identify areas of stress in research, education, and administrative regulations, and determine what the Federal government can do to address these problem areas. We expect to complete this study by the end of this summer.

As many of you already know, the White House and the nation's governors recently agreed to work together in an Innovation Partnership to promote economic growth by stimulating the development and use of improved technologies in areas such as advanced manufacturing, education, health care and electronic commerce. We will also extend the capacity of the Manufacturing Extension Partnership to help modernize the nation's 380,000 small- and medium-sized manufacturers. We will continue the work we have begun to streamline the regulatory environment for research and technology.

Finally, we need to continue our efforts to get our Federal agencies to work more closely together and with the private sector. We have had some notable successes, including the Partnership for a New Generation of Vehicles. PNGV is a cooperative effort among numerous government agencies and the U.S. automobile industry to produce a production prototype vehicle capable of 80 miles per gallon by 2004. We also have some other exciting initiatives, including the Global Climate Change Research Program, the High Performance Computing Initiative, convergence of civil and military weather satellites, and a major effort on Emerging and Re-emerging Infectious Diseases.

I cannot stress enough that bipartisan support will be critical for shaping a sustainable agenda. The American people want us to be partners, not partisans, and the vast majority in Congress support a strong Federal research program. The scientific and engineering communities also have the opportunity and the responsibility to help forge consensus about the future's requirements for America's research and education investments. History suggests that the cost of not making these key investments in technical and human resources will be far greater than that of moving ahead.

The Importance of Our Research Universities and Colleges

The American higher education system is unparalleled in producing world-class scientists and engineers. The tight weave of research and education that exists in our research universities, fostered through bipartisan commitment, serves the nation exceptionally well. It is our stewardship responsibility to maintain strong, competitively awarded, frontier research programs at colleges and universities so as to provide a steady stream of creative scientists and engineers as well as new knowledge. They will do much to shape our society and advance our national interests in the twenty-first century. We will also work to renew the university-government partnership that has been one of our best investments for promoting the public good.

America's colleges and universities have, for decades, produced the world's finest engineers and scientists and have been a principal source of new knowledge and scientific discovery. Today, we still look to our academic institutions for help in addressing our nation's major challenges -- fighting disease, improving the environment, protecting our national security, and sustaining our economic growth. But if we are to ensure the future vitality of these institutions, we must work together -- federal and state governments, the university community, and private industry -- to make the far-sighted investments in education and research that will enable us to master this moment of change and build a stronger America for the future.

One of the overarching themes of the Clinton Administration's support for science and technology is maintaining leadership across the frontiers of science. The Administration views S&T leadership as crucial to improving health care, agriculture, environmental management, national security, and economic prosperity. And key to maintaining this leadership is support for our nation's research colleges and universities.

America's colleges and universities are unmatched in their capacity to provide advanced education in science and engineering and to enrich it through cutting edge research. The tight link between research and education has been fostered by the federal government for over half a century and supported through a robust bipartisan commitment. The results of this support have been absolutely remarkable. The expression of scientific research in technological innovation has accounted for a major part of our economic growth, has underpinned our national security, and has promoted our ability to understand, prevent and treat disease, and alleviate environmental problems.

The promise of science and technology is far from exhausted, but will be realized only through continued strengthening of our world-class scientific enterprise. The bedrock of that enterprise is our system of research colleges and universities. Therefore, it is important that the partnership that exists among our academic research institutions, the private sector, the federal and state governments be nurtured and periodically examined, especially at a time when stresses can inhibit bold thinking and limit our reach or effectiveness.

A Time of Significant Stress

Despite the historic accomplishments of our university system, we are in a time of great and complex stress -- stress caused by significant changes in our research and education environment and in our nation, with the end of the Cold War, with the bipartisan recognition of the imperative to cut deficit spending and the necessity to balance the budget, with new demands for accountability in how federal funds are spent. And with the ever-increasing diversity of our student population, old assumptions and boundary conditions are no longer effective. Ironically, these changes, many of which are viewed as limiting our research and education potential, are occurring at a time when we see the brightest future for scientific advances and how those advances can serve the pursuit of national goals. This seeming disconnect between exciting opportunity and sobering constraints must be understood -- and addressed.

Regulations

It is often said that what were once virtues are now necessities. The Administration through the Vice President's work with the National Performance Review has committed to making government work better, cost less, and impose less of a burden on our citizens and institutions. The common sense approach that we are taking to government means that:

- government focuses on results, instead of burying us in rules and punishing those who don't comply;
- government recognizes that its customers come first; and
- the people get their money's worth – that government works constantly to be better, faster, and cheaper while delivering quality services.

Despite a litany of progress, we need to do more. Inefficient and overly bureaucratic regulations continue to erode the buying power of scarce federal resources. I believe that the regulatory arena, however complex, is ripe for reform. Unfortunately, the legal and bureaucratic structures that are in place to enforce many of these regulations have multiple constituencies and purposes. For example, should EPA regulate the relatively small amounts of hazardous wastes generated by a university labs the same way it regulates waste generated by industry? Balancing the statutory requirements, regulatory requirements, and other directives and orders requires careful attention so that the federal side of the partnership doesn't smother the university side. We must use common sense to identify and change those regulatory constraints that are redundant, not science-based, or erode Federal-university partnership.

For academic institutions conducting government-sponsored research, no issue raises more hackles than "OMB Circular A-21." This circular articulates the financial terms of the long-standing partnership between universities and the Federal government for the support of research. Just as the overall partnership must be dynamic to maintain its vitality in the face of changing circumstances, the guidelines in A-21 must also change periodically to reflect evolving responsibilities, scientific practice, technology, the laws of Congress, and changes in the financial environment, human resources, and the physical research infrastructure.

Over the past five years, we have made some significant changes to Circular A-21. However, I know that from the universities' perspective not all of those changes have been for the better. We are trying to balance competing interests: the need to maximize the impact of our federal research dollars with the need to ensure appropriate levels of fiscal accountability.

Because Federal regulations can have a profound effect on the efficiency and effectiveness of academic institutions and researchers, we have been working for several years with Federal agencies, academic organizations, and the Federal Demonstration Partnership to identify further regulatory reforms that can ease the burden. This process of progressive regulatory reform will only work if you -- our university partners -- continue to implement cost containment measures and monitor how your institutions fulfill the redefined requirements. Consider, too, that regulation is an arena where the more extensive but relevant experience of industry in producing efficiencies of outcome and other economies could shape projects by colleges and universities.

PRD

A major activity just getting underway, which I alluded to earlier, is a comprehensive Federal assessment of the rules and procedures that promote or constrain the Federal government-university partnership. Under the authority of the NSTC, I issued a Presidential Review Directive, or PRD, to form a multi-agency task force under the direction of the Committee on Fundamental Science, to focus on the major stresses in the areas of research, education, and administrative regulations, and to determine what the Federal role should be in addressing those stresses.

Much of the Federal research and education investment portfolio enjoyed bipartisan support during the President's first term. However, investments in some critical areas — such as studying the influence of human activity on global environmental systems, or innovative government-university-industry technology partnerships were sincerely challenged, partly for ideological reasons, sometimes because of lack of knowledge, and sometimes out of honest disagreement about the value to society of the programs. Whatever the causes, the innovation system, which accounts for so much of our national progress over the past half century, is in stress.

A major part of the strain results from the uncertainties of Federal research funding as we drive down the Federal budget deficit. However, on the other side of the ledger, the bipartisan commitment to deficit reduction is important for sustaining a business environment that encourages substantial investment in commercial R&D. Another part stems from the attempt to reshape and expand the research and education portfolio to meet some of the major new societal realities. Such changes do not come easily. As Francis Cornford, the late Cambridge University philosopher, sardonically observed near the turn of the last century, "Every public action which is not customary either is wrong or, if it is right, is a dangerous precedent. It follows that nothing should ever be done for the first time."

We, however, intend to escape this wry logic in framing today's science and technology and education agenda to meet tomorrow's demands. With the start of a new Administration and a new Congress, we look forward to working together in support of our entire research portfolio.

Budget Climate

In addition to increasing allocations for research, the Administration has begun a process of management reforms to improve effectiveness of the investment. Examples include

- Revising and streamlining regulations and agency directives.
- Eliminating regulations that are outdated or add no value.
- Automating research support functions (such as electronic

submission of research proposals).

- Developing performance-based organizations.

Lean but accountable research administration, both in the Federal agencies and in the performing institutions — universities, medical schools, national laboratories, and industrial research centers — will sustain our competitive position even as expenditures are constrained.

Clearly, one of the major challenges associated with balancing the Federal budget by the year 2002 is achieving that goal while maintaining our nation's leadership in science and technology. The constraints on Federal research funding are driven by the need to eliminate the budget deficit, which grew enormously during the 1980s and stifles investment today. This situation clearly affects the level of research support for universities, about 60% of which comes from the Federal government. In the face of austerity in discretionary funding:

- For five years, we have protected research and higher education against cuts (the dilemma of the "discretionary" program budget).

- In preparing its FY1998 budget, the Administration formulated a budget projection through FY2002 that protects funding levels for health research at NIH, fundamental research at NSF, and DOE's and NASA's science programs, along with the Administration's multi-agency S&T initiatives.

- Both basic and applied research budgets increase steadily during this period by about 5% over FY1998.

- The overall reduction in R&D funding by FY2002 stems from a planned 7% decrease in development activities, especially those related to defense activities.

These projections are consistent with the President's commitment to balance the budget by FY2002 and satisfy discretionary funding caps. The bottom line, thanks to the President's priorities and our favorable economic status, is that the FY1998 budget request for science and technology is substantially higher than we projected it would be a year ago.

In the FY98 budget request, we continue to promote the growth of programs that benefit basic research and therefore universities. Overall, programs that support university scientists did quite well:

- NSF and NIH would each be increased by 3%;
- Basic research funded by DOE is proposed for a 4.6% increase above FY97 funding levels (remember that previous out year projections had DOE programs sharply decreasing);
- The peer-review competitive grant programs at both the USDA (the NRI program) and EPA (the STAR program) are up 38% and 21%, respectively;

- DOD basic research in the 6.1 account is up by almost 8%; and
- Science research at NASA is up 3%, including a projected 7% increase in academic R&D.

Let me provide you with just a quick sketch of the President's S&T budget in the year ahead. The bottom line is that the President's FY1998 budget increases total Federal R&D funding by more than $1.6 billion over 1997, to roughly $75 billion. This marks the *fifth* year in a row that President Clinton has called for increases in science, technology and education. Funding for basic research and for university-based research is higher. Support for environmental research, as well as health, food and safety research also rises. Investments in computing and communications grow by 10 percent. There is significantly enlarged support for programs to bring modern information technology to American's classrooms to raise students' achievements to rigorous and challenging standards. Investment increases are also included for technologies essential for ensuring continued U.S. economic leadership and job creation.

Forecasting is always a dangerous game, perhaps especially so in areas driven by research, an activity that is all about the unknown. But as a noted economist, Paul MacAvoy, once observed, "If you don't forecast well, forecast often." Nonetheless, despite the yearly rumors of the imminent demise of our nation's R&D enterprise, the fact is that between the years 1998 and 2002, the President's plan will preserve civilian research funding while completing the job of balancing the budget. Our first guiding principle in formulating next year's budget is to protect or enhance funding levels for health research at NIH, fundamental research at NSF, and DOE's science, energy efficiency, and renewable energy programs, and NASA's science programs, along with the Administration's S&T initiatives. And above this base, I fully expect some increases — including those required to launch unanticipated but exciting new initiatives — to be presented each year, at the time that year's budget request is prepared and submitted to Congress. Our second guiding principle was to emphasize the association between research and higher education. Third, we have worked hard over the past year to provide budgets in the out years that give continuity to research, ironing out the ups and downs that were projected for out years in the 1997 budget.

When you consider our S&T budget *in toto*, advancing the development of enabling technologies becomes increasingly significant as the time horizons of industrial research and development grow shorter. While a short-term research focus can sustain a globally competitive position for some time, it does not provide breakthrough technologies that generate new industries. That is why the Administration continues to place emphasis on government-university-industry partnership programs aimed at mid- to long-term technology development in both the public and private interest. Industry and academia take the lead in identifying promising directions and, after independent merit review, government shares the risk. Although these programs have experienced significant partisan differences, the Administration will work to actively pursue partnership programs in a pragmatic bipartisan spirit. In particular, I believe these programs are now achieving a level of experience that will permit detailed evaluation and optimization of future investments.

Finally, let me return to our agenda for national S&T leadership for a moment. First, remember that science and technology leadership, or the lack of it, in one deeply affects the other. The required elements necessary to focus our efforts are: an educated, well-informed, and open society that embraces thoughtful change and has an eye to the future; a long-term, deep commitment to research and higher education; and a fertile policy environment that encourages entrepreneurship, experimentation, and innovation.

In closing, I am reminded of the story of the great French military leader, General Lyautey, who once asked his gardener to plant a particular tree. The gardener protested that such a tree was very slow growing and would not reach maturity for a hundred years. The General replied, "In that case, there is no time to lose. Plant it this afternoon." We, too, have no time to lose — we must continue to build the investment agenda that will shape America's success deep into the twenty-first century.

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Remarks of
John H. Gibbons
Assistant to the President for Science and Technology

Stresses on Research and Education at Colleges and Universities: Phase II

Government-University-Industry Research Roundtable
National Academy of Sciences

February 26, 1997

Thank you. I am pleased to be with you today and, first of all, to bring a message from the President of the United States.

Warm greetings to everyone gathered at the National Academy of Sciences to discuss an issue of utmost importance to the future of our nation: the continued vitality of America's research colleges and universities.

We live in a time of enormous possibility. We have an unprecedented opportunity to shape the Information Age, to lead the global economy, to develop new life-enhancing technology, and to create jobs for the work force of the next century. Our passion for learning and our sense of discovery have always driven this nation forward, and, if we are to make the most of this historic moment, we must renew our national commitment to education, to learning, and to research.

America's colleges and universities have, for decades, produced the world's finest engineers and scientists and have been a principal source of new knowledge and scientific discovery. Today, we still look to our academic institutions for help in addressing our nation's major challenges -- fighting disease, improving the environment, protecting our national security, and sustaining our economic growth. But, if we are to ensure the future vitality of these institutions, we must work together -- federal and state governments, the university community, and private industry -- to make the far-sighted investments in education and research that will enable us to master this moment of change and build a stronger America for the future.

I commend all of you for your dedication and leadership in this endeavor. By striving to revitalize the role of America's colleges and universities in scientific enterprise and to strengthen the foundations of support of this role, you are helping to create a brighter future for us all.

Best wishes for a productive meeting.

It is signed by President Bill Clinton.

One of the overarching themes of the Clinton Administration's support for science and technology is maintaining leadership across the frontiers of science. The Administration views S&T leadership as crucial to improving health care, agriculture, environmental management, national security, and economic prosperity. Key to maintaining this leadership is support for our nation's research colleges and universities. But they cannot do it alone. That is why the GUIR Roundtable was created to foster dialogue among partners, to share lessons learned, and to illuminate pathways to solutions either not seen or not yet taken.

While focusing on stresses on research and education, I would like to emphasize in my remarks the value of dialogue, learning across sectors, and the need to glimpse new solutions to the challenges that confront colleges and universities, and indeed the nation.

America's colleges and universities are unmatched in their capacity to provide advanced education in science and engineering and to enrich it through cutting edge research. The tight link between research and education has been fostered by the federal government for over half a century and supported through a robust bipartisan commitment. The results of this support have been absolutely remarkable. The expression of scientific research in technological innovation has accounted for a major part of our economic growth, has underpinned our national security, and has promoted our ability to understand, prevent and treat disease, and alleviate environmental problems.

The promise of science and technology is far from exhausted, but will be realized only through continued strengthening of our world-class scientific enterprise. The bedrock of that enterprise is our system of research colleges and universities. Therefore, it is important that the partnership that exists among our academic research institutions, the private sector, the federal and state governments be nurtured and periodically examined, especially at a time when stresses can inhibit bold thinking and limit our reach or effectiveness.

Of course, there is a corollary. The heightened importance in the public's mind of research and education, as keys to both national strength and individual well-being, brings with it heightened demand by the public and elected officials for measures of the health, the efficiency, and societal contributions of academe. Their opinions will be shaped by factors that extend well beyond research and education per se. But they are intimately tied to what colleges and universities are expected to do: expand knowledge and anticipate the skills their graduates will need to add productively to the nation's workforce, economic well-being, and leadership in the world. These goals create a forum for dialogue that must cross disciplines, sectors, and geographic boundaries.

The heightened demand by the public for performance, and the public expectations that tend to outpace it, should be welcomed. They are indicative of society's appreciation for the role of higher education in the knowledge age and for the solutions that academe, in partnership with industry and government, can provide.

A Time of Significant Stress

Despite the historic accomplishments of our university system, we are in a time of great and complex stress -- stress caused by significant changes in our research and education environment and in our nation. With the end of the Cold War, with the bipartisan recognition of the imperative to cut deficit spending and the necessity to balance the budget, with new demands for accountability in how federal funds are spent. And with the ever-increasing diversity of our student population, old assumptions and boundary conditions are no longer effective. Ironically, these changes, many of which are viewed as limiting our research and education potential, are occurring at a time when we see the brightest future for scientific advances and how those advances can serve the pursuit of national goals. This seeming disconnect between exciting opportunity and sobering constraints must be understood -- and addressed.

Budget Reductions

Clearly, one of the major challenges associated with balancing the federal budget by the year 2002 is achieving that goal while maintaining our nation's leadership in science and technology (S&T). The constraints on federal research funding are driven by the need to eliminate the budget deficit, which grew enormously during the 1980s and stifles investment today. This situation clearly affects the level of research support for universities, about 60% of which comes from the federal government. In the face of austerity in discretionary funding:

- For five years, we've protected research and higher education against cuts (the dilemma of the "discretionary" program budget).
- In preparing its FY1998 budget, the Administration formulated a budget projection through FY2002 that protects funding levels for health research at NIH, fundamental research at NSF, and DOE's and NASA's science programs, along with the Administration's multi-agency S&T initiatives.
- Both basic and applied research budgets increase steadily during this period by about 5% over FY1998.

- The overall reduction in R&D funding by FY2002 stems from a planned 7% decrease in development activities, especially those related to defense activities.

These projections are consistent with the President's commitment to balance the budget by FY2002 and satisfy discretionary funding caps. I am very pleased that the projections define a base funding level that is both realistic and achievable to serve as useful planning figures for each agency. I certainly expect that some increases -- including those required to launch exciting new initiatives -- will be realized each year, at the time that year's budget request is prepared and submitted to Congress. The bottom line, thanks to the President's priorities and our favorable economic status, is that the FY1998 budget request for science and technology is substantially higher than we projected it would be a year ago.

In the FY98 budget request, we continue to promote the growth of programs that benefit basic research and therefore universities. Overall, programs that support university scientists did quite well:

- NSF and NIH would each be increased by 3%;
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- DOD basic research in the 6.1 account is up by almost 8%; and
- Science research at NASA is up 3%, including a projected 7% increase in academic R&D.

Education

How stresses on research affect the climate and character of advanced education is the business of both colleges and universities -- the producers -- and of industry -- a prime consumer. One of the ten elements of the President's education plan is to "open the doors of college to all who work hard and make the grade, and make the 13th and 14th years of education as universal as high school." To help us meet this objective, the President has proposed:

- the HOPE scholarship, a $1,500 tax credit for college tuition, which should be enough to pay for a typical community college tuition;
- a $10,000 tax deduction for any tuition after high school;
- an expanded IRA to allow families to save tax-free for college; and
- the largest increase in 20 years in Pell Grants for deserving students.

While participation in higher education is sought as a key to a robust U.S. workforce, the form of that participation is changing. The information revolution, while creating new opportunities through technology, also is transforming the way colleges and universities accomplish their education mission. Access to university programs is no longer limited by geography or the availability of classroom space. Improvements in the Internet and networking, for example, open new possibilities for distance learning that challenge our traditional views of the resident campus and the clientele it serves. These developments not only expand greatly student and public access to academic life, but also create new pressures on what faculty teach, how they are rewarded, and what constitutes scholarship and good citizenship on campus and in society.

In addition to increasing access to higher education, the President has proposed an aggressive system of national standards in reading and mathematics for grades K through 12. The results of the Third International Math and Science Study, TIMSS, clearly demonstrated the need for our students to improve their overall math and science skills relative to other nations. While we were not at the bottom, our students only performed average compared to the other 40 participating nations. Average scores will not ensure our nation's future leadership in math, science, and technology, and will not ensure future economic prosperity. We must do better.

I dwell on K-12 education because our nation's colleges and universities have a key role to play in improving the performance of our K-12 students in math and science. Such improvements would clearly lower the stress on colleges and universities, too! The President's call for a voluntary national eighth grade mathematics exam is a way of mobilizing the resources of local communities to help schools and districts to identify the conditions and practices that improve academic achievement in all subjects. What better resource for improving science and math literacy and influencing careers than institutions of higher education? In various ways, faculty can help fortify teaching and learning in a classroom that is based on rigorous content standards such as those developed for science by NAS. Combined with high expectations for all students and internationally-benchmarked performance, standards-based instruction can become the norm in U.S. classrooms. Universities, business, and industry all gain through the superior preparation of students and workers. Working together, we can reduce this form of stress.

Specifically, colleges and universities can help students advance toward excellence in at least three ways. First, how we teach our future teachers is of paramount importance. We need a stronger partnership between colleges of education and colleges of science and engineering. Future teachers cannot build on students' natural curiosity about the physical world without first awakening their own, asking questions and developing an appreciation for experimentation, systematic observation, probability, and the making of inferences. Such "literacy" in the methods of inquiry as well as textbook answers is a prerequisite for teaching. If teachers are not equipped -- in content areas, in technology, and in hands-on, inquiry-based pedagogy -- their students (and our next generation workforce) will suffer. New teachers lacking preparation in standards-based instruction will also add to the costs of local professional development. Why certify teachers who are not state-of-the-art? Why add to the burden of retooling and retraining a veteran teacher workforce? These questions of investment in human resources are best addressed during study toward the baccalaureate. Colleges and universities can exercise quality control over what new teachers are trained to know and do.

Second, higher education is best positioned to increase the knowledge base on "what works" through research and evaluation of models and practices, and to suggest how standards-based classrooms can better utilize technology and sustain high performance in mathematics and science by all students. Through NSF's Systemic Initiatives and the DoED's Goals 2000 program, states and districts are now changing management structures and teaching modes to raise academic performance. We must learn from these experiments in real time. Colleges and universities must be reliable partners of school districts and their teachers, as many companies have been, if the latest research in science and technology is to be successfully adapted to the K-12 classroom. Higher education faculty are human resources for schools and communities. Tapping -- electronically or otherwise -- the diversity of disciplines and cultures among them puts a human face on science. It also increases the potential for mentoring students, as industry programs have long demonstrated.

Third, higher education is often the sector for drawing on talent in the national interest. The President has enlisted student volunteers from over 60 colleges and universities to serve as tutors in the "America Reads" program. To help all students perform to world-class standards in mathematics, a pool of algebra and geometry tutors could likewise volunteer in schools and community-based organizations, after school and on weekends, to augment classroom instruction and enrich mathematics teaching and learning by the eighth grade. Such an initiative, which higher education could organize and run in collaboration with industry, is citizenship in the purest sense of sharing knowledge and expanding options. We know that such interactions during the impressionable middle-schools years can make a big difference. The President has established annual awards for mentoring, which is especially important for under represented minority students studying math, science, and engineering both in K-12 and college. I solicit your commitment to do more in partnership with K-12 schools and students nation-wide.

It is in the mutual interest of the producers and consumers of new graduates to ensure that talent is drawn from all segments of the population, and that their mix of skills and knowledge is well-matched to the job opportunities of the 21st century. This is neither easy nor readily predictable. It is stressful. But colleges and universities are adept at tackling hard problems and forging new solutions, mindful -- at least some of the time -- that "the key to the future is to forget past successes."

Regulations

It is often said that what were once virtues are now necessities. The Administration through the Vice President's work with the National Performance Review has committed to making government work better, cost less, and impose less of a burden on our citizens and institutions. The common sense approach that we're taking to government means that:

- government focuses on results, instead of burying us in rules and punishing those who don't comply;
- government recognizes that its customers come first; and
- the people get their money's worth – that government works constantly to be better, faster, and cheaper while delivering quality services.

Despite a litany of progress, we need to do more. Inefficient and overly bureaucratic regulations continue to erode the buying power of scarce federal resources. I believe that the regulatory arena, however complex, is ripe for reform. Unfortunately, the legal and bureaucratic structures that are in place to enforce many of these regulations have multiple constituencies and purposes. For example, should EPA regulate the relatively small amounts of hazardous wastes generated by a university labs the same way it regulates waste generated by industry? Balancing the statutory requirements, regulatory requirements, and other directives and orders requires careful attention so that the federal side of the partnership doesn't smother the university side. We must use common sense to identify and change those regulatory constraints that are redundant, not science-based, or erode federal-university partnership.

For academic institutions conducting government-sponsored research, no issue raises more hackles than "OMB Circular A-21." This circular articulates the financial terms of the long-standing partnership between universities and the Federal Government for the support of research. Just as the overall partnership must be dynamic to maintain its vitality in the face of changing circumstances, the guidelines in A-21 must also change periodically to reflect evolving responsibilities, scientific practice, technology, the laws of Congress, and changes in the financial environment, human resources, and the physical research infrastructure.

Over the past five years, we have made some significant changes to Circular A-21. However, I know that from the universities' perspective not all of those changes have been for the better. We are trying to balance competing interests: the need to maximize the impact of our federal research dollars with the need to ensure appropriate levels of fiscal accountability.

Because Federal regulations can have a profound effect on the efficiency and effectiveness of academic institutions and researchers, we have been working for several years with Federal agencies, academic organizations, and the Federal Demonstration Partnership to identify further regulatory reforms that can ease the burden. This process of progressive regulatory reform will only work if you -- our university partners -- continue to implement cost containment measures and monitor how your institutions fulfill the redefined requirements. Consider, too, that regulation is an arena where the more extensive but relevant experience of industry in producing efficiencies of outcome and other economies could shape projects by colleges and universities.

PRD

A major activity just getting underway is a comprehensive federal assessment of the rules and procedures that promote or constrain the federal government-university partnership. Under the authority of the NSTC, I issued a Presidential Review Directive, or PRD, to form a multi-agency task force under the direction of the Committee on Fundamental Science, to focus on the major stresses in the areas of research, education, and administrative regulations, and to determine what the federal role should be in addressing those stresses. Dr. Ernie Moniz will speak to you about this later this morning.

Conclusion

In summary, we are counting on our colleges and universities, in concert with their partners and in the spirit of the GUIR Roundtable, to shoulder a significant set of responsibilities in this time of national reexamination and substantial evolution of our investments in the future. This reinforces our commitment to sustaining the health of the university system as part of a shared commitment to the prosperity, security, and quality of life of all our citizens.

In the President's State of the Union address, he issued a call to strengthen education and harness the forces of technology and science to enable the kind of future we aspire to. We have the mandate. We now must have the will to move together from rhetoric to action. Taken in the right spirit, stress, like the proverbial night before the hanging, can focus the mind!

# # #

Remarks of Dr. John H. Gibbons
Assistant to the President for Science and Technology

In Celebration of
The Presidential Award for Excellence
in Science, Mathematics, and Engineering Mentoring
to the
National Action Council for Minorities in Engineering, Inc., New York
Consolidated Edison Company
New York, NY
February 11, 1997

- I am delighted to be here to convey the President's congratulations on NACME's selection as one of the first institutions to receive the Mentoring Award.

- The significance of the President's Mentoring Award actually is modest compared to the lives that have been changed, and the talent that has been drawn into engineering and science, through the sustained efforts of NACME, its President and CEO George Campbell, and the NACME Board.

- Celebrating this award during Black History Month helps to remedy a historical wrong-- the unfortunate lack of material in science textbooks highlighting the roles of African Americans in the development of science and technology in the U.S.

- I was reminded, flying up from Washington this afternoon, of the accomplishments of the 18th century inventor, Benjamin Banneker, whose most notable, from among many, contributions to America came as a surveyor with the team chosen by President George Washington to develop the plans for the new U.S.Capital. President Washington appointed Major Pierre Charles L'Enfant, a young Frenchman, to be in charge of planning the new capital. But the bureaucrats of the day resented a foreigner being given so much authority. They frustrated him to the point of resignation, whereupon he took all the plans and maps back with him to France. Thomas Jefferson called a meeting in an attempt to salvage the project. Incredibly, Banneker told Jefferson he could reproduce the plans from memory. In two days he did. The work of laying out the city of Washington, DC, was completed, yet Banneker received little official recognition then or since.

- None of these accomplished scientists and engineers, they would tell you, and I can also personally relate, would have excelled without the interest, concern, caring, and guidance <u>of mentors</u>. This award to NACME epitomizes their spirit -- and our personal and national investment in the next generation.

- The Presidential Mentoring Award Program, which I believe was long overdue, was bestowed last September on ten individuals and six institutions. None of them had pursued the recognition. The awardees were nominated by their peers, colleagues, and partners not only for their convictions and continued efforts in behalf of engineering and science students, but also for their impact on supporting those talented students to achieve what many doubted they could.

- In addition, what is noteworthy about the NACME award is that it represents one of only two recipients that are what is euphemistically called "community based organizations." Unlike institutions of higher education, CBOs leverage resources and influence from outside the formal system. They do public service by concentrating the intentions and resources - both fiscal and human - of those who recognize, consume, and benefit by a skilled and versatile technical workforce.

- We all know that investing in human resources - through formal education and access to opportunity to earn baccalaureate degrees and beyond - is the best investment the Nation can make. When those human resources are being prepared to contribute to the processes of research, discovery, and innovation, they are a a gift to the next generation that "keeps giving." They, in turn, raise and reinforce our expectations.

- So it is with pride and joy, both as a scientist and the President's Science Advisor, that I thank NACME. The Nation is grateful for you. Your programs will continue to shape future cohorts of undergraduates who increasingly look like America. Your legacy are these engineers and scientists who are poised to contribute through their work and citizenship, to their professions, their communities, and to a dynamic global economy of the 21st century. Thank you.

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Divider Title: **Seattle**

Remarks of
JOHN H. GIBBONS
Assistant to the President
for
Science and Technology
Dael Wolfle Lecture
October 9, 1996
Seattle, WA

Original JHG 10/9/96

I am very grateful for the opportunity to be on campus and to present this year's Wolfle lecture. His is a life of service to science and society, and it's a pleasure to celebrate it in this way with you. And it's a particular pleasure for me because Dael directly contributed to the institutions to which I've been devoted for the past 17 years, including the President's science advisory apparatus; the National Academy of Sciences Committee that recommended the establishment of the Congressional Office of Technology Assessment; and the AAAS. In the history of the West, there was a hardy group of explorers, entrepreneurs, and independent spirits collectively referred to as the "mountain men." In the exploration and development of science policy, Dael epitomizes the Mountain Man.

Well, certainly today we are at another historic time for the nation. I guess each moment in time is a historic time. But with the ceremonial approach to the millennium, it is a good opportunity for us to make some critical decisions about where it is we want to be and how we want to get there in the 21st Century. And in a sense, we are doing no less than deciding about our future as a self-governing society.

There are many perspectives about the future. In my darker moments, I think of Pogo who once said to Churchy Lafemme, "Well, Churchy, as I see it, from here on down it is uphill all the way."

There are others who have a more optimistic view of the future. However, every thoughtful person should ~~we certainly~~ see ourselves as in a time of expansion of options through the proliferation of knowledge. Even though this means more opportunities, it is also a time in which a number of constraints, "constraints of complexity, of limits to physical dimensions of things, complicate and encumber our future.

It is also clear that science and technology ~~certainly~~ will continue to play a central role in our future, I believe, just as much, if not more so, than in the past. We will use these tools to help bridge our way into the 21st Century. And I expect that our journey into ~~that~~ the next millennium will certainly involve change and opportunity and challenge.

I think the President said it well in his 1995 State of the Union when he said: "...now we move to an age of technology, information, and global competition. These changes have opened vast new opportunities for our people, but they have also presented them with stiff challenges."

While some see this as a time of crises with mostly negative connotations, I take the more optimistic view that this is an exciting time for productive change and progress ~~growth~~ in many dimensions.

~~And I came across~~ This dichotomy of perspective is not new. ~~before, and~~ I think this was best articulated by Gramsci when he wrote in his prison notebooks: "The crisis consists precisely in the fact that the old is dying and the new cannot be born. And into this interregnum a great variety of morbid symptoms appear."

~~And~~ I think ~~that~~ Gramsci's observation is a fair characterization of how we find ourselves as we move to the millennium, away from the cold war, into an era of unprecedented competitiveness, economic integration, global environmental stress, rapid technical and social ~~transition~~ change, regional and ethnic conflicts, and of a lot of other things ~~driven by human activities with which we must wrestle~~.

I certainly cannot subscribe to the notion that science and its partner technology are in a crisis, at least a crisis of impending disaster. To my way of thinking, a true crisis in science would correspond, for example, to an approach to the limits of knowledge itself, or to a massive retreat of support for research. ~~And~~ Despite our extraordinary continuing adventure of discovery, John Horgan's "The End of S." notwithstanding, I think we have not to worry. We are still quite secure in our ignorance.

As Lewis Thomas observed in the Medusa and the Snail: "The only solid piece of scientific truth about which I feel totally confident is that we are profoundly ignorant about nature. Indeed, I regard this as the major discovery of the past 100 years of biology. It would have amazed the brightest minds of the 18th Century enlightenment to be told by any of us how little we know and how bewildering seems the way ahead."

Now that we have begun exploring in earnest, doing serious science, we are getting glimpses of how huge the questions are and how far from being answered. But we are making a beginning, and there ought to be some satisfaction, even exhilaration, in that fact. The method works. There are possibly no questions we can think of that can't be answered given the proper tools and resources.

Einstein ~~also referred to this business of discovery. He~~ said, ~~as I recall,~~ that one of the most remarkable things about the universe is that it appears to be understandable. Not so much that we understand it ~~,~~ now but it is subject to understanding.

~~Well, we certainly don't have to review the last century to record our notable achievements in science and identify profound open questions.~~

I used to wonder in awe at my father's lifetime in which the automobile and heavier-than-air transport became possible, the x-ray was discovered, the composition of the atom and quanta were discovered, the neutron and nuclear fission were discovered. A lot of extraordinary things happened that turned ~~that world~~ the science world upside down.

But then I began to reflect on events during my still somewhat tender age. It has been since I graduated from college that we have gone into space, that we have discovered the reason for the extraordinary species extinction at the KT Boundary in which a sudden cataclysmic event completely overwhelmed the slow underlying progression of Darwin's evolution. ~~and~~ That discovery dramatically broadened our view of evolution. We discovered continental drift to be a fact and were able to measure the velocity of crustal plate movement; we found the neutrino; we discovered DNA and molecular biology.

So the last decade, or even the year or event of the month will do just fine for me in talking about the progress and the state of science. For example, over roughly the past year, ~~new light has been shed on the quantum world.~~

- The Bose-Einstein condensate, a new form of matter, predicted a long time ago, has now been observed. This is a microscopic collection of atoms that have been cooled to such low temperature that their wave functions completely overlap and the whole group acts as a single atom. The "Schrodinger's cat" phenomenon, with which I'm sure you are familiar--it is deeply connected to the unsettling aspects of quantum uncertainty--has just been confirmed experimentally.

I have a little piece of paper in my office hanging on the wall that says: "Heisenberg might have slept here." And I ~~sort of~~ calibrate my visitors ~~to see~~ by seeing whether they smile quickly at that statement.

- Experiments focused on the very small (particle physics) and the very large (cosmology) are teaching us about the nature of mass itself, as well as about the elusive ~~unobserved~~ missing mass which appears to ~~compromise~~ comprise most of our universe.

- We are making stunning advances in our quest to understand the origin and ~~the~~ early development of life. The sequencing of an archaea genome, announced just this summer, has revealed a third form of life. One such organism, *Methanococcus jannaschii*, is found around hot vents in the ocean floor where the water is near the boiling temperature and the pressure is at 600 atmospheres. All that organism needs in order to live its life cycle totally away from sunlight is nitrogen, carbon dioxide, and hydrogen, from which it makes methane. It is neither prokaryote nor eukaryote. And thus textbooks need to be rewritten again as of the Summer of '96.

- Almost simultaneously, we have encountered intriguing evidence of the possibility of ancient life of Mars. There is clearly much science to do in reviewing and advancing these kinds of research. It reminds us about our ignorance of the origin of life, its many different manifestations ~~possible forms~~ here on earth, and its possible occurrence throughout the universe. A great scientific adventure certainly remains at the frontier for us and our descendants!

- Many systems with complex organization pose profound challenges to us. The recent paradigm of punctuated evolution has certainly fundamentally altered our understanding of evolution of the biosphere. Development of the brain and its development in response to external stimuli, especially in early years of life, are only partially explored subjects at the intersection of the life and behavioral sciences. Research in this area is filled with incredible intellectual challenge, and it promises also to be of tremendous importance to educational practice as well.

- And we have just begun to recognize the complexity of the earth system, a fascinating interaction of land and oceans and atmosphere. We have only recently recognized depletion of the stratospheric ozone layer, and we also have only recently come to understand how human actions can make it grow or shrink on a planetary scale.

We have only partial knowledge of the basic workings of the metabolism of the earth's living skin or the biosphere. More complete knowledge in this area is certainly going to be needed if we are going to address comprehensively the problem of climate change, indeed, of the impact between human activities on our spaceship earth and its performance and its durability.

We are early in the learning curve when it comes to the issue of ecosystem metabolism, of biodiversity and its importance to the working of the planet today and its importance as a collection of potential answers to yet unposed questions--questions of the future in the areas of food security and medicine, for example.

These dynamic issues of the global environment that are associated with the issues I just mentioned--ozone depletion, global warming, the loss of biodiversity--all have a common trait, a very long time frame far beyond the kind of time frame that I have to deal with in the White House or the Congress and most of us have to deal with in our daily private and corporate lives.

They and related phenomena, such as human population growth, develop over decades and centuries, not years. And even if they can be stabilized, the time needed for recovery is even longer for many of them, somewhere between human time scales and geological time scales.

Albert Schweitzer once said near the end of his life that "man has lost the ability to foresee and to forestall. He will end up destroying the earth." This from a man who had a full life of great optimism about the future. A very sobering observation from a very wise person.

Our short national history does tell us that we have difficulty addressing these relatively slow-changing, long-term issues. Adlai Stevenson, Jr, said that "...we Americans never seem to see the handwriting on the wall until our back is up against it." Thus — One almost has to develop a perception of crisis in order to effect action.

The ~~problems~~ anormous challenges that I see in the area of environment or sustainable development ~~or even more temporal issues~~ can't be solved simply by ignoring them. Innocence or inaction is not the route to salvation. In fact, such issues will continue to grow worse as long as we refuse to address them squarely.

At the same time I must observe that members of the Congress are trying to halt the funding of many global environmental research projects despite the fact that their scientific merit has been attested to by the National Academy of Sciences as being very high. Some in Congress want to stop this research~~.~~ by calling ~~They call~~ it liberal clap trap! I believe that their real problem is that they are concerned that this kind of scientific investigation may indeed disclose the kinds of limits of nature that are anathema to their political philosophy.

(OTA)

We are in the ~~earliest~~ formative stages of coupling the physical, biological, and social sciences in the pursuit of global knowledge. The admonition of C.P. Snow is still with us that we need to continue to try to bridge that ~~important~~ infamous gap between our cultures of natural science and social science in order to ~~really~~ effectively tackle many ~~of these~~ research questions.

This coupling certainly is essential if we are to define and understand and, therefore, react to the notion of a carrying capacity of the earth for humans. To resolve this issue, we must not only define the technology-~~development~~ dependent limits of the earth's resource base for supporting the human species and our activities, but we must also consider the quality of life that people ~~demand or are willing to settle for~~ seek.

And that requires being sensitive to numbers. Lord ~~Bertram~~ Bertrand Russell said that one of the problems of ~~humanity~~ people is that "we would rather commit suicide than learn arithmetic." But beyond arithmetic, there is a question of how far technology and science can carry us in altering the equation of carrying capacity. Capacity is a strong function of the degree with which we use our intellect through technology to provide for goods and services with minimal impact on resources.

~~And~~ A key ~~paradigm~~ proposition of the Clinton administration is that by embracing, supporting, and sustaining research in science and engineering, we can provide for environmental quality and the protection of our future generations while at the same time providing goods and services to our economy. ~~It~~ This proposition goes against the grain of the traditional paradigm that somehow environmental quality and other amenities of life are in fundamental confrontation with providing the physical amenities.

This seeming dilemma was illustrated in a cartoon in the New Yorker in which two people were standing on a busy street corner in ~~New York~~ a big city. One said to the other, "You know, the way I look at it, there is a tradeoff for everything. You want a high standard of living, you settle for a low quality of life."

Sci.+Tech. ~~I~~ would claim that is not necessarily the case. Indeed, so does the President. ~~But~~ We all too often ~~do~~ think of standards of living in terms of ~~as~~ convenient, economic measures of our progress. I would remind you of what Rene Dubos said about this. He said, "Just as important are the social amenities that make it possible to satisfy the longing for quiet empty spaces, for privacy, independen~~t~~ce, and other conditions essential for preserving and enlarging the peculiarly human qualities of life. These are in short supply already."

Let me turn to the issue of funding for science and technology for a moment because achieving our multiple goals can't be done just by wishing it! I think all of us need periodic reminders about the rewards of investing in the future. We have done this well in the past. Our global competitors in defense or aeronautics, environmental technology, medical devices, pharmaceuticals, telecommunications, computers, and a host of other areas have all learned from our example.

~~And now~~ Some of ~~them~~ these competitors now make similar or greater investments than we. While we cut our research budget, Japan is doubling theirs to provide for the future as well as spur their eco They already exceed us in research investment per capita. Before the turn of the century, they will exceed us on an absolute basis ~~of investment~~, even though they have half our population.

In the context of Aesop's Fables, some of our most worthy competitors are acting today like the ants. They put aside the seed corn for a cold and rainy day. We did it ourselves for many years. In years past, the Federal

Government saw opportunities to invest for a better future, persevered in those investments, and reaped ample rewards.

For example, fiber optics was a germ of an idea in an obscure area of basic physics only 30 years ago, but fiber optics now carry most U.S. long distance telecommunications.

- The global positioning satellite system represents a confluence of basic research in physics and software communications and high-speed electronics. First developed for miliary purposes, as was the internet, it is now rapidly expanding in the commercial markets for navigation and air safety, as well as contributing to agricultural and ecosystem management.

- Severe weather prediction emerged from the integration of space platforms, immense computing power, and atmospheric science research to help prevent the loss of life and property.

- Biotechnology resulted from decades of basic research in molecular biology and computer science and now provides diverse services from pharmaceuticals and health diagnosis to improved foods.

But I am concerned that we are becoming a little bit more like Aesop's grasshopper than the ant--the grasshopper who sang the summer away. In unison we sing less government, lower taxes. But there is dissonance when we try to talk about preparing for the future and putting aside something for our children and our grandchildren.

That is one reason I am very pleased to be in this Administration in which the President and Vice President constantly address this question of investing for the future, including providing for the effective replenishment of natural resources we consume with knowledge and technology that provides similar economic opportunities for future generations.

~~Somehow we must find and re-establish a degree of harmony between the Administration and Congress on these issues. And I certainly hope that will become evident over the next couple years.~~

~~American mastery of science and technology and its continued, thoughtful pursuit, will largely determine whether our citizens can capture new opportunities, good jobs, a higher quality of life, and continue to enjoy basic amenities, including safe and affordable food and shelter and a nourishing environment.~~

The Federal Government clearly plays a pivotal role in assuring our leadership in science and technology. ~~The nation's world leadership in science, math, and engineering fundamentally derives from Federal sponsorship. And there is no substitute for it.~~

Federal applied research and development investments partnered with private sector innovators have led directly to the kind of leadership of U.S. firms today in agriculture, aeronautics, electronics and semiconductors, computers, communications, pharmaceuticals, and other leading industrial sectors. Despite our self-imposed commitment to stop borrowing from the future to pay for present consumption, and the continued tight budget squeeze that will be required to balance, we believe it would be foolhardy cut deeply or eliminate the historic cost-shared partnership [illegible]

~~We are determined to continue these investments in science and technology for the future, despite the fiscal pressures upon us today and over the next several years. And we are convinced that Lewis Thomas was right: our greatest discovery of this century has been the discovery of the extent of our ignorance.~~

Finally, I would ~~also~~ like to reflect on the underlying ~~drivers or~~ causes of stress/pressures ~~the effects that~~ we now observe on society in general and ~~in many ways in~~ the science community specifically.

I would posit three factors that I think we ought to try to ~~keep in mind.~~ wrestle with. First ~~is~~ we need to address the consequences of our long-held paradigm that the exponential is our friend. Humankind, especially Western civilization, ~~I believe~~ has long viewed expansionism: expansion of human population, of ~~people~~, of consumption of natural resources ~~production~~, of occupation of the land, as a vital life sign, the route to a better life, a measure sine qua non of our progress.

Implicitly, science and technology have joined that metaphorical westward expansion that ~~economist~~ Ken Bolding titled the cowboy economy, route to prog namely, move west and produce more. The notion worked remarkably well for quite a time in our national history. But now we have run out of geographical frontiers, and there is much frustration with science itself, in part because it is now ~~defining~~ discerning limits that are not welcomed in a cowboy economy.

Herb Stein, a highly regarded economist, once addressed the ~~question~~ phenomenon of exponentia~~tion~~l growth in the following way. He said, "That which cannot continue forever must at some point come to an end." It sounds simple, but when you get down to the practicality of it and the paradigm change it implies for our society, it is a really great challenge for us. Is ~~it~~ the time not already overdue to re-define measures of progress and wealth?

The second thing I would hope we can take into account is the fact that, largely driven by accelerating advances in science and technology, ~~advances~~ and by the mounting complexity of our society, the ability of our ~~social system~~ society to accommodate and to adapt to change is sorely stressed.

This, I believe, is one important explanation for the international rise in revisionism, in ultra-fundamentalism, in anti-science and in governance: all emerge ~~emerging~~ from people's frustration with the situation ~~people~~ they find themselves in.

The third factor, is that ~~one might at least postulate that~~ there has been a loss or erosion of the social contract between society and the ~~scientific~~ research community. The implicit bargain of a half-century ago was to keep us out of a hot war with the menacing Soviet Union, and on the side to create economic wealth, and improve human health. That ~~was~~ constituted the underpinning to the support of science for decades.

The ~~system was challenged and questioned~~ mostly "white hat, cornucopia" image of S+T was properly challenged by Rachel Carson and by other events in which science, or at least the applications of science, often seemed to be taking us in the wrong direction. A couple of decades ago, Robert Heilbroner observed that ~~this~~ ours may be the last generation that has the opportunity for society to wrest control of ~~the~~ its future away from the unbridled forces of technology.

This discomfort with the way things were going was further underscored by the cancellation of the superconducting supercollider several years ago, reflecting in part a public conviction that this kind of science, however pure and non-threatening, is ~~was viewed by the public as~~ not sufficiently relevant to

~~its~~ the public's interest to hold its support. Even if science isn't understood, if people have a feeling it is going to affect their lives in a positive way, such as, for instance, research in molecular biology, people will still support it. But if they neither understand the science nor have a feeling that it is relevant to their lives, then the social contract is broken.

~~And I think that is a thing~~ These are issues we need to wrestle with rather than speculating about the limits to knowledge. There are attendant responsibilities of the members of the scientific community to better and more frequently communicate the activities that we are engaged in and their relevance, however ~~[illegible]~~ unpredictable, to the needs and wants of society.

~~So ultimately I think we have identified enormous challenges to our intellectual community to come to a better understanding~~ We need to integrate across disciplines, ~~both~~ to bridge between the natural and social sciences, ~~and~~ in order to address not only the frontiers of knowledge but also the frontiers of concerns of our society.

Divider Title: **Mentoring**

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Remarks by
The Honorable John H. Gibbons
Assistant to the President for Science and Technology

at the
Presidential Award for Excellence in
Science, Math, and Engineering Mentoring Awards Ceremony
Room 450, Old Executive Office Building
Washington, DC

September 25, 1996

The Significance of the Presidential Mentoring Program

I am very pleased to be here today to present the Presidential Awards for Excellence in Science, Mathematics, and Engineering Mentoring.

You are the first group of awardees in this program. The President intends the program to recognize outstanding mentoring efforts and programs that have served to encourage minorities, women, and persons with disabilities to study and to succeed in science, mathematics, and engineering. By the turn of the century, and the millennium, one-third of the American nation will be composed of minorities. In the highly competitive, knowledge-rich, information-intensive, global economy, every individual, no matter what gender, color of skin, or disability, must be provided the opportunity — and indeed encouraged — to pursue their interests and to develop their talents in science and technology whether it be as a career choice, or to be able to exercise full citizenship in the technology and information age we have entered. Our nation can no longer afford to underinvest in their potential or to have science and technology-illiterate citizens in its democracy.

The President has made education a major foundation of his bridge into the twenty-first century. He recognizes that role modeling and mentoring are critical ingredients in the nourishing of talent. Every one of us here today have benefitted throughout the years — starting as young children, through our grade school and into undergraduate and graduate years — from demanding, thoughtful, and caring mentors who have made such an enormous difference in our accomplishments. The mentoring program recognizes this basic fact in the professional development of scientists and engineers and seeks to ensure that individuals who have not had these same opportunities will have better access to them in the future.

The President established this award based on a recommendation made by the National Science and Technology Council. The award is jointly administered by the White House Office of Science and Technology Policy and the National Science Foundation. The award tangibly demonstrates the President's commitment to ensuring that all of our nation's citizens have the opportunity to spread their wings and for some to pursue careers in science and technology.

I congratulate each of you for the contributions you have made to the lifting of peoples sights; to the kindling of excitement about learning; and to the nourishing of spreading wings. You are strengthening the scientific and technological foundations of our universities and industries and therefore of our Nation. You are paying back your debt to those mentors, like our parents, scout masters, teachers, coaches, professors, and colleagues, who nurtured you and me in the past. And you stand as excellent examples of the very kind of service to others that the President seeks to recognize. Our nation deeply appreciates your service.

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Divider Title: **Energy**

original

Remarks of
Dr. John H. Gibbons
Assistant to the President for Science and Technology
and
Director, Office of Science and Technology Policy

at the

Council on Foreign Relations' Energy Task Force
Washington, DC
April 30, 1996

Science, Technology, and Energy Security

I. Introduction

I would like to thank you for inviting me to speak on the issue of energy security and the role of science and technology. Since the 1970s, when energy became a national policy concern, and we embarked on the "War On Energy," our nation has made important strides that are often not well appreciated. Yet the challenges that we will face in the future from growth in international energy demand without concomitant growth in supply will dwarf the challenges that we have tackled domestically.

As we look around the world, we find remarkable economic growth in many regions. Each time that I return to Asia, I am struck by the speed of the development underway.

However, accompanying this growth are increasing demands on our world's natural resources, including our energy resources. Since reliable access to energy is vital to national security, to economic growth, and to quality of life, the sustainable management of these resources will be a critical challenge to all countries, including the United States.

Many economists have forecasted that by around the year 2010, China will surpass the U.S. as the world's largest economy. Its economic growth will bring very large demands for energy services in a country which has today a low level and low efficiency of energy use.

When I met with the President of China, Jiang Zemin, last year, he discussed at length his concern over his nation's ability to meet its future energy needs, and to do so in a way that would be sustainable for the country's 1.3 billion people. Experts from both our nations took a deeper look at this issue last week when we launched a sustainable development dialogue with China under the auspices of Vice President Gore.

India, the world's second most populous country, has also taken steps towards economic liberalization -- steps that may bring greater industrial growth than economists currently project.

The sustainable growth of these nations is not just their own problem, however, as they will increasingly compete for resources in the global markets and add to transborder and global environmental stresses. The Chinese government, realizing that energy availability is one of the principal constraints on China's rate of economic development, is putting a premium on capacity expansion. In fact, China will be responsible for nearly 20% of the world's power growth over the next 10 years. At the same time, there is concern that China is not putting enough emphasis on energy efficiency opportunities that might mitigate the need for some of this additional capacity.

Of the oil that China does import, more and more will come from the Middle East, increasing from about 70% today, to perhaps 95% by 2010. This would not only affect resource allocation but also geopolitical alignment. And many other nations, alongside of China and India, share similar aspirations.

Our strategy for sustainable economic growth in the U.S. must therefore consider the trajectory of other nations and must be a strategy that places a priority on engagement with other nations. Guarding the shipping lanes is important, but is far from enough.

The growing need for engagement was reflected by Secretary Christopher earlier this month in his remarks at Stanford University. He noted that our approach to sustainable development:

> "must be global because pollution respects no boundaries, and the growing demand for finite resources in any part of the world inevitably puts pressure on the resources in all others."

A higher priority on international engagement allows us to work more closely with other nations to enable efficient energy use and conversion that will reduce competition for energy resources, relieve environmental burden, and help U.S. firms that are often highly competitive in these areas.

II. Holdren/Erlich representation

One useful way to understand how people and the resources they use interact to affect the livability of the planet is a mathematical identity first formulated by John Holdren and Paul Erlich in the 1970s. In this view, environmental costs can be expressed as the product of four terms (see Figure 1):

Pollution cost equals

Population times

Economic activity per capita (representing standard of living) times

Energy per unit economic output (or energy intensity of the economy) times

Pollution cost per unit energy production.

Reducing the burden on the biosphere means driving down the left-hand side of this equation. That, in turn, means reducing one or more of the terms on the right. The first of these terms, however, is not a promising candidate. World population will not drop in our lifetimes. Suffice it to say that for the foreseeable future, the best we can hope is to moderate its rate of increase and push toward equilibrium.

The second term -- economic output per capita -- can be taken to represent the standard of living, although admittedly there are problems with equating the two, and few would opt to drive that down.
Reducing the product of these terms, therefore, requires driving down the third and fourth terms by even more than the growth in the first two, and it is in these two terms that technology comes into play. The third term, representing the amount of energy consumed per unit economic activity, is a measure of the efficiency of energy use and the marketbasket mix of goods and services. The world response to the oil crises of early 1970s showed that the ratio between energy and economics was not immutable, but rather responded strongly to market pressures and availability of improved technology.

The fourth term represents the pollution costs associated with producing a unit of energy. Technology can also serve to reduce this term, as new sources of energy supply and technologies of conversion are developed that place less stress on the environment.

The third and fourth terms in this identity correspond roughly to the demand for, and the supply of, energy services. Let's treat each in turn.

III. Energy demand alternatives

Most of the increased demand will come from developing world. As we have seen in the case of China and India, the combination of high population growth and rapid economic development mean that developing countries, rather than industrialized ones, are likely to account for most of growth in energy demand over next several decades. A recent report on the fusion energy program by the President's Committee of Advisors on Science and Technology (PCAST) recounted that most long-range projections of world energy demand show it reaching 2-3 times 1990 levels by the middle of next century, with the lower end of this range being an extremely optimistic projection requiring unprecedented priority to energy efficiency.

This point is made quite clearly in the following figure. (See Figure 2.) The first pair of bars shows energy consumption by the world in 1992, measured in units of quadrillion BTU, or "quads." (50 major electric generating stations, each with a capacity of 1000 megawatts of electricity, typically generate about one quad per year of electricity.) On the left is energy consumed by the OECD countries (the developed world); on the right are everyone else (the developing world). Note that OECD consumes more energy, even though about 80 percent of the people and more than 90 percent of the anticipated population growth are in non-OECD countries.

The middle pair of bars shows a hypothetical projection for what OECD and non-OECD energy consumption would be in a world with twice the present population, if the ratio of energy consumed per capita (i.e. the product of the second and the third terms of the equation above) does not change. Much greater population growth in the non-OECD countries causes the non-OECD energy consumption to exceed the OECD total, even at much lower rates of energy consumption per capita.

Look, however, at what would happen if we realize the goals of international development and equalize the energy used per person at 1992 OECD levels everywhere in the world. Doubling the population is reflected in an astonishing increase in worldwide energy consumption as shown in the third set of bars. Without greatly improved technologies for both energy consumption and energy generation, the environmental costs of such growth would be staggering.

Fortunately, technology has dramatically improved the efficiency of energy use and substantially decreased the amount of energy it takes to produce a unit GDP, and further gains are expected. I should note that the work of the Department of Energy in this area has made important, but largely unrecognized contributions. A task force chaired for the Department by Daniel Yergin documented that $1.1 billion of DOE investment in energy-efficient industrial technologies over past 20 years has yielded $2.5 billion in energy savings and productivity gains. The savings from these investments are accumulating at an increasing rate, and will reach $10 billion annually by the year 2000.

Focused efforts can have a big payback. Some 80 percent of the energy consumed by the U.S. manufacturing sector goes to the seven most energy-intensive industries. These seven industries -- aluminum, petroleum refining, chemicals, pulp and paper, glass, and metal casting -- also generate 90 percent of the industrial sector's production of hazardous waste. Lowering energy used and pollution created by these industries is not only important for the U.S. but for the global economy, as developing nations often turn to these same energy-intensive industries for their economic growth.

Immediate efficiency measures that can be taken in all nations include the use of more efficient motors and other electrical devices, computer controls, and cogeneration. Recycling materials can return substantial savings in energy.

If we paid the full cost of energy in this country, greater efficiency would be even more attractive. But the United States seems peculiarly unable to capture the full costs of energy use in the price signals provided to the consumer. Unlike the other G-7 countries, the United States makes no attempt to recover the costs of securing access to Middle East oil supplies, or to provide more accurate price signals to consumers that would encourage appropriate improvements in fuel efficiency or reductions in miles driven. In at least one respect, that leaves us the most undertaxed nation in the world. Pricing oil at its true cost would make a great contribution toward the more efficient use of energy in the United States.

One of our principal efforts towards long-term savings in liquid fuel in the United States is the Partnership for a New Generation of Vehicles, or clean car initiative. This is a cost-shared research and development partnership between the auto industry and suppliers and a half-dozen federal agencies. The technological goal--as tough as putting a man on the moon--is to develop within ten years a manufacturable, saleable car with three times the efficiency of today's automobiles and very low emissions, but with no sacrifice in cost, comfort, or safety.

The global benefit to societies of such a car would be significant, including less dependence on oil and lower emissions of greenhouse gases and other pollutants. For the United States, such a car could have tremendous export potential, in addition to the domestic market, creating a wealth of new jobs. This is the type of partnership between the government and industry that has paid off so well in the past in areas such as aerospace, biotechnology, medicine, and agriculture.

Opportunities for improvements in residential and commercial building energy use continue to emerge in the improved efficiency of appliances and the design of the building envelope and building controls. Although we are making good progress from individual appliances to the building system, there is much work that needs to be done at the level of the community.

One small example: many cities have dark surfaces -- such as roads, roofs and parking lots -- and present little vegetation, creating "heat islands." This effect can cause the temperature of a city of a city to increase as much as 5 degrees. As pointed out by Charlie Curtis and Joe Romm in their article in the April edition of the Atlantic, a relatively small investment in developing and deploying highly reflective roofing and paving materials, together with planting shade trees, could help eliminate this 5 degree increase in the Los Angeles area, reducing annual air conditioning bills by $150 million. Also, because smog formation is temperature-sensitive, this cooling would reduce smog concentrations in the Los Angeles area by 10 percent, which would be comparable to removing three quarters of the cars on the road. Health related benefits in that areas could be worth $300 million per year.

If these techniques were applied nationwide, more than $10 billion of energy could be saved annually.

Let me add here that we cannot expect financially strapped city or state governments to shoulder the investments required to develop and test such materials, modest as those costs may be. For the same reason, the manufacturers of paving materials cannot expect to recover the costs of these developments by charging more to their municipal customers. If the public sector does not support this work, it is unlikely to be done.

IV. Energy supply alternatives

Let me now turn to the fourth term in the Holdren/Erlich equation -- the one representing the pollution costs of various sources of energy supply. Looking ahead to the year 2050, the PCAST fusion panel concluded that the energy options available in that year will be those already in use -- fossil fuels, nuclear fission, and renewable sources -- with the possible addition of nuclear fusion. Each of the options in use likely to play a role; each has potential for improvement; each has shortcomings and limitations.

In 1992, the Intergovernmental Panel on Climate Change issued six alternative future energy scenarios. I have illustrated one possible mix of energy sources in the future that assumes no concerted policy effort is made to reduce CO_2 (Figure 3). Oil and gas production peak in the early part of the next century and then drop off, with gas declining markedly by 2100. To this add a modest hydropower contribution; a steadily increasing supply of nuclear power, and contributions from solar power and biomass that become the second and third largest sources of supply. By far the greatest reliance, however, is made on coal – one of the dirtiest fuels, and emitter of the most carbon dioxide per unit energy produced.

In the interests of time, let me concentrate today on nuclear fission and on renewable energy sources and only make the briefest comments about oil, gas, and coal.

Oil. The preponderance of estimates indicate that world crude-oil production will begin to fall early in the next century -- i.e., within years, not centuries. Even enormous (and unlikely) increases in estimates of total recoverable oil buy little more than another decade. At first glance, this conclusion – drawing on work of Jim MacKenzie at the World Resources Institute - may seem like just another "Chicken Little" warning of the type that has proven premature many times in the past. However, the underlying evidence appears to be far stronger now than ever before. We know much more about petroleum geology than we used to; enough to be quite skeptical that new, major oil-bearing regions (with the capacity of the Alaskan fields or greater) remain to be discovered. Indeed, according to the US Geological Survey, the global discovery of new giant fields peaked 30 years ago. Of course, enormous deposits of hydrocarbons remain, including coal, oil shale, and tar sands -- but facilities for making synthetic fuels from these resource are costly and environmentally dubious, especially from a CO_2 perspective.

Gas. Natural gas is often referred to as a "bridge" fuel that will help ease us from the age of fossil fuels to one of renewable energy. The cleanest of the fossil fuels in terms of air pollutants and CO_2 emissions, state-of-the-art jet engine technology has been adapted to produce high efficiency gas turbine generators that are close to 50% efficient at turning chemical energy into electricity. Compare this to conventional coal-fired plants, which are closer to 33% efficient. Significant supplies of gas are widely available in most parts of the world – although, like oil, the richest deposits of gas are distributed quite unevenly.

Coal. Coal currently accounts for some 30% of all fossil fuel use. A sufficient resource base is available to take over the share now borne by oil and gas, and even to allow for considerable growth throughout the entire next century and beyond (as shown in Figure 3). However, it is dirty, inconvenient, and expensive to convert to liquid or gaseous fuels. For environmental reasons, we may wish to constrain coal and other fossil fuel use to below today's levels.

Nuclear fission. Nuclear fission now supplies about one-sixth of world's electricity. A quadrupling of nuclear capacity would be required to take over the share of electricity now generated from fossil fuels as well. Reliance on fission, however, is subject to a number of uncertainties. Even if prices become attractive, will utilities, regulators, and the public be confident that reactor safety, nuclear waste management, and proliferation concerns will be satisfactorily managed? This question is, as yet, an open one.

Even in the event that we become much more dependent on nuclear fission, there remains no foreseeable need to reprocess and burn plutonium. As you are aware, nuclear power plants generate energy largely from splitting the uranium-235 isotope, which comprises only 0.7% of natural uranium. When uranium was thought to be more scarce, and the demand for electricity was projected to be much higher than it has in fact turned out to be, it was assumed that the next generation of nuclear reactors would be breeder reactors. Breeders burn uranium and plutonium, which they themselves manufacture from the uranium-238 isotope that is largely untapped in present-day reactors. Switching to breeders would extend the uranium resource base by roughly a factor of 1,000: a factor of 100 representing the much greater abundance of uranium-238 compared to uranium-235, and an additional factor of 10 representing the much wider uranium resource base that can be mined economically if both isotopes of uranium were valued.

However, large-scale use of plutonium would require the separation, shipment, and use of many thousands of bombs-worth of plutonium, raising serious nuclear proliferation risks. It is absolutely clear that reactor-grade plutonium can also be used in nuclear explosives, even with simple technology such as was used in the Trinity device. Plutonium also incurs additional environmental and safety risks, and is vastly more expensive than reliance on once-through use of uranium fuels, in today's world awash in cheap uranium. In the late 1970s, the United States decided to forego this route. Even with vigorous growth in energy demand, we will be able to continue relying on uranium-fueled reactors used in a "once-through" fuel cycle in which spent fuel rods are considered as waste, rather than mined for the plutonium they contain, for decades to come.

A 1993 study by the Organization for Economic Cooperation and Development indicates that 3 million tons of uranium are recoverable from known deposits at a cost of $130/kg or less. (By comparison, today's spot market price of uranium is $25/kg. Note, however, that given the large capital cost of a nuclear generating station, the cost of electricity is not very sensitive to the cost of the uranium fuel.) Adding other high-grade resources whose recovery costs have not yet been assessed, together with estimates for undiscovered deposits, the study concluded that uranium resources total some 20 million tons. And vast new deposits have been discovered since then. To all this we could add a huge unconventional resource base, ultimately including uranium dissolved in seawater, which some estimates suggest is recoverable at about $330 / kg.

Therefore, there is ample uranium -- without the need for reprocessing plutonium -- even for the "high-growth, high-nuclear" energy scenario developed by the Intergovernmental Panel on Climate Change, which envisages a cumulative consumption of 5 million tons uranium by 2050 and 17 million by 2100. At that time, world nuclear capacity would have grown to 9 times its current value. Should the breeder reactor be needed in the future, there is plenty of time to develop it, and vast stocks of plutonium that accumulate in the spent fuel from civil reactors could be available to be used at that time. For now, even if plutonium were free, making fuel from it would be so expensive that it cannot compete in the commercial market. If you're not smuggling it, there's no money to be made in plutonium.

For all these reasons, we believe there is no need to stockpile surplus weapon plutonium for possible future use as a fuel. Instead, it should be disposed of as soon as practicable. The United States government is exploring several technical approaches to this problem, including using it on a "once-through" basis as fuel in existing reactors or mixing it with glass and high-level radioactive waste for eventual disposal. Getting rid of this material is important to international security, both to prevent proliferation and to ensure the irreversibility of nuclear arms reductions. We made major progress in this area at the recent Moscow summit.

We expect to make a decision by the end of this year regarding the disposition of our own excess plutonium inventory, and we are working with the Russians to develop options they can implement as well. Disposing of this material will cost hundreds of millions or billions of dollars -- a cost that should be seen as an investment in security, just as the cost of producing it once was seen.

Fusion. Research into nuclear fusion is important as a long-term hedge against the unacceptability of fission power, since it potentially has significant advantages over fission in terms of environmental and safety issues, resource availability, and proliferation potential. The United States is continuing to participate in the engineering design phase of ITER, the International Thermonuclear Experimental Reactor. Nevertheless, we are billions of dollars and many decades away from an operational fusion reactor.

Renewables. The long-term prospects are bright for renewable sources of energy, but their major contribution is still in the future. Low-tech applications of biomass -- in the form of fuelwood, charcoal, and dung -- even now supply some 20% of the world's *nonelectric* energy requirements. However, the contribution from these traditional sources of biomass energy will decline, not increase, as societies develop.

Only a bit over 1% of world electricity generation today comes from biomass, wind, and solar. New technologies can boost the contribution of renewable energy sources to electricity generation.

Under some extremely optimistic estimates of society's ability to lower overall energy demand through increased efficiency, coupled with equally heroic investments in renewable sources of energy, the Intergovernmental Panel on Climate Change developed a scenario whereby renewables supply all *new* energy requirements after 2050. Even this highly ambitious proposal, however, confirms that renewables will not be able to displace existing demand for fossil fuels until after the middle of next century.

Nevertheless, renewable resources will certainly be a part of the energy mix by that time. One of two planning scenarios produced by Royal Dutch Shell concludes that renewables may make up to one-third the supply of new *electricity* -- as opposed to new energy requirements of all forms -- within three decades, even if fossil fuel-produced electricity continues to decline in cost.

Technologies supported by the Department of Energy have great potential in this area. For example, in 1994, research sponsored by DOE led to the creation of a genetically engineered organism with an enhanced ability to ferment cellulose into ethanol. Through this work and other federally supported research, the cost of producing a gallon of ethanol has been lowered from $3.60 fifteen years ago to about $1.00 today. Five to ten more years of biofuels R&D investments at the current level could lead to ethanol production from wastepaper, fuel crops, and crop waste at $0.60-0.70/gallon (see Figure 4).

Windpower, now contributing less than one tenth of a percent of world electricity, can be cost-competitive with coal and nuclear generation at sites with good wind resources. The cost of wind-generated electricity has been cut in half since 1985 by dramatically improving the performance of wind technology (Figure 4). Ten million turbines of the size that appears to be most economic -- 300 kW (about 1/3000th that of a typical fossil or nuclear plant) -- would be required to generate as much energy as fossil fuels generate today (using wind conditions that are available are good sites, but by no means all sites).

The two solar technologies most likely to be applied at large scale are solar thermal (which concentrates solar radiation to produce heat, using that heat to generate electricity) and photovoltaic (which uses semiconductors panels to convert light energy directly to electricity). Photovoltaic technology has progressed dramatically since the early 1980s, with the price of photovoltaic-produced electricity having decreased by a factor of two to four in the past 10 years. It is still, however, considerably more expensive than wind energy. Generating photovoltaic electricity equal to the amount now generated through fossil fuels would require solar installations covering roughly 5% of the urbanized area of the planet. Solar thermal installations would require some half that area.

Hydropower. In terms of electricity, hydro supplies one-third the contribution of fossil, about equal to nuclear. Untapped hydro potential may total 2-3 times what has been harnessed to date. Most remaining sites, however, are less convenient or more costly to tap than the ones utilized so far, and there will likely be objections to developing them on environmental grounds or due to impact on the local populations.

V. Policy Challenges

"If we want a higher standard of living, does that mean we have to settle for a lower quality of life?" We need to increase the availability of energy services--which reasonably equate with wealth--without commensurate increased in resource flows, particularly fossil fuel resources.

I do not see any magic bullets. New technologies can, however, contribute. Scientific research and advancing technology have markedly improved the efficiency of energy use and substantially decreased the amount of energy it takes to produce a unit of GDP. This is good for the economy and for the environment. Abundant sources of clean energy and efficient use, after all, mean the difference between wealth and poverty, and between a clean world and a dirty one.

Although there is much to be done in the United States, we cannot meet these challenges alone. The costs are more than we can commit and the scope more than we can influence directly. Only by engaging with other nations will we be able to influence the global response that will be needed. Close cooperation allows us to share the investments needed for high energy efficiency as well as the costs of developing new energy sources such as fusion, reach the vast populations of rapidly developing nations, and expand opportunities for new export markets for our energy technologies globally.

Achieving true sustainable development will take a combination of technology, economics, and governance to meaningfully influence energy demand. And economically efficient energy transitions take decades, so we must choose our course now.

$$\text{Pollution} = \underset{\text{(People)}}{\text{Population}} \times \underset{\text{(Economy)}}{\frac{\text{GNP}}{\text{Population}}} \times \underset{\text{(Technology Market Basket)}}{\frac{\text{Energy}}{\text{GNP}}} \times \underset{\text{(Technology)}}{\frac{\text{Pollution}}{\text{Energy}}}$$

FIGURE 1

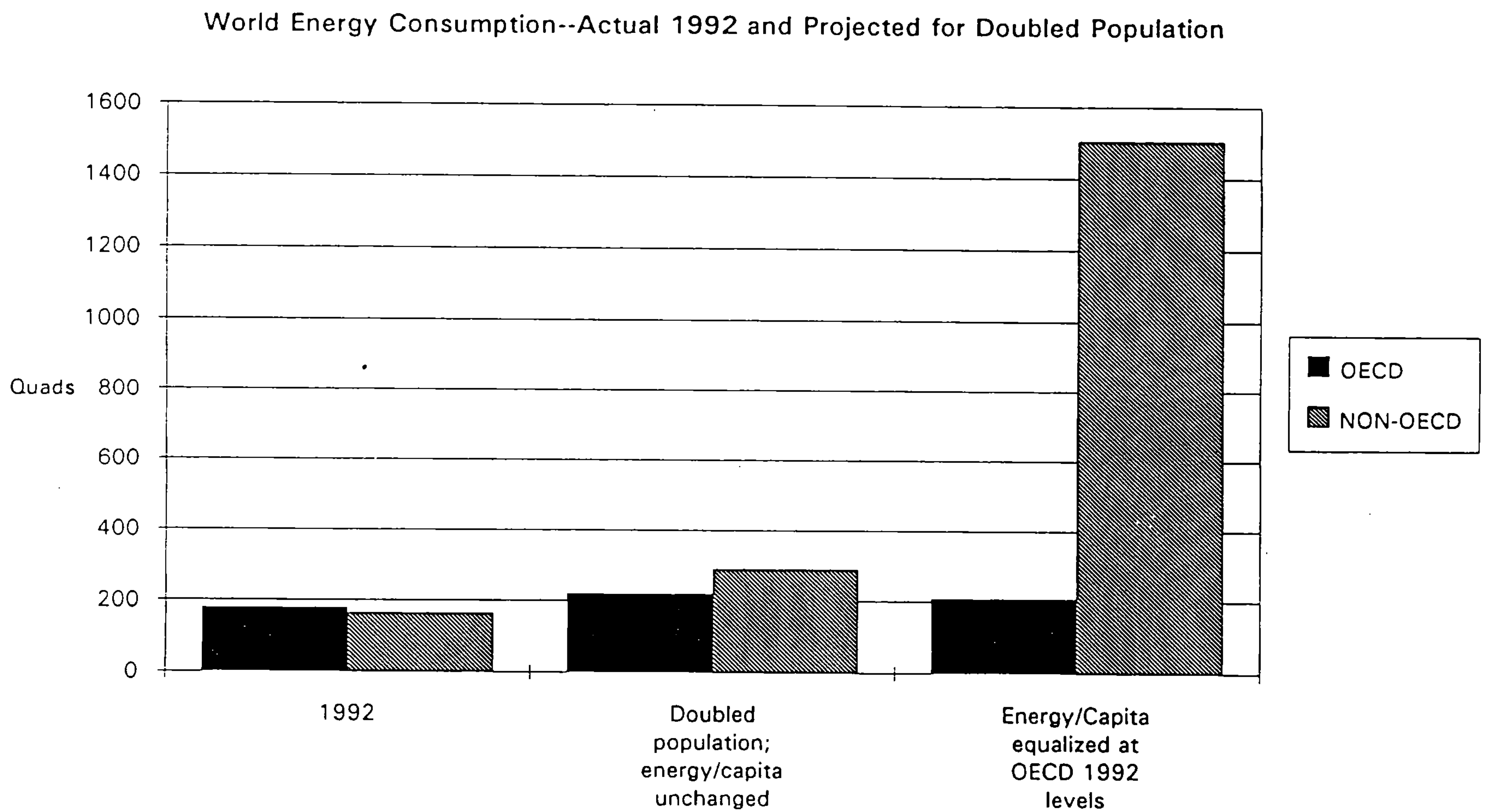
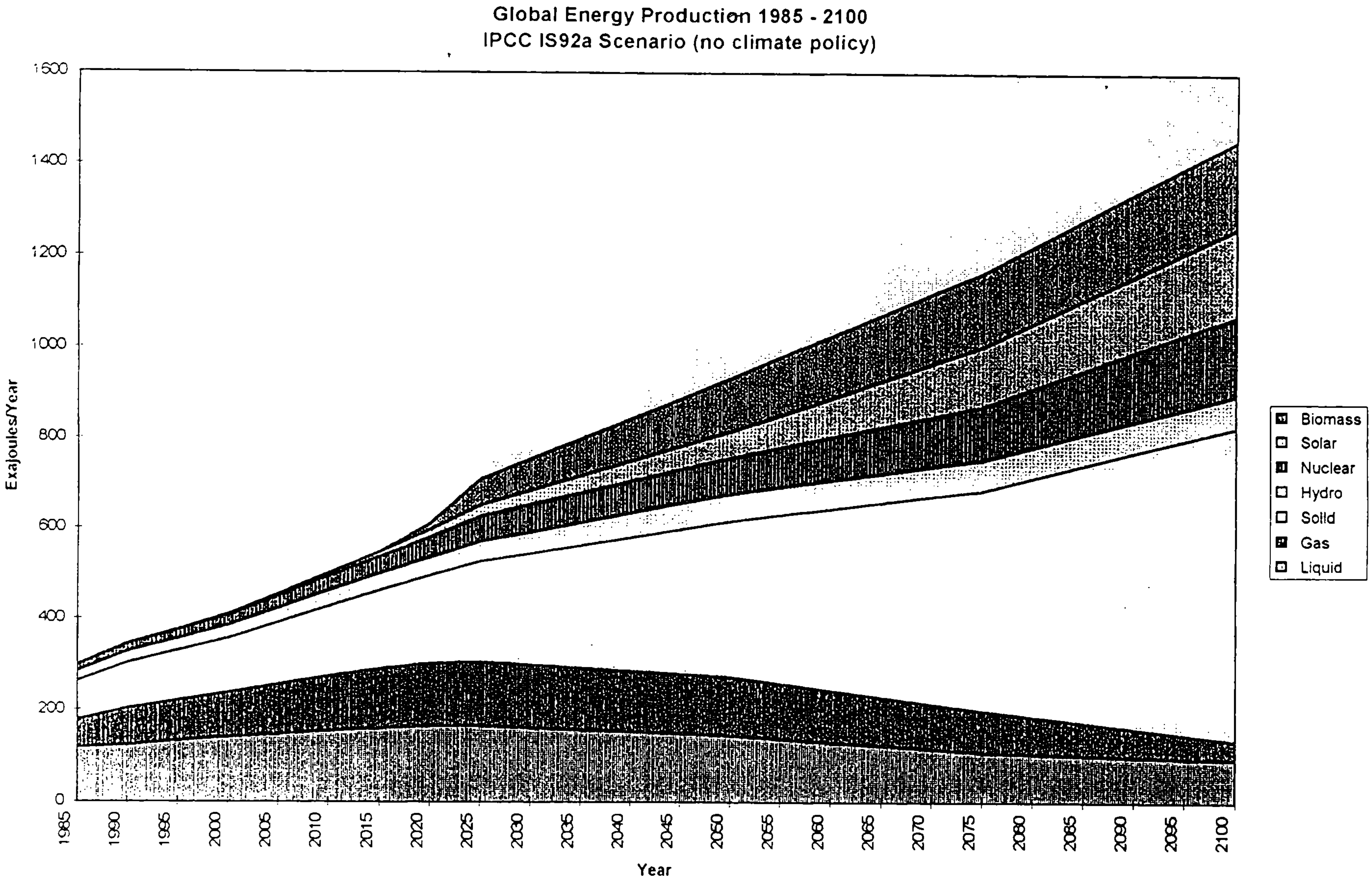

World Energy Consumption--Actual 1992 and Projected for Doubled Population
1600
1400
1200
1000
Quads 800
600
400
200
0
1992
Doubled population; energy/capita unchanged
Energy/Capita equalized at OECD 1992 levels
OECD
NON-OECD

FIGURE 2

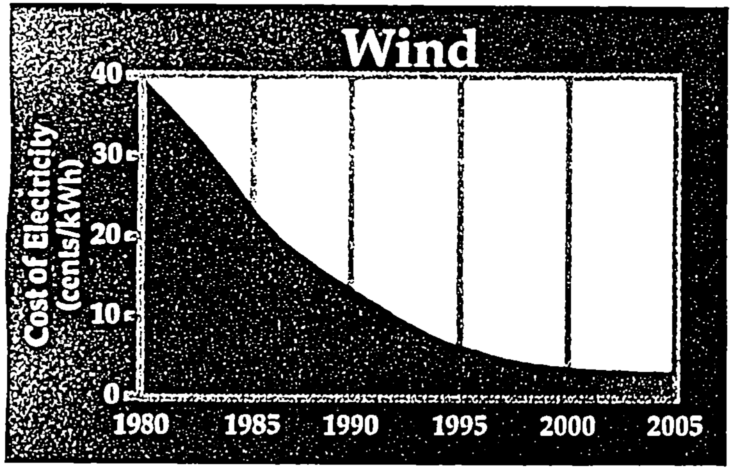


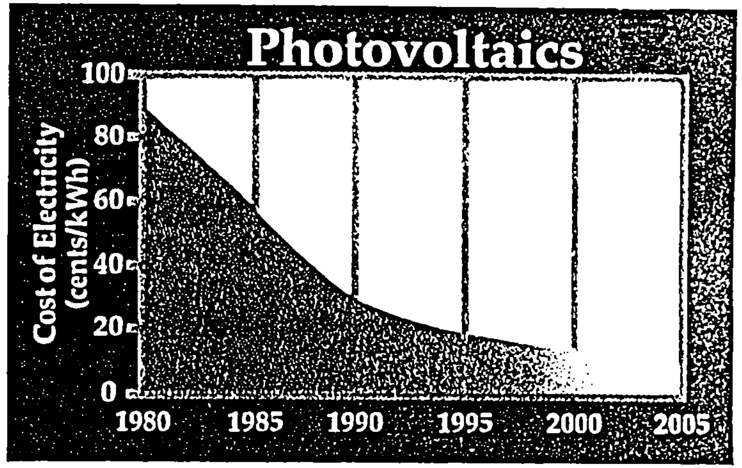
Global Energy Production 1985 - 2100
IPCC IS92a Scenario (no climate policy)
Exajoules/Year
0
200
400
600
800
1000
1200
1400
1600
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
2080
2085
2090
2095
2100
Year
Biomass
Solar
Nuclear
Hydro
Solid
Gas
Liquid

FIGURE 3

ENVIRONMENTAL TECHNOLOGIES: CHALLENGES & OPPORTUNITIES

RENEWABLE MARKETS





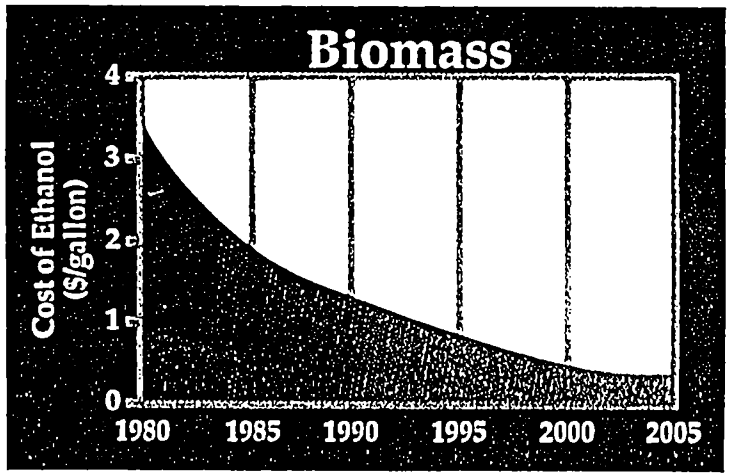


FIGURE 4

Clinton Presidential Records
Digital Records Marker

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Divider Title: **AAAS 1996**

Remarks of
JOHN H. GIBBONS
Assistant to the President for Science and Technology

AAAS Policy Colloquium
April 17, 1996
Washington, DC

"SCIENCE IN THE AGE OF POSSIBILITY"

Thanks very much for inviting me again this year to the AAAS Policy Colloquium, a chance for us to collectively think, discuss -- sometimes debate -- and then arrive at consensus on how best to harness the enormous potential of the American R&D enterprise for the benefit of all Americans, and of the world.

Today, I cannot help but observe that we have lost one of the most articulate and gifted of the thinkers, discussants, and debaters among us -- Secretary Ron Brown. Over the past two somber weeks, much has been written and said about the enormous impact Ron had in redefining the role of the Department of Commerce, in fostering American business overseas, and of building a spirit of can-do competitiveness in industries here at home. It remains for us here to eulogize him for another set of accomplishments entirely -- he was a tireless advocate of the role of technology and the science that supports it, a gifted intellectual entrepreneur who was able to focus our attention and our research investments on technologies that would bring the greatest good to the greatest number of people. His thoughtfulness, eloquence and passionate belief about what was the right thing to do often carried the day.

And that may be Secretary Ron Brown's greatest legacy -- he was a consummate bridge builder, a forger of consensus and a person deeply committed to public service. He never lost sight of what we have in common even when we were in the midst of our most heated battles. We all will miss his temperance, his energy and can-do philosophy, and his greatness of spirit as we go forward together -- regardless of party or disciplinary affiliation -- into the 21st century.

In that vein, let me begin our discussion today by reaffirming that -- hard as the last year has been -- still we have reached important common ground between Congress and the Administration on a number of key issues. We are jointly committed to continue the President's historic string of deficit reductions to balance the budget by the year 2002, and this will be is a tremendous accomplishment for the nation. And today, the Congressional Budget Office certified that the President's budget balances in 2002, which the Office of Management and Budget had previously certified. It is the first time in 17 years that a President's budget balances based on <u>both</u> Administration and Congressional estimates.

In science, too, we have found common ground. The nation's flagship agencies of fundamental research, the National Institutes of Health and the National Science Foundation, enjoy broad bipartisan support. And a similar bipartisan consensus seems to exist for making sure that America is second to none in science and technology as we head into the 21st century. Given these successes, doesn't it seem reasonable that we could come together on the issues that still divide us? I remain hopeful that we can.

Support of science and technology is a priority dear to the heart of the President. That's why he fought for four budgets in a row that increased spending on civilian R&D while simultaneously cutting the annual deficit in half. That's why he kept R&D on the table through the past six months of budget negotiation with the Republican leadership.

He didn't have to fight for R&D; he has no compelling political motivation to do so -- it's not as though the White House West Wing is filled with scientists, or that science lobbyists are jamming the halls of the Old Executive Office Building. Nor is it the case that the scientific community has the deep pockets or voting blocs that turn elections. The President simply believes that we must invest in science and technology for the good of the country, for the sake of enabling the bright future we desire to become a reality. He's right, of course -- and he has set in motion the kind of positive changes that will ensure that these investments yield their extraordinary promise, revitalizing Federal government to make it more responsive and cost less, promoting public-private technology partnerships to maximize taxpayer-funded research, and cutting red tape and regulation to free up private enterprise and capital.

In President Clinton, the nation has a bold vision of the real future, a future in which the fruits of science and technology are accessible to all Americans. A future in which business, government, and universities pull together and form innovative alliances to learn how the universe works and how to protect and improve the quality of our lives.

The Emerging Budget Picture

What is at issue today is NOT the President's commitment to science and technology -- that commitment is clear. He's demonstrated it four times over, most recently with the budget released last month for FY97. This budget **increases federal civilian S&T funding as traditionally defined by more than $1 billion over 1996, and pegs total federal R&D spending at roughly $73 billion.** These increases for FY97, however modest, represent real commitment, coming as they do in the face of a falling nondefense discretionary budget.

Nevertheless, I am sensitive to the needs of you Missourians in the crowd today who need to be shown rather than just told. For you "Show-Me-State" citizens, let me remind you that **the President's FY97 budget boosts funding for research.** The budget proposes $14 billion for fundamental research, an increase of $278 million (2 percent) over 1996. This includes, for example, a 4 percent increase for the National Science Foundation on the civilian side, and maintaining our defense-related fundamental research activities.

Moreover, the President's FY97 budget invests in technologies to create new jobs and new industries. We've boosted investments in critical technology initiatives like the Advanced Technology Program (ATP) at the Department of Commerce, which gets a 15 percent increase over last year, as does the Commerce Department's Manufacturing Extension Program, which -- in partnership with state governments -- helps small businesses take advantage of new technologies to make them more profitable and more competitive against their global competitors. There are increases for computing and communications research (up 3 percent), breakthrough technologies for clean cars (up 5 percent), and new building and construction technologies (up 20 percent). Also included in the portfolio of programs that directly support economic growth are full funding of information technologies to make our roads and highways safer and less crowded, including a $337-million program of new technology partnerships aimed at the 75 most congested urban areas in the U.S.

The President's FY97 budget invests in 21st-century education. Information technology has revolutionized America's businesses, but largely bypassed its classrooms. In too many areas of the nation, we are entering the 21st century with educational technologies designed for the schoolrooms of the 1800s. This budget contains a down payment of $250 million on a new, $2-billion, 5-year program that challenges state and local governments to invest in educational technology in schools in partnership with business. The Administration's overall support for educational technology research goes up by 9 percent.

The President's FY97 budget provides increased support for health and safety research. The budget for the National Institutes of Health (NIH) contains a 4-percent increase that includes increases for research on HIV/AIDS-related illnesses, breast cancer and other women's health issues, minority health initiatives, gene therapy, and advanced communications technology to improve health-care delivery. The FY97 budget also funds a new NIH Clinical Research Center, a state-of-the-art research facility that will help bring new medical technologies from the laboratory bench to the patient's bedside.

Human safety also is the hallmark of programs at NOAA to modernize outmoded weather service and satellite systems, saving lives by providing earlier and better warnings of severe weather and natural disasters. New transportation technologies supported by the President's FY97 budget to increase safety and effectiveness could save countless lives each year with safer cars, better airplane navigation, and improved train safety, among others.

The President's FY97 budget increases funding for environmental research. This budget continues to invest in critical environmental research needed to provide clean air, pure water, and safe food. The FY97 budget allocates $5.4 billion (a five percent increase over FY96) for a broad environmental research agenda, including $1.9 billion (8 percent increase) for understanding and predicting global climate change and its consequences for human health, food production, and ecological systems. Over the past few years, we have learned much about climate change and can focus our attention on the key science questions of mitigating and adapting to climate change. This research will address those questions.

The FY97 budget also supports research into new environmental technologies to provide better environmental protection at lower cost, while generating jobs and exports. It includes $72 million for the Environmental Technology Initiative -- a partnership between industry and government -- as part of a total of $127 million for all of EPA's environmental technology efforts. We have also increased solar and renewable energy programs at DOE by $88 million to provide clean energy sources for the 21st century. The budget proposes $133 million more than FY96 for energy efficiency and pollution-prevention R&D critical to the Administration's climate action plan, for a total of $551 million.

The budget sets aside $115 million for the STAR Program (Science To Achieve Results), a 21-percent increase over 1996 for this merit-reviewed EPA program that awards research grants for promising new environmental research, some in collaboration with other agencies such as NSF.

The President's FY97 budget continues the President's strong support for the Space Program. The budget continues level funding for the International Space Station at $2.1 billion; a strong commitment to Mission to Planet Earth at $1.4 billion; a $549- million investment in smaller, less costly but more capable spacecraft for space science; and $266 million for developing a Reusable Launch Vehicle program.

The President's FY97 budget supports research and technology needed to maintain the security of our nation. This budget maintains spending on basic defense research at last year's levels, even as other parts of Defense's budget have declined. Through innovative programs such as the Dual Use Applications Program, funded at $250 million, we leverage federal funds with private funds to benefit both our military and civilian needs. These funds are the wellspring for the advances of tomorrow that will be needed to ensure that the United States continues to hold a commanding lead in defense technology.

America has no higher security priority than ensuring that rogue nations and terrorists don't acquire weapons of mass destruction. Tomorrow, the President flies from Japan to Moscow to meet with President Yeltsin and other leaders to strengthen nuclear safety and security, including the security of fissile materials. Last year's Tokyo subway nerve gas attacks are a chilling reminder of what is possible, but imagine what might have been if that cult obtained plutonium and fashioned a crude bomb. The FY97 budget provides $327 million, 10% more than last year, to Russia and others to dismantle and destroy nuclear and chemical weapons and secure fissile materials that could be used to develop bombs.

As we left the Cold War behind in 1993, we decided to forego further nuclear testing. President Clinton's 1995 announcement to pursue a zero-yield Comprehensive Test Ban Treat is leading us into a safer world, but we still must be able to maintain a safe and reliable nuclear deterrent. Accordingly, the FY97 budget provides a 5% increase (to $1.6 billion) for DOE's Science Based Stockpile Stewardship Program. This program underpins our commitment to sign a Comprehensive Test Ban Treaty this year by helping us maintain a safe and reliable nuclear deterrent without developing or testing nuclear weapons.

The Lure of the Future -- However Grim

At last year's colloquium, I framed my discussion in terms of what differentiated the new budget for S&T emerging from the new Congress from the R&D strategy outlined by the President and this Administration. Much of the discussion of the last year has centered on just what those defining differences are, and unfortunately I could probably revisit my speech from last year's colloquium and still find it apt and timely. Al Teich and his colleagues have done their usual excellent job of analyzing the President's budget request for FY97 and comparing it to the Congress' R&D funding proposals over the past year. This analysis reinforces my anxiety about the future of research in America and provides more than ample opportunity to point out the very different choices the Congress and the Administration would make to reach a balanced budget.

What I'm wary of in this forum today, though, is the temptation to be drawn into discussion of theoretical events in a distant future -- and anyone who's ever worked on the Federal budget-setting exercise knows that the year 2002 might as well be a century away for all our ability to accurately predict the details of federal spending that far out. Seven years ago, for example, we were locked in a pernicious spiral of deficit spending that didn't seem to worry people and that looked like it would go on forever.

Even given that history, I suspect that the discussion and coverage of this policy colloquium will dwell more than it should on the long-term horizon of FY2000 or FY2002, despite the fact that the numbers and assumptions that might inform that dialogue border on the meaningless in the realpolitik of day-to-day budget negotiations. Meanwhile, across town on Capitol Hill, the budget committee in Congress may be set to follow last year's drastic slashing of Federal R&D funding with similar draconian cuts on FY97 that will make our discussion of out-year budgets wishful thinking. The new House Budget Resolution is likely to cut substantially from the discretionary budget proposed by the President, and the long knives will be out in the halls of Congress for the $73 billion in R&D to make up the shortfall.

Yet today, given this grim scenario, we are arguing about what science we'll be funding in 2002. Friends, I'm honestly much more worried about what we'll be able to do in FY97 than I am about FY2002. Congress still hasn't given us an FY96 budget; my agency, OSTP, and many research agencies are still struggling along on week-to-week stop-gap funding agreements. Research commitments, appointments, and personnel actions are on hold. Widespread furloughs, layoffs, and program terminations are predicted. Morale is not what I would describe as upbeat. The bottom line is that we are in the middle of a crisis <u>this year</u> and <u>this month.</u> I don't know what 2002 will bring -- neither does the Congress, neither does AAAS.

I'll be happy to have the debate over the out years when we know more about them. What I want to focus on today is where I think we need to be at the end of 1997, and what we're doing to get there. And I want to point out the differences between President Clinton's commitment to science, and the seeming disdain some in Congress display for the increasing knowledge base that research makes possible -- differences all-too-easily obscured by our obsession with numbers on a ledger sheet.

What I want to focus on today are the two, distinctly different visions of the future of R&D in this country. On the one hand, the President has consistently supported the science and technology to move us into the next century. On the other, some in Congress seem hopelessly mired in a Cold-War mentality, plying our military with hardware the Defense Department doesn't want while cutting R&D for civilian and dual-use technologies. This is a Congress that still talks in outmoded terms like separating basic from applied research...that believes you can clearly separate the theoretical calculations and the laboratory bench from product invention and development...that wants to hamstring our ability to generate new knowledge because that knowledge may be at odds with deeply held and vigorously defended ideology.

You don't have to look to the year 2002 to see these differences play themselves out. The President's budget for FY97 calls for increased investment in science and technology to help prepare us for an uncertain and more complex future. The Congress balances the budget by cutting research to finance tax cuts for the wealthy. Instead of maintaining the research base that has guided us to improved health and environmental protection, Congress walks away from decades of bipartisan support for clean air, clean water, and healthful food.

In the Administration, we have made the tough choices to bequeath a bright future to our children. We both balance the budget and protect critical investments in R&D. I challenge my many good friends and colleagues in Congress to do likewise. And I challenge you in the audience to keep this issue before the Congress in the weeks and months ahead.

I would be remiss to suggest that the President or the Administration or Congress can go it alone in supporting the research enterprise. To retain world scientific leadership will take more than Federal dollars. We need a NATIONAL research program, not just a FEDERAL research program. To that end, President Clinton has called on the government's key S&T partners -- the states, industry, and the universities -- to help make his vision of the future a reality.

The states have an important enabling role to play in bringing this future about. Over the last year, at my request, former Governors Richard Celeste of Ohio and Dick Thornburgh of Pennsylvania, working with the National Governors Association; the National Conference of State Legislatures; the Carnegie Commission on Science, Technology, and Government; and the American Society of Mechanical Engineers, formed the State-Federal Technology Partnership Task Force to recommend ways to improve State-Federal technology partnerships, with particular emphasis on ways to stimulate economic growth.

I believe that the report issued by that task force contains important recommendations for strengthening our national science and technology system -- recommendations that the Administration is eager to work jointly with our nation's Governors to implement.

At the heart of those recommendations is the need for a mechanism to bring state government leaders -- governors -- together with Federal government leaders to develop and implement a better-integrated science and technology strategy in order to improve economic growth and achieve other critical national goals. I have asked the Chairman of the National Governors Association to work with the Administration to convene at the earliest opportunity a meeting of governors and Federal leaders to agree on such a structure and move it forward.

Likewise, our colleagues in industry will continue to be crucial partners in the R&D enterprise of the future. Just last week, the Council on Competitiveness released a report on the future of support for science and technology that calls not only for strong support of science, but also for greater reliance on the kinds of research and technology partnerships like ATP, TRP and the Partnership for a New Generation of Vehicles that President Clinton has advocated -- often over strong objections by Congress. With this kind of affirmation from the private sector for the role of the Federal government in sparking innovation and priming the research pump, we will redouble our efforts in Congress to obtain support for these key partnership programs.

The Council's report also calls for a national summit on R&D funding, a dialogue that would include the science and technology stakeholders. I strongly support this recommendation, and have told my friends at the Council to count on us to participate. In the meantime, I hope to meet with key industry, university, and state and local government leaders across the nation for regional dialogues on R&D funding.

Critical to the success of any plan for the future of R&D funding is the role of the universities in supporting research and technology. America's system of research universities is a priceless national resource and the envy of the world. It produces the most talented scientists and engineers in the world by emphasizing rigorous merit review of research linked with strong graduate education programs in a setting of innovation, inquiry, and entrepreneurism. As funding priorities are set across the scope of the Federal budget, and as tough choices are made to reach a balanced budget, our commitment to the federal government's partnership with our nation's research colleges and universities will be upheld. For FY97, we are proposing to increase university-based research by **more than $250 million** to total $13 billion.

Science in the Age of Possibility

Our willingness to adapt to new and changing environments -- even when it's painful -- is a hallmark of the American people. We are tinkerers, and fixers; improvers and builders. We are a bold and innovative people. We are visionaries and pragmatists. We are inventors every one -- and today we are inventing America's future in this room, in every laboratory, every classroom and every boardroom across the country.

Even though it is easy for all of us to obsess over shrinking federal R&D budgets, it is important that we keep in mind what can be accomplished with the resources that we have available. As the President said in his State of the Union address:

"We live in an age of possibility. A hundred years ago, we moved from farm to factory. Now we move to an age of technology, information, and global competition. These changes have opened vast new opportunities for our people, but they have also presented them with stiff challenges."

To meet these challenges, we will rely on the fruits of our S&T investments. Advances are occurring at unprecedented rates across many disciplines of science and engineering. So there is every reason to believe that the historic, extraordinarily high rates of public return on our research investments can continue in the future. As disciplinary barriers come down, there will be increased opportunity for interdisciplinary cooperation, making possible new approaches to old problems. For example, as biologists, chemists, and engineers tackle tough pollution cleanup and containment problems, cost effective bioremediation technologies are being developed. As neuroscientists, using increasingly sophisticated imaging technology, develop a better understanding of the brain, behavioral scientists will be able use this information to enhance our understanding of learning and applying it to early-childhood development and education.

Expanded international cooperation on large projects will help the United States continue to push the frontiers of science. International cooperation is commendable and salutary in its own right; science has always operated in a world without borders. But budget pressures amplify our need to pool resources and work together even more closely with our international partners. U.S. participation in the Large Hadron Collider project at CERN will lead to new insights on the composition of matter. International cooperation on sequencing the human genome will greatly accelerate completion of this important biomedical project. Other examples of successful international efforts include the multinational efforts in space to enable further advancement of science and exploration, and our work with the OECD Megascience Forum explores new models and approaches to international cooperation. We must nurture these arrangements, learn from them, and seek out similar opportunities.

Scientifically, these are exciting times that hold much promise for remarkable discoveries. Even under the present and foreseeable tight budgetary conditions, our funding priorities are set to maximize the scientific return on our R&D investment. I am inspired by the creativity already evident in meeting the challenge of doing more science with less money. Necessity is the mother of invention. We can make striking progress even under the constraints of a negative-sum dollar game -- by streamlining, triage, and the kind of entrepreneurial ingenuity that is such a strong suit in America. When one asset falls short in the human enterprise, others find fuller use. For organizations as well as individuals, change -- even seemingly adverse change -- can be a productive force..

That's how at NASA, Dan Goldin aims to help astronomers break one riddle of the universe after another using smaller, cheaper, and more sensitive equipment. Consortia like the Partnership for a New Generation of Vehicles are making extraordinary strides in boosting fuel efficiency while retaining automotive safety and ease of use. Using electronic communication to cut red tape and redundancy at NSF and NIH is adding weeks of productive research time to the calendars of scientists who once spent too many days fine-tuning grant proposals. The Global Positioning System -- the subject of a recent review and policy directive from the President that accommodates the needs of both civilian and defense users -- is making commercial air flight safer and less expensive.

But I'm a pragmatist, too. I know how hard and how abrupt must be our course changes in science and technology funding over the coming years. But I also know how resilient we are, how innovative and how spirited. I know how much progress we've already made. It is faith in the community of scientists and engineers, and in their inexhaustible creativity, that girds my hope for the future and that can sustain us as we approach the new millennium.

I expect to be here -- in the audience, if not at the podium -- in the year 2001. I'll be happy to take your questions then about FY2002. Meanwhile, let's focus on continuing our work to raise awareness and appreciation about the central importance of science and technology to our future.

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Divider Title: **Global Change**

Remarks of
Dr. John H. Gibbons
Assistant to the President for Science and Technology
and
Director, Office of Science and Technology Policy
at the
International Forum on Forecasting El Nino
Washington, DC
November 6, 1995

The Challenge of Global Change and Sustainable Development

We live in a natural world that is constant, yet always changing, a world of mysterious cycles and unheralded events. Throughout human history, and even today, humans spend a good deal of time observing, speculating, researching, and interpreting the causes and meaning of these events and cycles. The most obvious examples are the seasons and the weather, whose seeming regularity is in itself reassuring. For the United States, the Santa Anna winds blow every year, and the hurricane season always spans late summer and fall. The summer brings thunderstorms to the desert Southwest as surely as winter blizzards blanket Canada with snow, and the swallows always come back to Capistrano.

In contrast, the suddenness of events like volcanic eruptions and earthquakes shocks and disturbs us. More gradual, yet profound, changes in natural processes and features that seemed comfortably constant also concern us. The retreat of alpine glaciers and the bleaching of coral reefs are occurring all over the world today. The devastating impacts of the collapse of sardine fisheries off of California, and decades later, off Peru signaled powerful, unknown forces at work. Perhaps the most unsettling is a significant change in the cyclical events to which we are accustomed. Loss of the autumn salmon run. Years of painful drought following close on the heels of years of steady, regular rainfall. Yet some events, however unpredictable from year-to-year in the past, appear--when they do--at the same time of year: hence "El Nino".

Such discontinuities and changes have often been seen as warnings, and omens, signs of things to come (mostly unwelcome). And they often were. But I think one of the most troubling aspects of such changes in the past was that people often didn't understand enough about why the changes were occurring to be able to predict them accurately, and thereby to adapt. Fortunately, over time we have learned a lot about the workings of nature. Perhaps Albert Einstein said it best when he noted that "the remarkable thing about the universe . . . is that it appears to be understandable." Our increased knowledge of the world in which we live, of the Earth system, is one of the most significant products of the scientific endeavor and has enabled humankind to accomplish things beyond even the dreams of fabled King Croessus.

In fact, it is no exaggeration to state that the advance of the Earth sciences during the last thirty years has dramatically revolutionized our understanding of our planet and of the forces that affect the environment within which we live. The recently coined term "Earth system science" indicates some of what has occurred. The advent of Earth observing satellites has given us the ability to monitor in exquisite detail the entire Earth, to measure global-scale processes and their interactions. And let us not forget as we wrestle with the rich complexity of the biosphere, that simply seeing pictures of the Earth floating in space changed people's point of view forever. We have become part of one interconnected world, one space-ship for all of us. Our generation has come to realize that we all are deeply dependent on our environment and on each other, and that the environment, from local to global, is increasingly affected by human activities.

Advances in computer and communications technologies permit us to gather and analyze data from many different sources, and have contributed to the creation of virtual institutes that extend across multiple nations, yet are closely collaborating on all kinds of research. The traditional Earth science disciplines have advanced and interdisciplinary research has become increasingly necessary to unravel complex phenomena, such as the causes and consequences of climate change.

It is instructive to think of the various processes and components of the Earth system like the pieces of a puzzle. As we discover the pieces and learn their characteristics and how they are connected and proceed to assemble them, a larger picture emerges. Through advances in Earth system science, we are creating a picture of reality that is more complete, and this is a valuable and worthwhile pursuit just for its own sake. But knowledge can be a many-splendored thing; there is also a practical side to this activity, a deeper utility. A more complete understanding of the environment in which we exist can guide us in addressing some of our greatest common challenges, help us use the planet's resources more effectively; and, also enable us to anticipate . . . and thereby avoid or mitigate the impacts of unwanted change.

We live in a world of great contrasts. Even though millions of people around the globe enjoy a prosperity unmatched in all of human history, more than one billion of the Earth's citizens live in abject poverty, and roughly two billion people lack access to basic sanitation. And even though some parts of the world have witnessed significant progress in protecting the natural environment, we know that we face critical and worsening problems such as air and water pollution, degraded forests, declining fish stocks, and the loss of biodiversity.

If we can not learn how to reconcile the economic and environmental needs of today's population, it will be impossible in coming decades as world population continues to climb dramatically. The 5.6 billion people on the Earth today may all-to-soon become 10 billion. Health, economy, and environment are linked with population. Better understanding of our environment is necessary to allow us to protect human health, to have sustainable economic growth, and to continue to improve our quality of life and that of the rest of the planet. These things cannot be separated.

At the nexus of science and policy is an understanding of the Earth's carrying capacity and our shared efforts to revise man-made economic systems, such as the market system, in order to be capable of thriving within the parameters of the physical Earth system. And, of course it is only through developing and refining our understanding and technologies that we can assure sustainable development. It is only by making development sustainable that we can assure well-being and livelihood -- food, water and health -- for all the world's people down through the generations. Most fundamentally, we require knowledge.

The thoughtful application of knowledge can help us ameliorate today's environmental problems, and prevent those of tomorrow. We have successful examples to inspire us. Consider the case of <u>stratospheric ozone depletion</u>, of which we are all so vividly reminded by its recognition in this year's Nobel prize for Chemistry. All of us, and more importantly, our children and grandchildren, are safer because of the research of two Americans, Mario Molina and F. Sherwood Rowland, and a Dutch citizen, Paul Crutzen. They predicted that industrial chemicals would deplete the Earth's stratospheric ozone layer that protects us from the damaging ultraviolet radiation that causes skin cancer and may also be an important factor affecting other areas of biological productivity.

Their groundbreaking study of atmospheric chemistry was verified and proven by the work of other scientists using ground-based, aircraft, and satellite measurements, together with laboratory studies and theoretical models. The scientific community worked together to produce a tremendous advance in our understanding of atmospheric chemistry. But the story doesn't stop there. The results mattered to more than the science community. They led to a global agreement to ban the production and use of man-made chemicals that are at the heart of the situation. Thus, a problem was demonstrated conclusively by science, and industrial chemists (who devised substitutes that are far less damaging) and political decisionmakers responded effectively. Society made use of scientific information to <u>anticipate</u> a gathering problem, mount cooperative international activities to forestall the worst effects, and the whole world will reap the benefit.

Clearly, we <u>can</u> affect the future in a positive way. I think we should keep in mind the words of C.P. Snow: "A sense of the future is behind all good politics. Unless we have it, we can give nothing--either wise or decent--to the world."

Increasing our understanding of the natural climate system and the impact of human activities is a necessary part of this endeavor to gain a sense of the future. As we consider the future, we must consider weather and climate on a wide variety of time-scales, ranging from hours to centuries, because the climate is one of the fundamental determinants of the productivity of the Earth system. This research requires improved modeling and prediction of tornadoes, cyclones, and hurricanes, of seasonal-to-interannual variations in climate, and of human-induced global warming over decades and centuries.

The Earth's climate has been relatively stable during the present interglacial (i.e., the past 10,000 years), the period during which human society has evolved. However, the Earth's climate is now changing. The Earth's surface temperature this century is warmer than any other century during the last thousand years; it has increased by about half a degree centigrade over the last century; and eight of the last ten years have been the hottest this century. 1995 may end up the hottest on record, another mark on the evidence of global greenhouse warming (possibly reaching a global annual average of 16° C for the first time).

In addition, there is evidence of changes in sea level, temperate zones glaciers are retreating world-wide, and the incidence of extreme weather events (such as the record number of Atlantic/Gulf hurricanes this year) is increasing in some parts of the world . . . all consistent with predictions of the global greenhouse effect.

The Intergovernmental Panel on Climate Change (IPCC) projects that the global mean surface temperature could increase by another 1 to 4°C by 2100. This rate of change in temperature would be significantly faster than that observed during the last 10,000 years, certainly too fast for natural ecosystems such as forests to adapt. So we are embarked on an uncontrolled global experiment.

Regional and global changes in temperature, precipitation, soil moisture, and sea level associated with this "greenhouse-induced" change are expected to have wide-ranging effects on agriculture, water supply, fisheries, human health, and coastal development, thus affecting the economy and the quality of life for this and future generations.

Climate change adds another stress in a world where many ecological and socio-economic systems are already threatened by pollution, increasing resource demands, and non-sustainable population growth rates and natural resource management practices.

How are we to mitigate and adapt to climate change? Clearly, increased understanding is our greatest ally. Examination of natural climate variability and its consequences provides valuable lessons for the future. Our efforts to adapt and manage today's conditions are also investments in the future.

Within the context of natural climatic variability is an amazing range of recent events. The 1992 drought in southern Africa destroyed one of the region's principal subsistence crops and the U.S. experienced a traumatic multi-year drought in California at the same time. Other regions have seen frequent instances of extreme flooding. The Mississippi basin here in the U.S. has recently endured two "500-year" floods within a space of three years, each of which cost billions of dollars. Right now, Thailand is suffering one of the worst floods in its history. This year, the U.S., Central America, and the Caribbean have experienced an unprecedented string of major hurricanes.

A common thread in these <u>seasonal and interannual changes</u> in weather and climate is the El Nino phenomenon. This change in the circulation pattern of the Pacific ocean influences precipitation patterns around the world, affecting the weather from Australia to South and

Central America, the United States, and Africa. In addition to the significant warming of the ocean off the coast of South America, which affects fishing productivity, the change in currents produces droughts and flooding in different regions, as well as significant changes in the frequency and intensity of severe storms.

These fluctuations can overstress already vulnerable systems. In countries where resources are already scarce, meeting the daily needs of growing populations and growing economies is a formidable challenge. The social and economic vulnerability of agriculture-intensive economies to episodes of extended drought or flooding is well-known. Damage to the agricultural sectors can threaten the food supply, employment, foreign exchange, and reduce economic growth.

These brief examples suffice to demonstrate that we face formidable challenges from the climate system right now. I'm glad to note that we are gathered for this meeting to review some successful responses to the increased scientific understanding, responses that suggest further steps we can take together.

Research on the processes that link the tropical Pacific Ocean to the global atmosphere has, over the past several years, enabled scientists to understand the underlying physical phenomena sufficiently to begin to actually predict the onset of El Nino events and their effects on weather patterns. Although El Nino-driven changes in the weather cannot be prevented, the ability to predict extreme changes months in advance allows for protection of agriculture and improved water resource management. Early forecasts of the dramatic climate shifts associated with these events have already enabled farmers in several South American countries to prevent crop losses of hundreds of millions of dollars, keeping food available and prices from rising sharply.

A good example is Brazil. Agricultural production in Northeast Brazil was devastated in 1987 when it fell to 15% of normal yield because of a 70% decrease in rainfall from the historic average. However, in 1992, agricultural production was maintained at near-normal levels despite a similar reduction in rainfall because the El-Nino-associated drought in that region was predicted and suitable farm management practices and changes in crops were adopted in time. The economic benefits of being able to avert crop failures could be worth billions of dollars to us collectively every year.

We are thus faced with a success that can be built upon and expanded. By working together to improve understanding of the El-Nino phenomenon and to produce and disseminate climate forecasts, we can use that knowledge for the betterment of the human condition. This cooperation is an important step in achieving sustainable development, an opportunity for us to learn to use knowledge to dependably provide goods and services to our people while protecting our environment, health, and security. Rather than overcoming the natural world, it is smarter and better to be a part of it, through scientific understanding. Such cooperation in research and analysis is therefore an essential investment in the future.

It is apparent to me that our future progress is dependent on several factors, and I'd like to leave you with these thoughts.

First, the benefits achieved to date are dependent on the open and unrestricted flow of data and research results, among researchers, meteorological services, government agencies, and affected people. This practice must be continued and enhanced. There is a disturbing trend among some nations to place restrictions on the open flow of data, a trend with the potential to impede precisely the kind of mutual progress we seek.

Achieving sustainable development requires both increased understanding of the natural system and increased understanding of the vulnerabilities of socio-economic systems to natural perturbations. We have much to gain by working together in a coordinated international approach to global environmental issues that know no boundaries.

Second, some crises in the global environment, like ozone depletion, climate change and loss of biodiversity have long time constants - on the order to decades to centuries to develop. The time needed for recovery (if they can be reversed) is much longer - on a time scale ranging from decades to millennia. Political time scales are more often on the scale of hours to months so there is a disconnect. Rene Dubos recognized our focus on fast-changing or short-term phenomena as one of the great tragedies of humankind. We must not let the spirit of budget-cutting and immediate concerns mortgage the future of our children, and our planet.

Third, we must work together to maintain scientific research to address these long-term problems. Building networks of monitoring sites, developing simulation models, conducting ocean and atmospheric research to understand our fragile spaceship Earth requires sustained international commitment.

We in this room are part of the group that must address, and I hope, help solve these problems. The nations that are able to take advantage of new opportunities and that can respond to environmental and economic challenges will indeed be the future leaders of the world.

Finally, the lesson that stratospheric ozone research and policy taught us is that science and diplomatic agreements of cooperation between governments can combine to cut short major planetary problems. Let us work together to make progress on understanding and living with El Nino; and, in doing so, gain momentum towards resolving the other challenges that beset us. To do less would be to betray our stewardship of the earth and our children who will inherit it.

Remarks of
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Good afternoon, and thank you for inviting me to share a few thoughts about the health of the science and technology enterprise in 1995 and our outlook for the year ahead. I look forward each year to the AAAS colloquium as an annual milestone, a chance to draft a report card for the work that we've been doing over the past 12 months to foster innovation, conduct research along the frontier areas of science, protect our environment, and bring the fruits of technology to the American people and to the world.

As I stand here today , though, I can't help but think a year ahead to what next year's keynote speaker will be saying about the 1995 year-in-science. Will that speaker be able to say that 1995 was the year America ceded leadership in science and technology to foreign competitors, or that America retained and bolstered its lead? That the 104th Congress shut the door to a Federal role in supporting critical technology research and development, or that Congress renewed the science and technology partnerships vital to American economic, environmental, health and national security?

These are not idle questions. What has played out over the past 100 days in Congress for those who follow science policy is a clear dichotomy between some in Congress who desire to <u>cut government</u> seemingly at any cost, versus the Administration's commitment to <u>cutting the deficit</u> while boosting overall productivity and investing for the future..

One of the things that will stand out about 1995 is that it is the first year that we have really felt the pain of living with true public fiscal austerity -- the escalating budgets of the spendthrift '80s are over. I think this is where I'm supposed to say, "I feel your pain."

One of the reason we've been insulated from the pain so far, is that this Adminstration has been carefully, judiciously cutting the deficit for three budget years in a row, racking up more than $600 billion in deficit reduction. We've been working very hard to try to minimize the pain, or at least balance it out in an equitable fashion.

The President's projection for FY96 implies a $200 billion deficit. That's about half of what it would have been had he not commenced two years ago his deficit reduction plan. It's important to note that $200 billion amounts to the interest we pay every for the <u>increase</u> in the national debt callously racked up in the heady Reagan-Bush years.

I don't want to say that our work over the past few years has been painless; money is scarce across the Federal spectrum. Yet despite deep cuts in virtually every other domestic discretionary account, research funding actually has risen modestly -- a signal of the Administration's commitment to science and technology as the engine of growth in jobs, the economy, and our quality of life. And basic research received the greatest percentage increase.

So I give high marks to the coordinated process that built this budget, and to our President who supported science as an investment meriting increases -- increases that could only be provided by shifting funds from other Federal activities. In this middle of the fiscal pain, the Administration has held fast to the principle of wise investment in science and technology -- not because it's a good thing politically, not because there's PAC money here, not because there's a great and clamoring constituency -- but **because it's important and the President and Vice President believe in it.**

This kind of priority-setting -- difficult as it is -- represents the actions of deliberate and dedicated government, husbanding and making careful, multiple use of the resources for the future for our children and our grandchildren. It reflects the vision of the Clinton Administration -- science and technology in the service of society, an engine of growth for the economy and the creator of knowledge that is the key to a new world condition. It is a vision that draws people into science and brings many of us here today.

Crafting such a vision requires great care. It cannot be done by a Congress motivated solely by the desire to move dollar signs from one side of the ledger to another. It cannot be done in 100 days, or 200 days, for that matter. It cannot be done by simple fiat or decree. It cannot be done by a Congress so weary it can't see straight; so driven that it doesn't even have time to read the material on which it is about to vote.

It must not be done with a meat ax when the precision of a scalpel is necessary.

Yet the spectre of finishing the first session of the 104th Congress with S&T resources slashed by a meat ax is a real one. In their rush to cut government, (Dan Greenberg, I think, recently labeled it "demolition politics") some Members have launched a wholesale attack on anything that isn't nailed to the table -- including R&D, and especially the "D" in R&D. But don't be lulled into thinking that basic research is sacrosanct.

The bad news for R&D reads like a litany of the lost. Congress already has agreed to cut half-a-billion dollars from this year's budget for science and technology in the military supplemental, and they're about to take another half-billion whack in civilian recissions supplemental. Most of the cuts so far have been in technology programs, but science has taken a substantial hit, too -- $100 million from the Department of Defense programs in computer science, mathematics research, and engineering education at universities; upwards of $80 million from the National Institutes of Health; and $45 million from DOE research on materials, climate change, and the human genome.

This is bad enough. I realize these cuts are well-intended, that they spring from a belief that deficit reduction is the only name of the game in town these days. But it's a short-term strategy that will lead to the Nation having eaten its seed corn for the future.

The cuts we've seen already are nothing compared to what they are thinking about doing: The Chairman of the House Budget Committee, Rep. Kasich, recently released an "illustrative list" of cuts for next year's budget, in which the toll for science and technology was a whopping $2.5 billion. Over the next five years, it's targeting $13 billion. More than half-a-billion of these "illustrative" figures for FY96 come from NIH -- $2.5 billion over five years. Agricultural research declines by $1.3 billion over five years.

And while NSF hasn't appeared on a public hit list yet, Director Neal Lane has been told to expect at least a 20 percent cut. That's more than $600 million -- nearly all of it from the research bench, since 95 percent of NSF money goes out in grants.

Now, I don't want to raise the false expectation that we in the Administration will be able to completely insulate science and technology from the real fiscal pressures that will drive the next decade of budget policy. The reality is grim for science and technology funding. There will be cuts; R&D will have to take some of them. But the cuts should be judicious and managed, not across-the-board salvos that wreak havoc throughout the research enterprise.

My hope is that wise heads in Congress will intervene, that history will record that they saved the nation from permanently damaging our research and development base by moderating the hasty, ill-informed or ideology-driven decisions -- penny-wise, pound-foolish decisions we have seen in attacks on technology partnerships and environmental protection, and in irresponsible regulatory reform. But my fear is that history will record that extremists in Congress prevailed as prevailing in an atmosphere of budget chaos driven by a fundamental disregard for reinvestment in science and technology.

Now, I'm an optimist by nature, even under these trying circumstances, and I think most Americans share that trait. A lot of our native optimism rests on the belief, based on our nation's history, that breakthroughs in science lead to advances in technology and vice versa -- the two are inextricably linked. Our scientific enterprise still is the envy of the world, and the technologies it spawns lead to a better life and a brighter future. Just the other day, the President released the 1995 Critical Technologies Report from OSTP concluding that the United States -- at least for now -- is the world leader, or equal to the best, in the 27 technology areas it identifies as critical to national and economic security.

But it's hard to be an optimist in the face of the sobering caveats contained in that report. Yes, we are among the leaders in those 27 areas of technology, but our lead is fragile and shrinking. Now, Europe is dead-even or only slightly behind us in 25 of the 27 areas; Japan is tied or just a nose behind in 17 of the 27, and is closing fast on 5 more. If we want to maintain leadership -- or even parity -- we can't afford to stand still.

It's harder still to maintain my optimism in the face of the Congressional response to this situation. The technology investments that have been a hallmark of this Administration are in great peril. They are our first and best defense against further erosion of U.S. leadership in critical technologies, yet they are marked for the wrecking ball -- at least by some members. I hope, however -- and this is the optimist in me coming out again -- that we are making progress in educating some of the new members about the value of these crucially important programs.

According to the World Economic Forum, the U.S. Federal government already under-invests in federal civilian R&D compared to our world competitors. Equally distressing, the U.S. private sector under-invests as a percentage of gross domestic product compared to other nations. Our negative balance of trade in technology products is testament to how poorly we are doing in this area -- the worst among all trading nations. We must correct this investment failure. In doing so, the Administration has addressed this issue by supporting R&D tax credits and industry-led, cost-shared programs to develop technologies that have widespread returns to the public -- better transportation, safer buildings, cleaner air. I'll talk more substantively about those programs in a moment. But I view the new congressional majority's decimation of these programs as a ruthless attack on this nation's future, an attack erroneously labeled corporate welfare.

To offset years of inadequate long-term investment, this Administration has concentrated on building up some rather modestly funded but indispensable activities in which the federal government makes partners of private industry, universities and community colleges, state and local governments, and community organizations to develop technologies that benefit all of us. We've done so for two reasons: (1) For national security, and (2) because much of the generic science and technology critical to economic growth can't attract adequate private investment -- the firm that takes the risk and makes the investment can't capture enough of the benefits.

Furthermore, today's fast-paced, highly competitive economic climate makes well managed federal research investment in growth-enhancing technologies more critical than ever. Faced with short product cycles and intense international competition, many companies are cutting costs to the bone and using available research money on projects with near-term payoffs. The new model of how best to accommodate this changing business environment is to create public/private, cost-shared partnerships for generic R&D -- teaming with other companies, with universities, and with the government.

These programs represent a reasoned and compelling continuation of our successful government-industry partnerships going back, in some case, for more than two hundred years -- in transportation, aerospace, navigation, exploration, national security, agriculture. They represent a 21st-century vision of commitment to the programs and values that made America great. They are the way the Administration is building the National industries of the future. They are programs like:

o The Advanced Technology Program run by the National Institute of Standards and Technology (NIST) in the Department of Commerce -- industry-led, merit-based, and cost-shared. ATP awards support development of new technologies today that will be the backbone of the tomorrow's manufacturing, construction, and commerce.

o The Partnership for a Next Generation of Vehicles (also known as Clean Car), designed to tackle an extremely tough technical challenge -- to develop within ten years a production prototype car with three times the efficiency of today' s autos and very low emissions, with no sacrifice in cost, comfort, or safety.

o The Environmental Technology Strategy -- working with industry on cost-effective technologies to clean up pollution from the past, prevent pollution in the future, and help build a U.S. environment industry that is a leader in rapidly growing world markets.

o Education and training technologies that have multiple public and private benefits: exciting education challenges for our children; lifelong learning opportunities for all Americans, including those who need retraining to handle changing technologies on the job; and a rich potential commercial market for the technologies themselves.

o The Technology Reinvestment Project (TRP) at the Department of Defense, another cost-shared program designed to propel the commercial development of technologies critical to the military, since low-cost commercial manufacturing practices and economies of scale from commercial production will make those technologies more affordable for military users.

o Policy support for and end-use research on the National Information Infrastructure, which will bring the knowledge of the world to a desktop in rural Montana; or tap medical expertise from Paris, France for a patient in Paris, Texas. This program also will assure the Nation's continuing leadership in high-performance computing.

o Promotion of energy efficiency and renewable energy through our Climate Change Action Plan to improve air quality while simultaneously reducing emissions of greenhouse gases and conserving energy resources..

o Industry-led CRADAs -- cost-shared, cooperative research and development agreements -- that have grown from a few hundred at the beginning of this Administration to more than 3000 today. CRADAs move important new developments on the laboratory bench into the commercial market, improving health care, transportation, home design, and hundreds of other technologies to improve our quality of life.

Most of these programs are cost-shared, meaning that industry is the senior partner. If they don't invest, there is no deal -- industry is picking the winners and losers, not government. Economists, investors, technologists, and industrialists understand and widely support this activity ... but in their rush to judgement, it sometimes seems that some Members in the new Congress don't want to be confused by the facts.

These innovative partnerships -- which have done much to boost technology investment and innovation in the American economy, and which promise so much more for the future -- may be a matter for the history books alone unless concerned Members of the Senate and House act to restore funds for technology programs. Based on their work and words to date, it's getting harder and harder even for me to retain any kind of optimism.

The question for us today is: Can we moderate these demolition politics soon enough to avoid grievous harm to the science and technology that drive our economic growth and national security? If not, we risk losing more than just figures on a pie chart. We lose jobs, security, and our children's opportunities.

Congressional number crunchers promise that money saved in downsizing the federal government will be reinvested in science and technology -- if there's any left over after paying down the deficit some more and increasing funding for pet projects. If you believe this, I have a bridge to sell you.

One of their preeminent proposals is the creation of a Department of Science.

Veteran attendees at this colloquium will note that this Department of Science proposal is not a new idea. It was first proposed in 1884, and again over 100 times over the past three decades. As Guy Stever once said of Antarctic blizzards, this isn't new snow -- it's the same old snow being blown around again and again.

Let me be very clear about one thing -- **this Administration unequivocally opposes the creation of a Department of Science of the kind now being discussed in Congress.** We are not against change; under the leadership of the Vice President, we have been remaking the very structure of federal agencies -- not just shuffling programs around and renaming them. But we are against change for change's sake -- or for the sake of as-yet-undocumented savings in federal resources.

Congressional supporters of the Department of Science idea argue that it's important to have all the science programs centrally located -- except, of course, for health ... and defense ... and agriculture. They say this, by the way, as though it were a given and without a shred of evidence about its effectiveness. But the genius of U.S. science policy to date has been its recognition that pluralism of support and diversity of performers allows the crucial freedom of enquiry that unleashes the creative spirit of our world-class researchers and their students. The proposal to create a Department of Science flies in the face of this pluralism by instituting a command-and-control model of rigid bureaucracy.

We are all in favor of making science more responsive to the needs of the Nation. But we believe the worst possible thing you can do to policy and associated missions is to divorce them from a science base. To say that food safety will be greater because someone, somewhere in that science agency across town is doing some kind of pesticide research is ludicrous -- Just as in industry, Federal agencies depend on the feedback from research that is inextricably linked to their mission. There is no productive way to unhitch science and policy. Nor should we. The result will be poor science conducted in a vacuum and even poorer policy.

If this is such a good model, why hasn't private industry adopted it? Why not take Bell Labs in New Jersey, an IBM facility in New York, maybe a Silicon Valley research consortium and plunk them all down together in the middle of the Great Plains? That might consolidate some overhead, but would it actually help the bottom line or the future viability for any of the companies involved? Of course not -- their competitive edge demands access to the research that drives productivity, just as the mission agencies require free and easy access to the best science available.

The President's report "Science in the National Interest" says it succinctly:

"Federal support of fundamental science and engineering is characterized by a healthy pluralism. All Federal departments and agencies that depend heavily on scientific and technical knowledge and human resources support fundamental research and education in these areas. This improves their capacity to attain their evolving goals as new challenges emerge."

What we have to keep in mind is that, as we face increasing fiscal austerity, it is particularly important that the nation's science leadership understand the "mosaic" of science support and performance by federal agencies, universities, and industry; to understand how the support by DOD of research and graduate training in engineering and computer science complements the work by NSF, and how together they provide a knowledge base and the human resources for advances in the private sector; to understand how materials research and high-speed computing and networking at the Department of Energy contributes to breakthroughs in biomedical research support by NIH; to understand how the biological research and long-term ecological monitoring supported by NSF provide further elucidation of natural phenomena crucial to wise environmental policymaking by the EPA; to understand how to mix advanced technologies and research so that both military and civilian services can be provided from the same investment.

What we must understand -- and there are those in Congress who would ignore this at the Nation's peril -- is how federal agencies, together, support our overall science base: and we must especially recognize the increasing interdependency among their efforts. Significant cuts to one program can have substantial effects on other national initiatives. We must be smart and deliberate in any trimming -- mindful of these important connections as we attempt to make our Federal government work better. But this does not mean that all Federal science efforts ought to be merged into a single entity.

On the other hand, if the Congress truly wants a leaner, more efficient Federal S&T system -- not just cosmetic surgery -- it need not look far for a model. Under the President's "Reinventing Government" initiatives, we have already pared more than 100,000 jobs from the Federal bureaucracy. That'll total nearly 150,000 before we're finished.

o NASA alone has plans to cut more positions as it streamlines its operations than the 5000 jobs that supporters of the Department of Science claim their move will eliminate.
o EPA, FDA, and other regulatory agencies have slashed regulatory red tape -- by contrast, regulatory "reform" as passed in the House of Representatives would only, in the words of last Sunday's Washington Post editorial page, "put sand in the gears of the Federal regulatory process."

o And in the next few weeks, I will be briefing the Vice President on new and innovative ways being tested at NSF, NIH and the Department of Energy to use the information superhighway to reduce the mountains of paperwork required of Federally funded researchers and grantees. We want to free up administrative time and costs for professors and their institutions, time that can be reinvested in teaching, research, and scholarship.

This Administration has a mechanism to encourage cooperation where advantageous, consolidation where necessary, and coordination overall. It's the National Science and Technology Council -- the first time in history that the United States has had a comprehensive coordinated Cabinet-level body devoted to reviewing the Federal R&D enterprise. The principal purpose of the NSTC is to establish clear national goals for federal science and technology investments, and to ensure that policies and programs are implemented that contribute to those goals. The NSTC provides a structure through which we can prioritize the many legitimate demands on the public's R&D dollar. It assures a forum where critical national needs cannot be pushed aside by urgent and parochial agency needs. It sensitizes agencies to the advantages of symbiosis over isolated pursuit of objectives.

Isn't this what the promoters of a Department of Science say they want?

There is a good way to go about reform, and there is a bad way. I venture to say that each of you has been trained in the good way -- experiment, observe, and test your observations before implementing innovation across the system.

Is this the process that we've seen at work in the Congress over the past 100 days? It is not. Rather, we have seen dog-tired Members marching lockstep ahead with their eyes fixed only on the end of the 100 Days. Many of the changes wrought by the House were passed without the benefit of a single hearing, or at best with a minimal legislative record. Is this what Jefferson and Madison had in mind?

Now, Speaker Gingrich is fond of referring to Thomas Kuhn's model for revolution in science, a model that stresses cataclysmic change as the driving force when scientific paradigms are replaced with newer, more powerful ideas. The Speaker stresses that the election in November and the ensuing 100 days' activities are just such a Kuhnian shift.

When paradigms shift in the Kuhnian sense, they do so because the weight of accumulated evidence and data become so great that the old paradigm topples beneath them. There is no hard evidence and there are no compelling data to support abandoning our historic commitment to science and technology. Rather, at times this Congress seems to run screaming from anything that looks like research or credible data ... even pushing to eliminate their only bipartisan and bicameral Congressional resource for S&T analysis, the Office of Technology Assessment.

Nowhere is this more clearly illustrated that in the area of environmental protection. Environmental policy in the 104th Congress has been driven by a crazy-quilt of anecdote, anxiety, and homespun homily -- tall tales and outright fabrications of workers having to wear moon suits to pick peaches and whole villages lost to forest fires because of kangaroo rats. Whatever other motivations may obtain, environmental policy in this Congress has not been driven by knowledge, and certainly not by science.

In fact, the Contract with America never once even <u>mentions</u> the word environment.

Still, we've managed to end up with ill-conceived legislation like the House-passed Risk Assessment and Cost-Benefit Act, which makes fundamental changes in the way the Federal government protects public health, safety, and environmental quality. The Senate has a similar bill on its docket. Both chambers may compromise on language that would require agencies to go through a maze of costly, inflexible, and bureaucratic procedures -- creating along the way infinite new opportunities for petitions and litigation -- and new jobs for lawyers.

It's also why we're seeing proposals to eliminate the National Biological Service -- a national inventory of our natural plant and animal resources. Such a move is analogous to book-burnings of yesteryear. Since when is ignorance a promising route to deliverance? The NBS isn't a land-grab, as its detractors claim -- science doesn't get much purer than this.

And it's why the Congress seems bent on gutting research on energy efficiency and sources of renewable energy that will be critical to combating global warming. Next on the chopping block is likely to be global change research itself -- leaders in the new Congress call it "politically motivated." Since when does it require <u>political</u> motivation to want to understand the world in which you live?

And of course, Congress' lack of regard for scientific evidence is likely to put a halt to funding for endangered species research -- the dismantling of the Endangered Species Act is a probable priority item for later this year on the Hill.

Science and technology programs in the 104th Congress are the legislative equivalents of endangered species. In Congress' rush to slash government and lower taxes -- taxes that alreay are among the lowest in the industrial world, I might add -- we are in danger of losing the very excellence in technology that has made our country the envy of the world.

Surviving with our national R&D portfolio even relatively intact will require aggressive action. We must engage the R&D community, the industrial community, the education community, Congress -- ultimately, we must engage the American people, if they mean to remain their own governors.

Congress must be part of this dialogue. I respect the leaders of the new Congress as hard-working agents of change, and I truly believe they think they are doing what's right for America. I admire their conviction, and their tenacity. But I want to work with the Congress to make sure every Member understands the enormity of the change being proposed, and its impact on the ecosystem we call the Federal R&D enterprise.

We have had periods of similar intellectual foment in our country before -- and survived them. The optimist in me takes heart in this. And the optimist in me is bolstered by the words of Thomas Jefferson, penned in a similar time of national frenzy: (and I quote)

"A little patience, and we shall see the time of witches pass over, their spells dissolve, and the people, recovering their true sight, restore their government to its true principles."

Thank you.

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The New Frontier:
Space Science and Technology in the Next Millennium

The Honorable Dr. John H. Gibbons
Assistant to the President for Science and Technology

Wernher von Braun Memorial Lecture
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A new millennium is nearly upon us. The next few years mark the transition between the twilight of one age and the dawn of another. During this transition, we will have the opportunity to reflect on the great and dynamic changes that are taking place around us.

Here at home, Americans are asking fundamental questions about the social contract that binds them to each other and to their government. Around the world, new forms of cooperation between governments are reducing barriers to commerce, technology, and culture, thus enhancing the prospects for new forms of collaboration and defining anew the meaning of national boundaries.

Dramatic and unparalleled advances in technologies for information, health, transportation, and the environment are fundamentally redefining how we live and work. We continue our struggle with the problems of environmental degradation and overpopulation, with violence and famine caused by centuries-old ethnic and religious conflicts, and with an increased threat of proliferation of weapons of mass destruction.

I would like to reflect on the role that the space program has played, and continues to play, in enabling technological and societal change and how these changes have, in turn, altered our perception of space research and exploration. I would like to share with you a vision for the future of United States and international space activities. It is a vision that is simultaneously optimistic and affordable; practical and yet, I believe, exciting.

Space technology has been one of the defining forces of this century. The Soviet launch of Sputnik in October 1957 and the ensuing space race to the moon came to symbolize the conflict between the competing world views of communism and democracy. Space became the ideological battlefield upon which each country sought to demonstrate its prowess and win global influence.

This titanic struggle yielded dark moments—such as the Cuban missile crisis when it seemed to many that technology would ultimately be the undoing of mankind. There were, however, also bright moments, such as the Apollo moon landing, when space technologies seemed to light a clear path to the future.

Space applications are now a practical and essential part of our daily lives. Satellites provide essential communication services to both the developed and the developing world. Whether it is the global distribution of news and entertainment or the regional delivery of health care and educational programming, satellites constitute a critical component of the emerging global information infrastructure.

Space also provides a unique vantage point from which to analyze and monitor our complex planet. Satellites have dramatically increased our ability to predict the weather and its many consequences. Multi-spectral imagery from space has provided unprecedented advances in regional and global resources management, and satellites for treaty verification have helped us to keep the peace.

The diverse scientific, military, and commercial applications of the Global Positioning System (GPS) are revolutionizing how we work, play, and travel. Although originally developed for military use, the United States has welcomed the global use of GPS for a wide range of peaceful purposes and anticipates the pivotal role that GPS could play in the global air traffic management systems of the future.

Space research and technology can also make us better stewards of our planet. The very first images of Earth from weather satellites and from the Apollo missions literally changed our view of the planet. In these pictures—particularly the one known as the "Blue Marble"—Earth, hanging in empty space, seemed, for the first time, small and fragile.

Astronaut Bill Anders, remembering his first view of Earth from the Apollo 8 command module, said: "Looking at the Earth and seeing it floating like—I thought, since it was Christmastime—a little Christmas tree ornament against an infinite black backdrop of space...it seems so very finite. It was this view of the fragility and finiteness of the Earth that is the impression, frankly, that I hold more in my head than any other."

It was Dr. Sally Ride, the first American woman in space, who later pointed out that although we had sent highly sophisticated spacecraft to study other planets, we had not taken a similar interest in our own planet. She led a study group that recommended a program to accomplish this task and dubbed it, somewhat ironically, "Mission to Planet Earth."

The simple truth is that we still don't understand well enough how our planet works and how human activities are affecting the biosphere. Space technology can play a pivotal role in this research. For example, we learned more about ocean circulation from a single United States-French satellite than in the whole history of ocean research. Satellite measurements also played a critical role in monitoring and understanding ozone depletion in the upper atmosphere, thereby averting a major health and biological catastrophe.

And we are just getting started. Some two dozen missions to study the global environment will be flown by the year 2000. NASA's Mission to Planet Earth, and its companion programs in the United States and other nations, are building the knowledge base that is a critical prerequisite for achieving a sustainable future.

Space exploration is providing phenomenal insights into the nature of the universe. 1994 was an absolutely outstanding year for space science. Indeed, astronomer John Bahcall has called it—perhaps with only a little exaggeration—the most important year to be alive for astronomers since the dawn of man. The Hubble Space Telescope is simply wowing the world. Most recently, it has given us striking evidence that the universe may be billions of years younger than we thought. It's found conclusive evidence that massive black holes exist at the core of active galaxies. And, it's brought us the first views of infant galaxies, which formed only about two billion years after the Big Bang.

And that's not all. Hubble data have confirmed the existence of protoplanetary disks around newborn stars. This is the strongest evidence yet that the same basic process that formed the planets in our solar system may be common throughout the galaxy.

Looking Earthward, the Compton Gamma Observatory contributed to the discovery of a strange new phenomenon known as upper atmospheric flashes that may provide a link between phenomena in the Earth's lower atmosphere and events in the upper layers of our atmosphere.

The Comet Shoemaker-Levy's collision with Jupiter in July was a seminal event for astronomers. Such events may occur in the solar system only once every thousand years or more. The early detection of the comet by the Near Earth Object Program allowed unprecedented preparation to observe this event from ground and space-based observatories, sparking worldwide interest from the scientific community and the public.

Cooperation in space offers us a new vision of global cooperation. International cooperation in space offers a rare opportunity for nations to pool their interests and resources in exciting and challenging ventures. Such cooperation is a laudable successor to the dark conflict that characterized the birth of the space program. The Apollo moon landing was, assuredly, an American victory; yet it seemed then, as now, "a giant leap for all mankind."

The Cold War, however, did not end with Apollo. For years, the United States and Russian space programs continued along their separate paths, not really competitors, but not yet partners. Then the Berlin Wall came down, the Soviet Union fell apart under its own weight, and the world changed dramatically. The space programs of both countries had to adapt to a changing world. Gradually, we came to see the space program as a tool for building peace and international understanding rather than as a weapon of the Cold War.

This is why, in 1984, the United States invited our close allies in Europe, Japan, and Canada to join us in building a space station. And this is why the Clinton Administration, a decade later, took the bold step of inviting the Russians to be full partners in the International Space Station.

But what next? Are the glory days of the space program in front of us or behind us? Although physicist Niels Bohrs warned that "It is very difficult to make an accurate prediction, especially if it's about the future." I feel confident in predicting that the best days of the space program are yet to come. In the future, space will play an increasingly important role in our daily lives, in our science, in our adventures, and in the security of this nation. I would like to examine some of the ways in which space technology will continue to change the world in which we live.

Today, we are in the midst of a digital revolution that promises to transform the way we use and share information. Satellites, including the new generations of hand-held mobile and broad-band communications satellites, will play a critical role in this revolution. They will provide affordable links to the global network from the most remote corners of the planet. And they will help link existing terrestrial networks as well. The result will be more open markets, more freedom of information, stronger democracies, more productive workers, and a higher quality of life for billions of people around the globe.

Satellites will help communications and computer companies to develop ever more sophisticated products and services. A new generation of "information appliances" will replace today's computers, cellular phones, and televisions. Wallet-sized, wireless, personal digital assistants will help you organize your life and keep in touch with your office; digital newspapers, magazines, and books will be delivered directly to your laptop computer; and new learning tools using virtual reality or providing access to huge digital libraries of information will be available. These new tools will enable users to access and manipulate data in ways that we cannot even imagine today.

We can see examples of what will be possible in the future in the research community today, particularly among scientists using remote sensing data and computer models. Because their work is so data-intensive and because it requires interdisciplinary collaboration, researchers have developed software and networking technology that enables people around the country to access, manipulate, and share huge data files of imagery. Experiments currently being conducted by NASA and industry on the Advanced Communication Technology Satellite are demonstrating that satellites too will play an important role in networked, high data rate communications.

In the future, we will continue our exploration of the solar system and beyond. This exploration will , however, proceed in ways that would have surprised, and I think fascinated, Wernher von Braun.

The von Braun paradigm—that humans were destined to physically explore the solar system—which he so eloquently described in Colliers Magazine in the early 1950's, was bold. His vision, however, was highly constrained by the technology of his day. For von Braun, humans were the most powerful and flexible exploration tool that he could imagine. Today we have within our grasp technologies that will fundamentally redefine the exploration paradigm. We have the ability to put our minds where our feet can never go. We will soon be able to take ourselves in a virtual way—anywhere from the interior of a molecule to the planets circling a nearby star—and there exclaim, "Look honey, I shrunk the Universe!"

Today, the great challenge of space exploration and utilization is making it affordable and efficient. I am happy to say that's exactly what Dan Goldin and NASA are trying to do. The Jet Propulsion Lab, for example, is now developing concepts for a ten-pound spacecraft that is no bigger than your fist.

The next century will likely see the flowering of a new manufacturing revolution, enabling an armada of tiny, intelligent machines to travel outward from Earth to explore new worlds. These small spacecraft will require less power and smaller, lower-cost launch systems. They will take advantage of next generation on-board intelligence capabilities and will have little need for elaborate terrestrial control and operations centers. The result will be to greatly increase the science output while reducing the physical and human resources required to develop and operate a mission.

There will even be occasions when we conduct dramatic new exploration missions without ever sending spacecraft to distant worlds. In the not too distant future, we may have the technology needed to image planets that may he orbiting nearby stars. It might be possible to infer through spectroscopic analysis of their atmospheres or the color of their occans whether they are life-bearing. What a revelation that would be!

All of these options will greatly enhance our research into the human role in exploration. We are firmly committed to the space station, not only because it opens a door to new research, but because it is an essential step in understanding how humans react to the space environment. Early in the next century we will hopefully understand the difficult questions of bone loss and blood chemistry that currently beset astronauts spending long periods in space. With this knowledge and the knowledge obtained from our robot explorers, we will be prepared to answer the important questions about the next destination for humans in space.

As we set out to explore new worlds, we must also be good stewards of the one world in which we all live and the only world we can count on. In the words of Robert Burns:

> O wad some Pow'r the giftie gie us
> to see oursels as others see us!
> it wad frae mony a blunder free us...

Perhaps it was the view from space that Burns was imagining. One of the space program's most important contributions is to increase our understanding of our planet so that we may enhance life on Earth.

As the century ends, the United States and its international partners will have an array of sensors in Earth orbit measuring the atmosphere, oceans, biosphere, and land surfaces, as well as the interaction among these elements. These sensors will be linked by sophisticated information systems providing data to scientists and researchers. This work will produce answers to fundamental questions about Earth, how its systems interact, and how and why it changes.

We will have powerful new tools for analyzing weather, for the longer-term prediction of floods, drought, violent storms, and the dynamics of biological change, such as disease and the migration of flora and fauna. We will have a complete survey of the Antarctic ice sheet, and we will be making the first assessments of changes in thickness of the Greenland ice sheet and the first global rainfall assessment. In the future, routine forecasting of El Nino occurrences and consequences will be possible with enormous potential for economic savings.

Soon we will be able to perform repeated global inventories of land use and land cover from space, evaluate the consequences of observed changes, and analyze the consequences of different preventative and adaptive practices. We will use satellites for the first global assessment of air pollution in the lower atmosphere, leading to continual assessment of changes in global air quality.

In short, space technology can give us the information we need to understand the role that human activities play in this complex cycle as well as the influence of "natural phenomena." This knowledge is absolutely essential if we are to be responsible stewards of this planet.

Space science and exploration has inspired and enriched us. What more could we ask? Well, as they say, "happiness can't buy money. " The current review of budgets and programs in the Administration and in Congress implies that even high priority programs, such as space science and exploration, will be coming under increased scrutiny. That's the bad news. The good news is that much of what we must do to develop an aggressive space program for the future has already been started.

We are truly reinventing NASA. This means that we must take an organization established during the Cold War as a federally mobilized response to Sputnik and transform it into an agency that is more relevant to today's economy and today's world. It must be an agency that will once again define excellence in space science and technology. This task will be difficult and it will not be done without some legitimate pain.

However, reducing the size of NASA is not an end in itself. We must also work with NASA to change the way it does business. The aerospace industry has matured considerably since the days of Apollo. As a result, the private sector can now accomplish many of the tasks formerly done by the government. Satellite communications, space launch, and remote sensing were all originally government programs but are now being offered successfully by the private sector. In the future, we must ensure that NASA does only those things that it does best.

NASA's 1996 budget contains a number of programs that already incorporate this new approach. For example, the Reusable Launch Vehicle (RLV) program will focus on developing low-cost, next-generation launch vehicles, while the Discovery program will seek to advance the state of the art of spacecraft for space exploration. Both of these programs have sought, from the beginning, to include significant industry participation, management, and funding.

Finally, we must to seek creative ways for the space programs of the world to combine their talents, resources, and facilities to accomplish goals that are beyond the reach of any one country. The space station and Mission to Planet Earth provide us with early examples of this trend. In the future, we must seek other opportunities to build durable links between our individual efforts in space science and exploration.

In 1965, President Johnson asked: "As [man] draws nearer to the stars, why should he not also draw nearer to his neighbor? As we push even more deeply into the universe, we must constantly learn to cooperate across the frontiers that really divide the earth's surface."

I look forward to participating with you in this important venture.

About the author

John H. Gibbons is the Assistant to the President for Science and Technology and Director of the White House Office of Science and Technology Policy. Dr. Gibbons is charged with providing expert scientific, engineering, and technological advice to the President, federal officals, and Congress, and with coordinating science and technology policy throughout the federal government.

An internationally recognized scientist and an expert in energy and environmental issues, Dr. Gibbons has a deep concern about support of science and the impact of technology of society. After receiving a doctorate in physics from Duke University in 1954, Dr. Gibbons spend 15 years at Oak Ridge National Laboratory in Tennessee. In the late 1960s, he pioneered stuides on the use of technology to conserve energy and minimize the environmental impact of energy production and consumption. He became the first director of the Federal office of Energy Conservation in 1973, but returned to Tennessee in 1975 to direct the University of Tennessee Energy, Environmental and Resources Center. In 1979, he returned to Washington to direct the Congressional Office of Technology Assessment, which provides Congress with nonpartisan, comprehensive analyses on a broad spectrum of issues involving technology and public policy. His tenure there lasted until his current Presidential appointment in February 1993.

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Governing in a Technology-Driven Age: Progress and Problems

Some Key National Issues

Let me turn now to some key issues that are being faced by the nation.

The first broad issue area is defense and military security. What we have seen in the last year is probably unprecedented in terms of the historical rate of change of major economies and military balances of power in the world.

We've seen a forty-year focus of our nation on our role as the peacekeeper against the forces of darkness suddenly become anachronistic and in need of total rethinking. My first observation is that probably the most powerful thing that caused that collapse of centrally-planned economies was technology; namely the technology of information processing and transportation, which globalized world markets and made central planning, in an increasingly complex world, less and less capable of competing with market economies, and the whole system fell apart. So I think we have witnessed something driven by changing technology that is most extraordinary to see.

The question now is: What next? What is the new paradigm for our own national role in the global context? What happens as we shift our own economy toward some new state, this so-called economic transition that some of our defense industries have been in for five years, but which is likely to accelerate in the next five or 10 years? What do we need to hold onto in terms of defense technology to enable us to continue to protect our freedom? What other changes should be occurring that will enable us to face more realistically the awesome problems we're having in terms of economic competitiveness in world markets?

Stuckenberg Lecture, Washington University, St. Louis, MO, October 1991.

Perhaps we're not in the middle of a free fall, but we're certainly moving down some rapids and we're not quite sure what the end will look like, our neighbors in what used to be the Soviet Union.

So what is the new paradigm? What do we do about nuclear weapons? The new perception of nuclear weapons is that they're more of a chore and a burden than they are a device of utility, other than as a deterrent. So we're seeing countries like South Africa, Brazil, Argentina, and others announce that they're walking away from any notion of trying to develop nuclear weapons. At the same time, we're finding nuclear weapons spread around the new countries that used to comprise the Soviet Union to the point that France, which used to be number three as a world nuclear power, is probably number six or seven now.

The question of proliferation and our realization of what people can do even in a country as small as Iraq, presents us with a profound new challenge regarding the management of this technology. It certainly places new demands on technology in terms of verification and monitoring so that we can be assured going into international treaties that people aren't cheating.

What do we do about the plutonium as we dismantle these weapons? Should we sell it to countries that have reactors that can burn it and turn it into electricity? What do we do about things like Star Wars defense which is purported to shield us from oncoming missiles from some hypothesized enemy, versus say Star Schools, which is another approach to using public funds, in this case to educate our kids better? What about defense conversion?

We have a whole panoply of issues now suddenly on our plate that we couldn't have imagined eighteen months ago that we must deal with as a nation. What do we do about re-focusing our industrial strengths toward the new challenges of competitiveness?

That leads me to the second issue, namely of economic security and competitiveness. If you think about it seriously, there isn't a lot of good news out there.

Real income for most of us in the States has been falling for a decade or more. Our science and technology lead around the globe is falling. There's a narrowing; in fact, we have been passed by some other countries in some areas of technology now. Our physical infrastructure is decaying, and our investment there is far less than what is required for its maintenance.

Our manufacturing market share is falling dramatically, and it's in manufacturing that the good jobs are located. We were the world's largest creditor nation 12 years ago, now we're the world's largest debtor nation. Our education and skills are such that Mexican workers making a fourth of our wages or less are just as skilled and productive and error-free as our own workers. Our labor rates are not competitive with places like Mexico, but the Japanese and German labor rates are passing us now, so labor may become less of an issue.

Executive compensation, on the other hand, is twice the world average for other industrial countries. The *Washington Post*, in an article about General Dynamics, says that the chairman has a new plan that doubles the salary of some of the two dozen of their top executives if they can only push the price of their stock up by 10 points or more over a ten-day period—an unbelievable short-term focus on performance.

So I think there's a lot of tough news out there that we haven't been very honest with ourselves about. There is evidence, however, that we are still a very innovative nation and that we're capable of changing, and there are many public policies that, in fact, could be changed. We have a lot of tax policies, fiscal policies, and research and development policies at the federal level that, if anything, hinder motion in the right direction in terms of improving our competitiveness. And technology is a common theme throughout that whole area.

Third, *health care, health technology, and health costs* are clearly a big concern. We spend about twelve percent of our GNP on health care now. The average for other industrial countries runs about eight percent, but the health care outcome is not all that much better here; in fact, it's not as good in many areas. Why? We are the leaders in new technology in health care, but we are hemorrhaging funds because of the way we're running our health care system. So questions of cost-effectiveness, of productivity and of efficiency in health care are questions that are constantly before the Congress.

There are a lot of ethical dilemmas that are emerging at the same time with the advancing technology, such as the issue of how we treat our elderly; how we strive for longevity, sometimes at the expense of quality of life. We have forgotten the Greek proverb that says "The thing to do is to die young, but as late in life as possible." And sometimes we want to be heroic and extend the lives of people when even their own loved ones know it's too late.

We have problems of insufficient attention to teenage adolescent health problems, teenage pregnancies, drugs and the like, which should begin at home, but ultimately do affect federal policies with respect to health reimbursement and health research. Health issues of all kinds consume about 25 percent of OTA's time and effort these days.

Environment is the fourth on my list of issues. We certainly know that environmental problems arise from the inability of a market economy to handle this so-called tragedy of the commons. We therefore have environmental externalities, ranging from local problems of water quality being eroded by folks upstream, to the issue of the upper atmosphere losing its ozone and ultraviolet rays coming through to give us more skin cancer and other big problems, to the global warming issue which is an extremely serious situation in terms of its implications. That now means that we need a new sense of who we are and who our neighbors are and what we mean by a community of people.

So we have to face these "market failures" not only on the local level in terms of environmental controls, but also on a planetary basis.

On the good news side, the Clean Air Amendments are working. We finally had an accommodation after a half a dozen years of tough wrangling. We've got municipal solid waste problems that are enormous in every community but are finally being addressed. One of OTA's roles is to try to help Congress understand what the federal and state governments can do about municipal solid waste. We know that people, such as you and I, are willing to do a lot of work to separate trash. But if in good faith we do that and we prevent the trash going to a landfill which is more and more expensive, who is it that's going to buy this recovered material and use it in the downstream economy, the so-called secondary material markets? Without such markets, recycling will fail.

So when we set goals for separation of trash, at the same time we have to think about markets that will pick up and utilize that trash, or we may find ourselves spinning our wheels. Market approaches to residuals management is a very important issue that occupies a fair amount of OTA's time and attention.

Green manufacturing is, in a sense, the next phrase of that theme. Can we not only reduce the amount of problems we've inherited from past years, but also begin to design products thinking about a closed system; that is, not only choosing the materials in the manufacturing so that you make a successful product, but also keeping in mind the ultimate disposition of that product when it reaches the junkyard or its final stages.

Problems that are "not in my backyard" range all the way from Superfund to nuclear wastes, or even to medical wastes. And the global issues are overriding.

One potentially enormous problem is that we're pouring carbon dioxide into the atmosphere at a rate that exceeds that of resorption, and also methane, particularly from anaerobic digestion in animals and in rice production. So the atmosphere is beginning to change its character at a much faster rate than we've seen since the beginning of the Industrial Revolution. What happens? Those gases, particularly carbon dioxide, begin to trap the outgoing infrared radiation from the earth, and we find that we basically are building ourselves an effective greenhouse before we have a good idea what its long term impacts will be.

There's no question but what the gas concentrations are increasing. There is some question about what the net total effect of that increased concentration is going to have in the near term on the earth's climate, on the location of storms, on rainfall patterns, on the warming of the season, and therefore on the expansion and flooding of wetlands.

Given the uncertainty about the future, and the fact that we are loading in changes that inevitably will affect our future, what is our responsibility now? This is not only a local issue. It is a U.S. issue. It is a world issue. But the U.S. has a special role for two reasons: One is that we possess technology that can enable us to take a different economic road to the future that is less greenhouse-intensive. The second reason is because the U.S., with only a few percent of the world's population, accounts for 25 percent of the greenhouse load at this point. So we have a special and undeniable responsibility. One thing that OTA has been doing is trying to evaluate options that the U.S. could take through a variety of mechanisms, which would enable us to continue our economic growth but shift away from the production of so much carbon dioxide per unit of GNP produced. OTA studied the options using three scenarios: (1) business as usual; (2) CO_2 reducing measures that could be done at low cost, no cost, or at a net profit; (3) serious CO_2 reduction at a cost ranging up to the present cost of environmental controls. The results (Figure 1) showed that highly significant reductions in CO_2 can be achieved over the next 25 years despite major economic growth, depending on the

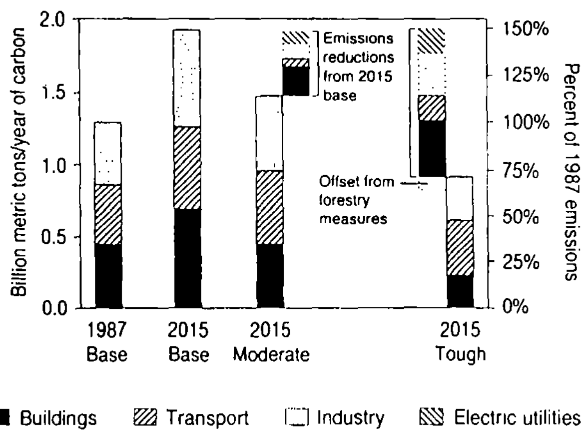

FIGURE 1. Carbon emissions under the base case, moderate, and tough scenarios. NOTE: The boxes outlined with dashed lines represent the reductions in carbon emissions associated with control measures applied in each of the three demand-side sectors (i.e., buildings, industry, and transportation) and electricity supply (electric utilities); additional carbon offsets afforded by forestry measures are also shown. The boxes outlined with solid lines represent total emissions from each demand-side sector. Emissions associated with electricity generation have been allocated to the three demand-side sectors. Source: Office of Technology Assessment, 1991.

form and strength of specific public policies. This information gave Congress a detailed map of what can be done over time.

The elucidation of options and their costs is the sort of thing Congress and other governing bodies need to have when they try to think about public policies related to global change. Related to environment is a fifth area that integrates the others, and that is *energy strategies*. You know that the Administration and the Congress have been wrestling over what our national energy strategy should be. We seem to go through this about every 10 years with discouraging regularity.

As seen from the Congress end of Pennsylvania Avenue, the Administration's national energy strategy has been long on rhetoric but short on specifics, and the Congress is trying to get to some definite plan that makes sense in terms of the overriding concerns such as our economy, balance of payments, security, dependence on Mid East oil, and our environment—local, regional and global.

I want to underscore that any strategies taken with regard to things like energy are useless unless they are applicable for the long term; that is, 25 to 50 years. That's a long time for a member who seeks election every two years. But, that's the time frame we must deal with if we're serious about these long-term, socio-technical issues.

One approach we tried was to visualize some strategies that are specific enough in terms of long-term goals that they can be the basis for accepting or adopting policies to try to reach those goals. And, of course, we have to be very compact about defining these goals, as Lewis Carroll (who wrote *Alice in Wonderland* and was also a mathematician) said, "There's nothing quite so useless as a map that's been laid out on a one-to-one scale."

When we talk about energy strategy, clearly one of our biggest problems is oil because it's so handy: it's plentiful, storable, and transportable. It runs our transportation system for all intent and purpose, and it is also intimately related to energy security costs ranging from military forces in the Middle East to the strategic petroleum reserve. It's a major reason why we went into Kuwait. So if you talk about oil, you have to talk about transportation. And if you talk about transportation, you have to talk about moving people, that is, cars and light duty trucks, because that's where the real action is and that's why there's so much focus on automobile fuel efficiency standards.

If we look at oil overall, it's a very interesting situation. Our domestic production is shrinking. In contrast, as we move toward the future, our demand is growing. Now, the question is: What do you do about it? What are the implications of this long term trend? Some might argue "So what? Japan depends far more than we do on imported oil and they get along fine." The problem is that Japan also is able to sell enough in overseas markets that they have a positive balance of trade. We do not. Our oil exports last year accounted for half of our stubbornly large balance of payments problem. So we have, before we even talk about security or environment, balance of payment issues.

What can one do about this? It seems to me there are two options: One, to expand supply or at least slow down the decline; and two, to slow down demand growth using options like higher efficiency. OTA laid out a number of options, costed them out to see if they'd be attractive, and came up with some alphabet soup for the Congress to consider. The details, are illustrative.

On the supply side, while North Slope production will be steadily declining in the 90s, there are other frontiers that may hold oil, in particular the coastal area of the Arctic National Wildlife Reserve (ANWR). It turns out that even if one obtained permission to explore the Arctic Wildlife National Reserve and did find oil there, the kind of difference it can make is hardly discernable on total U.S. supply (Figure 2). You can barely see the effect ("Alaska II") out in the year 2020, but it's there, and it's touted as an extremely important option by protagonists. But how important is it compared to changing automobile fuel efficiency from twenty-eight miles per gallon to, say, 38 miles per gallon over the next 15 years? Well, ANWR, even if it were successful, turns out to be almost minuscule compared to that one option of using innovative technology on the demand side.

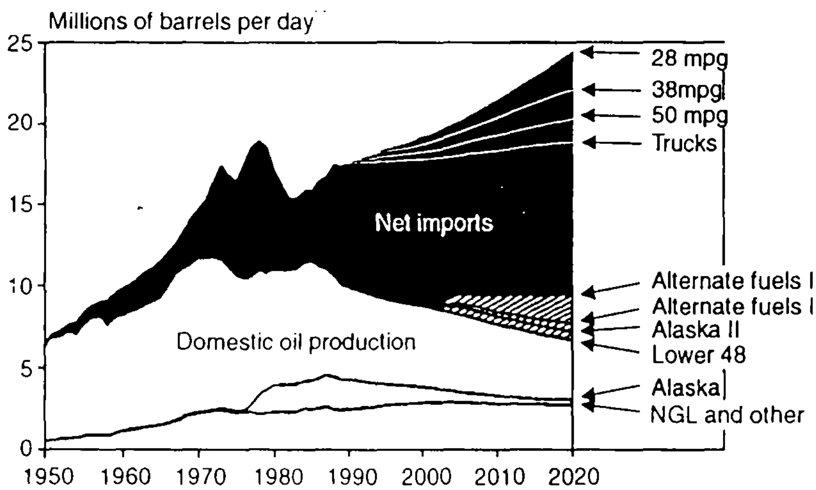

FIGURE 2. U.S. oil supply and demand futures, impacts of improved domestic oil supply and fuel economy, and oil backout. Source: Office of Technology Assessment 1991.

The big argument between Congress and the Administration is that the Administration wants to open up the Arctic Wildlife National Reserve but do nothing about fuel efficiency. And so the argument is taking place about whether or not to include both of these options in the legislative package or to take one versus the other.

One national energy question that emerged from this situation is whether the nation, for a variety of reasons, would like to hold our imports of oil to no more than 50 percent of consumption. This idea has been espoused by both the Administration and the Congress as being a worthy goal. The only question is: How do we do it? What do we have to do to get there?

Our conclusion from detailed analyses is that we would have to work very hard on both the supply and demand sides. Furthermore it seems imperative to do what one can in foreign policy to diversify the sources of oil beyond the Middle East. Of course, there's a big problem with this idea, as three-fourths of all the oil resources we know about are in the Middle East. So we have to be careful about how optimistic we can be about expanding and diversifying the sources of oil, and rather think much more carefully about what we can do in developing alternative fuels through use of natural gas and renewable resources.

Another observation is about our energy efficiency goals. It's interesting if you look at the ratio of energy consumption per unit of Gross National Product (GNP) produced; it was consistent from about 1952 all the way up to about 1976, and then with the change in oil price and the price of energy including some of the external costs, such as environmental pollution cleanup, efficiency began to improve and the amount of energy it took to produce a unit of GNP fell rather steadily through the late '70s on through the middle '80s till about 1986 or so when it leveled off, and in fact, it's now getting worse. Fuel efficiency of new cars, for example, is dropping. Generally the long-term trend to higher efficiency that began in the early '70s has begun to level out, and yet we know technically that efficiency can keep improving by at least another factor of two.

So one national goal one might derive from this situation is that, if we chose to, we could increase the efficiency of energy use by probably 15 to 20 percent per decade. And that might be an interesting national goal for us to set out over the next, say, one or two decades: to continue that trend of using our technological smarts to become a much more energy-resource-efficient economy. Such a goal would have a number of ramifications then in terms of specific policies and research and development priorities and the like.

Finally, if one looks at electricity use per GNP, you see a different interesting situation. In this case, up to about 1970 electricity use grew much faster than GNP; then it leveled out as the price of electricity stopped falling and the ratio has basically been constant ever since the early 1970s.

Again, because the goods and services that are obtained with the help of electricity are so influenced by new technology, one can continue to improve, we believe, the amount of goods and services provided by electricity without having to actually increase the electricity supply all that much. And so one national goal might be to profitably maintain this recently developed condition; to ensure that electricity use grows only at about the rate of GNP. We believe there are good reasons to say that this can in fact be done.

Is such a goal both desireable and achievable? The answer is probably yes, if we're serious about it. We see things beginning to happen in a variety of ways. The deregulation of electricity generation and the allowance of rate of return to utilities for making investments on the demand side of the meter are causing a lot of utility investment now to flow to the demand side.

Exponentials and Sustainability

My last theme is a bit more blue-sky, it is *demography and long term transitions*. I was amused by a comment of Kenneth Boulding, the economist, who once said that "The only people who believe that you can have exponential growth in a finite system are economists and other madmen."

Here are some of the facts. World population growth is exponential. The exponential growth rate of resource use, for example of iron ore, is even faster than population growth because multiplying growth rate of population times economic growth rates gives an even faster exponential. Those are both long-term unsustainable rates of expansion in a finite system.

What do we do about it? One thing is we can work on trying to transform exponentials into constants, especially the ultimate driving force, namely human population. There is a lot of optimism that with luck and hard work, world population can level off sometime in the next century. Where it levels off and the rate at which it moves to that condition, though, is a very contentious matter, one that's not being given the attention it merits, but one that ultimately has a very, very important impact on the future of our planet...including people.

You usually see the population curve bending over with a negative slope sometime out in the future. Right up to now it still looks like a pure exponential but if you look at the margin—at the birth rates, for instance, in Mexico and in other advanced developing countries—there is cause for optimism that we're finally beginning to see a turn.

There is more evidence that our projections of the future are becoming less exponential and more like saturation curves. One example is called the NERC fan (Figure 3) which is an annually updated long-term projection of electricity demand. Each year the long-term projected demand has been dropping and following much closely the curve of what actually happened.

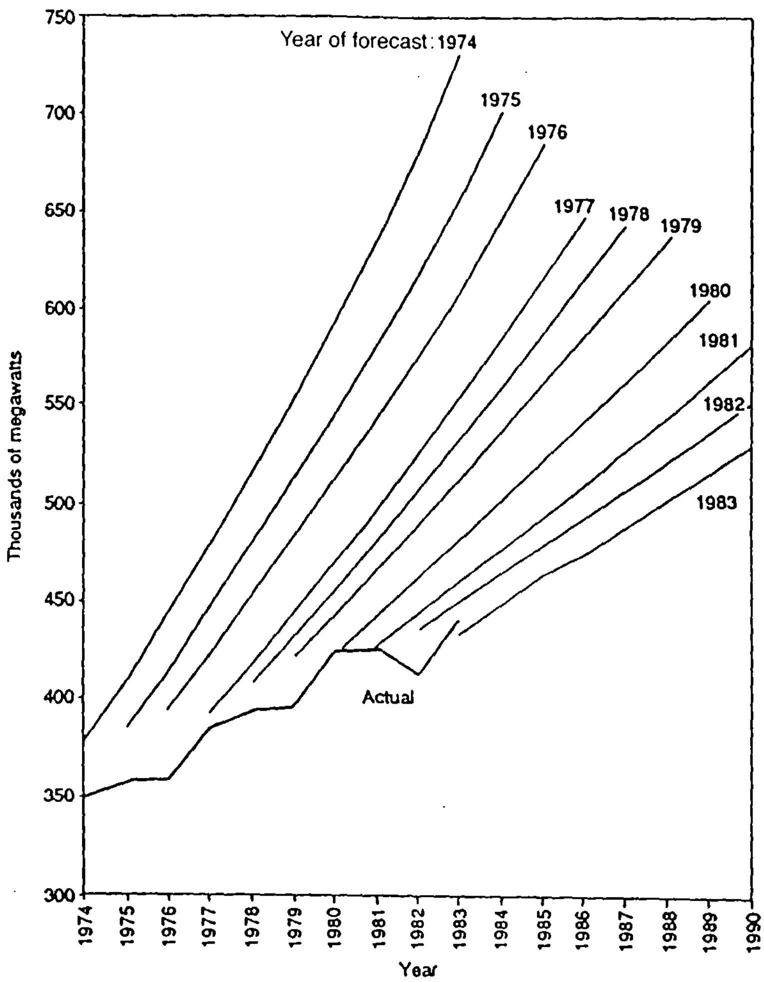

FIGURE 3. Summer peak demand projections comparison of annual ten-year forecasts Nerc-U.S. Source: North American Electricity Reliability Council, Annual Electricity Supply and Demand Reports.

So there seems to be some evidence that we're moving from an exponential world into a world that might be classed as one that's more sustainable.

Well, you can simplify this thought to an identity that describes the relation of "pollution," whether it be global greenhouse or some other form of pollution, to both population growth and economic growth in terms of an identity:

$$\text{Pollution} \equiv \underset{\text{(Technology)}}{\frac{\text{Pollution}}{\text{Energy}}} \times \underset{\substack{\text{(Technology,}\\ \text{Market Basket)}}}{\frac{\text{Energy}}{\text{GNP}}} \times \underset{\text{(Economy)}}{\frac{\text{GNP}}{\text{Population}}} \times \underset{\text{(People)}}{\text{Population}}$$

The first term in this identity is *pollution per unit of energy*, and that, of course, reflects the way you make energy, whether in a nearly pollution-free way or in a very polluting way. So that term is very influenceable by the application of technology.

The second term, *energy per GNP*, relates to the market basket of the services and goods that we choose to provide with our resources (including energy). We have moved to a much less energy-intensive market basket over these past 20 years. But there are many more things one can do there and especially in the substitution of technology for energy. For example, a microprocessor now works in your automobile which automatically makes it more efficient, and therefore you use less energy while you still have horsepower.

The third term is basically *per-capita economic growth*, which one would presumably try to keep growing. And the last term is *population*. Certainly that is the most fundamental long-term driver we have in this identity and one that we can ill-afford to ignore any longer, because population dynamics, barring catastrophe, are very slow to change.

All this translates to two kinds of ways of viewing the future: one is an exponential world, that's the world we try to live in now. Nowadays, if you talk to people about introducing just ten percent more efficiency into our energy system, the response is, well, that's all fine and dandy, but all that does is take you down to another trajectory that'll get back up to the same energy demand in a few more years. So all you've done is buy a little time. That's the inevitable consequence of an exponential world. It is not sustainable.

If, on the other hand, the world is moving toward a sustainable condition, following the so-called S-curve that any life scientist is quite familiar with, that same translation of higher efficiency in the system leads not to just a gain of a little time, but to a gain in terms of the resources required at any time in the future to sustain ourselves at a given level. So a notion, then, of a non-exponential future becomes more and more imperative if we think about these transitions that we must be going through over the next 25–50 years.

Thomas Jefferson once said that "Sometimes the right direction means a change in course." And it seems to me that such a change in course is what we as a people now must seek. Meanwhile, we're faced with two kinds of forces of governance throwing us around. In physics jargon, they are the centrifugal forces that throw us outward, and centripetal forces that pull us inward.

In political terms, the centrifugal forces move us toward the imperative for a new world order, for an integrated global economy and arms control, for managing stratospheric ozone and our global atmosphere—those things that, in other words, throw us toward international arrangements.

And then there is the other force that pulls us inward: our loss of confidence in central government, a tragic loss of a sense of nation. This tends to pull us, for economic or political or even cultural reasons, backward to boundaries that are almost tribal in nature, and you can see this happening in Eastern Europe now, but also in our own culture.

Well, what is that new world order that we now seek but only dimly perceive? Was George Orwell right, that we need some perceived external threat so that we can work together on common causes? I would fret and worry if that were the case, but it does seem that as external threats disappear, we seem to encounter an acute shortage of the kinds of forces and rationales that keep us together as a nation, as a people.

What is the role of technology in this kind of uncertain future? Can we provide new options that will assist the world in moving toward a long-term sustainable future where we can grow, but in ways that are somewhat different from the way we used to think about growth? We have an urgent impulse to do something, but I wonder if we have the knowledge base to do it. A seventeenth century historian once said that "Zeal without knowledge is like fire without light." Well, at least in Washington, there is a lot of fire, but I'm not sure how much light.

Recall that James Madison said that "A popular government without popular information or the means of acquiring it is but a prologue to a farce or tragedy, or perhaps both. Knowledge will forever govern ignorance, and a people who mean to be their own governors must arm themselves with the power that knowledge gives." OTA, we hope, is an example of that kind of experiment in participatory democracy that does give people, including our elected citizen governors, access to power. But we are sobered by the reality of politics. It was Victor Hugo who said, "Science has the first word on everything and the last word on nothing."

Grace or Good Works? Reformation of Science & Technology in the 1990s

Throughout this century, we have experienced dramatic changes in social structures, political regimes, and industrial development—in many ways driven fundamentally by scientific and technological advance. These changes have become so pervasive and profound that they now compel a reformation of science and technology. A comprehensive rethinking of how and why they are practised is needed if we scientists, engineers, and science and technology policy makers hope to play a robust role in the Twenty First Century. In the United States, we have initiated some needed reforms despite, I would say, Machiavelli's warning:

> There is nothing more difficult to plan, more doubtful of success, nor more dangerous to manage, than the creation of a new system. For the initiator has all the enmity of all who would profit by the preservation of the old institutions and merely lukewarm defenders in those who would gain by the new ones.

Let me describe, briefly, why I am nonetheless optimistic about our opportunities for success.

Past is prologue, and the course of science and technology in this century reveals them to be, on the whole, extraordinarily positive forces for change. We leapt into the Twentieth Century with electricity from the dynamo, and have continued at a stunning pace. Advances in aeronautics, information technologies, and molecular biology, to name a few, have helped to create enormous wealth, to enhance access to people, places, and ideas, and to eradicate disease and improve health. Besides all of this advance in technology, Louis Thomas has aptly observed that perhaps the greatest discovery of the Twen-

Zuckermann Lecture presented in London, 3 December 1993.

tieth Century is the discovery of the extent of human ignorance. Scratch any surface of the known world and you will quickly encounter the unknown. As scientists, engineers, and technologists, we therefore confidently anticipate similar displays of the tremendous power of science and technology to help achieve human ends for as long as bright, inquiring minds receive the support they merit.

But some people, influential leaders among them in the U.S., UK and other industrial countries, do not share that extent of confidence. Some argue that nations have blindly followed a course mapped out by the practitioners of science and technology rather than using science and technology to reach destinations defined by common values. For example, some view nuclear energy with great ambivalence and fault science for failing fully to anticipate its negative consequences. Some believe that the global economy created by advances in transportation and communication technologies has vastly increased the distance between the "haves" and "have nots" of the world. They also wonder whether, with the end of the Cold War, science and technology can be transformed to not only push back the boundaries of ignorance, but also to address newly prominent concerns such as loss of real income; mounting debt and trade deficits; unemployment; inequities in health care; burgeoning population; and global environmental degradation.

Scientists and engineers must address these concerns. Our contributions to security, the economy and quality of life have been recognized and rewarded for several decades at least. We do not, however, enjoy an indefinite state of grace. We must constantly earn our salvation, which comes in the form of generous support for basic and applied research and development. We must earn that salvation by contributing to the felt needs of the societies in which we live. We must articulate a vision that more convincingly links science and technology to national and international goals. A better defined trail that leads from the laboratory to real-world concerns can help to capture the enthusiasm and support necessary to bring the potential of science and technology to fruition and to renew a commitment to pursuit of knowledge as a societal good innovative of itself.

In the United States, we are entering this reformation with, I think, substantial momentum. Our history, like that of the UK, is replete with appreciation for science and technology. This struck me forcefully yesterday as I wandered through the halls of the Royal Society, noting that at every turn were the great heroes of English S&T history. Immediately following World War II, we in the states adopted a policy for basic research, which was described by its principal author, Vannevar Bush: "Progress in the war against disease depends upon a flow of new scientific knowledge. New products, new industries, and more jobs require continuous additions to knowledge of the laws of nature, and the application of that knowledge to practical purposes." Similarly he says; "Our defense against aggression demands new knowledge so that we can develop new and improved weapons. This essential new knowledge can be obtained only through basic scientific research." If you think back, until World War II the United States had borrowed much of its basic research and technology, primarily from Europe. But the advent of the atomic bomb, radar, nylon, synthetic rubber, computers, and a host of other products demonstrated the power of fundamental research when combined with engineering skills and vision, and convinced us as a nation that we could better secure our nation's position of leadership by making our own sustained investments in science.

Our commitment to Vannevar Bush's premise has been maintained over the years. The tension between mission agency needs and the need to ensure the overall strength of the research base has waxed and waned in response to events internal and external to the nation, including Sputnik, problems in our cities, the energy crises and others. We find ourselves in the 1990s, however, more firmly convinced than ever before that the research base is a critical component of the S&T enterprise, which is absolutely essential to the existence and maintenance of a modern state. Our history of support for research directed toward economic improvements is even longer than our history of support for fundamental research. Beginning with the request of President Thomas Jefferson to the Lewis and Clark expeditions to explore the west in the early nineteenth century, the Federal government has supported research and exploration that contributed to the development of our nation's economy. The Geological Survey and the National Bureau of Standards were established to serve the needs of private resource exploitation and industrial development. The Agricultural Extension Service and Land Grant colleges begun in the mid-nineteenth century were both a public and private means of developing a long term sustainable economy. The Atomic Energy Commission was created to make the benefits of nuclear technology available to industry, agriculture, medicine, and the electric utilities. The Government's National Advisory Committee for Aeronautics (NACA), the predecessor of NASA (National Aeronautics and Space Administration), played a major role in the expansion and commercial success of civil aviation. Most recently, long-term federal support of research in molecular biology has begun to pay off in diverse areas of biotechnology.

In many ways, it appears the deck is stacked and the future secure in favor of continued support for science and technology by our government. But there are wild cards, particularly national debt, that can trump what looks to be a sure hand. Over the last decade, 80 percent of Americans experienced a loss of real income. Our federal debt, which grew by leaps and bounds over now about 60/40, military to civil. We intend over the coming four years to change that ratio back to its more historic ratio of about 50/50 which obtained during the post World War II years;

- adopting fiscal and regulatory policies that generically promote innovation and investment in our society;
- investing in education and training, not only during the formal school years but in the school-to-work transition in our adult years, because all of us, especially younger people, will probably go through four or five different jobs during their adult years, it is important to have great versatility to respond to a changing job situation; and now, more than at any in our past, other time;
- supporting critical transportation and communication infrastructures; a public investment that in turn enables the private sector to flourish.

We are using information technology, investment in energy efficiency, and reform of procurement policy to demonstrate the utility of science and technology in making government itself more streamlined and user-friendly. We are fighting hard to protect the federal investment in R&D from the budget-cutting ax, advocating the importance of investing in our future even as we cut into the overall deficit. I am pleased to observe that the same kind of protection seems to happen in the UK. We are trying to fence off these budgets from the kind of fiscal pressures that are going to have to be maintained in our public budgeting.

We believe, though, that our R&D investment portfolio must adapt to changing times. Defense build-up and a 40-year focus on Cold War scenarios must now yield to a new force structure reflecting changed world conditions, to foreign policies that aim more directly at the underlying causes of conflict and to an increasing emphasis on civilian sector programs. Historical Federal agency missions must give way to evolving national goals. Success in establishing new funding priorities requires a Presidential mandate and close co-operation between the Administration and the Congress, as well as between the public and private sectors. So to this end, President Clinton established by Executive Order two new institutions of governance: the National Science and Technology Council and the President's Committee of Advisors on Science and Technology. These are being created to help us better guide and use the power of science and technology as a public instrument.

To coordinate and shape the federal investment in science and technology, the President has established the cabinet-level National Science and Technology Council (NSTC)—the first and most important step. This Council, which is directly analogous to the National Economic Council, the National Security Council and the Domestic Policy Council, was recommended by the Reagan and Bush years, is now so large we're no longer simply mortgaging our children's future, it's become a multi-generational affair. The U.S. lead in many sectors of the international economy has steadily diminished. The public we call upon for support wants to know: Where were science and technology while this was happening? Can science and technology help resolve these problems?

Faced with these questions, and with no cold War bogeymen to create distractions, I believe that scientists and engineers must take an active part in re-establishing the social contract. We find ourselves smack in the middle of the predicament described so well by Antonio Gramsci: "The crisis consists precisely in the fact that the old is dying and the new cannot yet be born; in this interregnum a great variety of morbid symptoms appear." As assistant to the President for Science and Technology, and as Director of the White House Office of Science and Technology Policy, I have been given an opportunity to initiate changes of governance that are intended to maintain support of science and harness technology for national purposes; in other words to relieve those morbid symptoms, as we move through the great interregnum.

President Clinton and Vice President Gore clearly stated recently that this Administration intends to direct S&T toward certain definable goals:

1. Long term economic growth that creates jobs and protects the environment; environmental protection and economic growth are not necessarily antagonistic as many people have posited.
2. Maintaining world leadership in basic science, mathematics, and engineering.
3. Making government more efficient and more responsive to its clients. That translates, in the White House, into an announcement to me three weeks after I arrived that in the name of efficiency my office would include the functions of the National Space Council and the National Critical Materials Council all folded into the OSTP. At the same time I was to endure a 25 percent reduction of resources. The hard lessons begin at home; while it does focus the mind, it wears out the body a bit.

We recognize science and technology as fundamental underpinnings of our nation's future. Thus, we intend to use science and technology to stimulate economic recovery and economic growth by:

- more directly supporting the development, commercialization, and deployment of new technology; i.e., to no longer simply depend upon serendipitous spin off from military research and development, but rather spend more of our resources focusing on the civil side of the equation. Of our total federal R&D budget, which amounts to about $76 billion, the ratio of that expenditure in military versus civil sectors is the "Reinventing Government" study led by the Vice President. Its establishment also has bipartisan, bicameral congressional support. So we are very optimistic about the opportunity that this provides. The President chairs the Council, which will include the Vice President, Cabinet Secretaries and agency heads with responsibility for major science and technology programs, and key White House officials. The Council will have several functions:

- Coordinate the science and technology policy making process.
- Ensure science and technology policy decisions and programs are consistent with the President's stated goals.
- Help implement and integrate the President's science and technology policy across the Federal Government. As you know, many of these programs are embedded in a variety of agencies and this can create an integrating structure across those agencies.
- Further international cooperation in science and technology, an issue of importance to us all.

One of the most critical tasks the NSTC will undertake is preparation of an integrated overview of federal spending on research and development. The Council will prepare coordinated R&D budget recommendations for accomplishing national objectives. At present, we contemplate the Council working through probably nine Committees. These have not been formally established, but I thought I would mention some of them to you so that you have an idea of how we are organizing ourselves. The Committees will be formed to reflect the notion that technology, like energy and many other things, have value only in terms of the way they reflect and respond to overarching national goals.

- Food, Health, and Safety R&D
- Fundamental Science and Engineering Research
- Communication and Information R&D
- Environment and Natural Resources Research
- Civilian Industrial Technology R&D
- Education and Training R&D
- Transportation R&D
- National Security R&D
- International Science, Engineering, and Technology

These areas of emphasis reflect the Administration's commitment to aim its long term S&T investments more directly at national goals, in conjunction with agency missions and the Federal Government's investment in research and development. The Council will also oversee key specialized initiatives. For instance, the so-called Clean Car Initiative that was recently announced falls within the scope of the NSTC's work on civilian industrial technology. Ad hoc working groups of the NSTC will also address issues such as space launch policy, convergence of military and civilian weather satellite capabilities, and the need for infrastructure renewal in our universities.

The President has also established, as I mentioned, a new President's Committee of Advisors on Science and Technology and this re-established traditional group will ensure private sector advice to the NSTC. Private sector involvement with the S&T Council via this advisory committee will be essential to developing public policies and activities in science and technology that will help American businesses achieve sustainable growth and help create high quality jobs, as well as to maintaining our academic and research institutions' world leadership in science, engineering, and mathematics. The Advisory Committee will be comprised of distinguished individuals from industry, education and research institutions. The Clinton/Gore Administration has premised many of its plans for national revitalization on the concept of public/private partnerships. Our goal for this Advisory Committee is to help devise those partnerships and to make them work successfully. We will rely on the Advisory Committee to establish links to the private sector necessary to help steer federal investments and policy decisions in science and technology toward national goals.

With the help of these new institutions, I believe the Administration can improve the overall effectiveness of federal science and technology investments and policies for national and global objectives. We hope in part to remedy the dilemma framed so eloquently here by Edna St. Vincent Millay. In a long poem she wrote, the title is "Huntsman, what quarry," a fragment goes as follows:

> "Upon this gifted age, in its dark hour,
> Falls from the sky a meteoric shower of facts.
> They lie unquestioned, uncombined.
> Wisdom enough to leach us of our ill is daily spun
> But there exists no loom to weave them into fabric."

The NSTC provides a framework in which to prioritize the many legitimate demands on the public's R&D dollar. It assures a forum where critical national needs cannot readily be pushed aside by urgent and parochial agency needs in the competition for resources. It can sensitize agencies to the advantages of symbiosis, over the isolated pursuit of narrow objectives so readily encountered in agency focused activities.

Given the degree of interaction contemplated between public and private sectors in this endeavor, we may approach closure on the issue of whether "positive externalities," for example pollution prevention or enhanced security, justify the use of government funded S&T in pursuit of economic goals. We may answer at least in part the question of whether projects like the Clean Car Initiative engage the government too closely in private sector affairs, or whether they denote continuation of the traditions of the Morrill Act of 1862, which created the agricultural research system, one of our great scientific and economic success stories. Is it appropriate for the government to help assure that the economy proceeds in an environmentally sound fashion just as it helps assure a safe adequate food supply and a common defense? It appears that division of responsibility between the public and private sectors is determined more by history, tradition, and political muscle than by attempts to calculate an investment's contribution to general health and welfare. We know as a historical fact that public investment in research has an unpredictable but consistently large payoff. We intend to focus much of our effort on shifting the terms of debate to the latter perspective.

Even without the new S&T Council and the President's Advisory Committee, we are beginning to overcome the inertia of the situation the Clinton/Gore Administration inherited. For example:

- We've forged the Clean Car Initiative, a historic alliance with the nation's big three auto-makers to develop the generic technologies that can enable a new generation of high performance cars and trucks that are attractive and affordable, highly fuel-efficient, and virtually pollution free. As one CEO described it, our aim is to try to take the car out of the pollution equation. This 10-year technical collaboration with industry is a huge technological challenge, in a sense an Apollo mission on the ground, but could mean huge payoffs for all parties in terms of environment, petroleum import dependence, resource efficiency, and good jobs.

- We've reorganized the Advanced Research Projects Agency (ARPA) at the Department of Defense and launched the Technology Reinvestment Project (TRP) to stimulate the public and private sector transition from defense to dual use technologies that have both military and civilian applications. The TRP, led by ARPA, is a fully integrated effort by six government agencies working, as it were, as a single team. President Clinton has already announced the first 41 awards under this program. We received proposals from teams representing more than 12,000 companies, universities and local governments. Significantly, the proposals offering over $8.5 billion in matching private funds and they were received in competition for a federal program of $470 million. Now, of course, one has to be careful in how one offers, and the expectations of, public sector assistance to the private sector. I once

> lived in Tennessee and there was a story of two deer hunters who were dragging a deer they had just killed back through the bramble woods, they were having great difficulty because of the brambles and out of the shadows stepped a person who said, "Gentlemen, I've noticed your problems here at getting through the woods with that deer. I'm from the government and I'm here to help you. So I note the way you are dragging the deer by the antlers. If you were to take the deer by the other end you would overcome your problems." Well they thought for a while and they decided to take up the man's advice, so they picked up the deer by the other end and started to walk along. One hunter said to the other, "You know that fellow was right, we're moving a lot faster through the woods now", and the other hunter said, "Yes, but do you know we're getting further and further away from the car."

So we do have to remain goal orientated and check our progress by various means as we try to move along.

- At the National Institutes of Standards and Technology (NIST), under the Department of Commerce, despite a very tight federal budget we've expanded threefold the funding in 1994 for the Advanced Technology Project (ATP) to promote industry's development of high-risk, high-payoff commercial technologies. This is not dual use, this is innovation in the market place of high technology. ATP explicitly abandons the outdated emphasis on spin-offs from military R&D as the basis for subsistence and focuses directly on the objectives of civil sector economic growth. Mind the deer hunters again! It requires matching funds, a market-orientated management plan, and consortia efforts. Awards are made via competitive, peer-review.
- We've initiated a network of manufacturing extension centers across the nation to work with state governments to assist small and medium-sized manufacturers, many of whom are still using 1950s technologies. These centers disseminate to manufacturers information on new technologies and best practices.
- We've decided an action plan for the National Information Infrastructure. This infrastructure—computers, computer data banks, fax machines, telephones, video displays, wide band of networks—has as its lifeline a high-speed fiber-optic network capability. The technology is improving at an unprecedented rate, expanding both our imaginations for its use and its effectiveness. Of course, the technology is moving so rapidly that it is difficult to think what can be a sensible set of governmental regulatory policies that can assure access capability and inter-operability and competition in that system. That is one of the

tasks before us; to see if we can catch up and get beyond the copper cable, as we think how to regulate and have a fair competitive environment for this extraordinary technology. The federal role is not to go out and lay cable, but rather to enable that process to occur by making favorable fiscal and economic regulatory policies. The role we see for the government is to be a user; to experiment at the end of such a highway and to make effective use of this new technology for public sector services as well as private.

While federal technology programs are important, they cannot succeed without change in other government policies. Many existing fiscal, trade and regulatory policies stymie rather than encourage investment in new technologies and new products. The Administration intends to change that. Already we have cut our deficit spending, which in turn we hope will maintain low interest rates and therefore more patient capital. We are downsizing some of our agencies with a goal of over 260,000 fewer civil service jobs over the next four years in addition to military downsizing. We feel that cutting of the deficit is so fundamental to achieve our ends here and now and also to lay a framework under which we can look forward to a resilient future. I should mention my new theorem called "The Rule of Holes." That is, if you're in one, the first thing you ought to do is stop digging. That is why we have continued to say we were going to stop digging the debt hole we have been digging for a dozen years. But it takes more than stopping the digging. It also requires an ability to climb out of the hole and that rationalizes the investment in other strategies that will enable us to pull out of the hole, for example:

- We achieved a three-year extension of the Research and Experimentation (R&E) tax credit, and we're still working to make a permanent tax credit. In other words to provide gained investments to those who are willing to make these kinds of investments in the private sector towards future products and services. We've also secured a reduced capital gains tax for investments in small business.
- Liberalized export controls on computers, telecommunications, and other technologically sophisticated equipment. Once held up in the name of Cold War, the process has only just begun, we hope to have trade liberalization in the months ahead.
- Aggressively pursued bilateral and multilateral trade agreements such as NAFTA, US-Japan, and the Uruguay Round of GATT that will expand access to foreign markets for America's high-tech companies. Approval of NAFTA by the Congress, I believe, is a major step forward in this victory in the quest to increase competitiveness in world markets.

I must say that I think my boss stepped out on a pretty long limb when he crossed swords with many of his long standing supporters in order to champion this cause and I was greatly relieved that he won.

- Announced major changes in federal purchasing and procurement practices to make government a better, smarter customer for commercial goods. We hope to substitute for many of the past times in which we had military specs that cause companies to have to have two different lines of production: One to satisfy military specs the other to compete commercially with virtually the same product.

The force pushing commercialization closer to the leading edge of research, that is the drive for international competitiveness, reinforces the conviction within government and industry that we must maintain a strong base in foundational science and engineering research. Among the many factors that have influenced industry's perceptions of basic research, perhaps the rise of biotechnology has done the most to persuade them to strengthen their links to academia. Industry and government depend on the universities to train people and to do fundamental research, so we have committed to support them. The Clinton/Gore team has identified world leadership in science, mathematics, and engineering as a primary goal of the Administration. In San Francisco, I talked to some CEOs in biotechnology. They underscored to me the absolute importance of continued federal support for fundamental research. They alleged that had it not been for that research support in molecular biology and the later accommodations as this information began to move, that the entire industry, which is now only at its early flowering, simply would not exist.

But this does not mean that basic research escapes the requirement of reform. We have run up against limits on resources even as many basic research projects grow bigger and more expensive. Worldwide access to research results causes national governments to question whether they're supporting more than their fair share of the world's basic research and generic technology development. Thus, particularly in a time of seriously constrained resources, we must shake off the expectation that science budgets will consistently and indefinitely expand more rapidly than economic growth. As Herb Stein, a noted economist cogently observed, "That which cannot go on forever, must come to an end." A lesson to those who do not understand the exponential. We must not recoil from the need to make merit-based choices among worthy projects, but we need to agree on some ground rules for the triage. I suggest that, especially for large projects, we need to look not only at the intellectual excitement the proposal arouses among peers, how much of a floodlight can it be, as well as a search light, but also the project's potential contribution to the rest of science and its broad relevance or potential contribution to the nation—to the nation's goals that transcend the agreed goal of pushing out the frontiers of ignorance.

Though my last criterion, i.e. of potential contribution and relevance to national goals, is still the subject of much debate, I believe science can be more responsive to national needs without compromising excellence or creativity. One way to do that is to give more encouragement to multi-investigator, multi-disciplinary efforts. Such an approach favors a problem orientation that often lends itself more readily to "relevance" than does strict disciplinary research. Accommodating this type of research requires reform of some long standing mechanisms for research funding. I will never forget my first interdisciplinary proposal to the National Science Foundation which carefully brought together a number of disciplinary things into a coherent whole, which I was convinced was greater than the sum of the parts. I found out later that when it arrived at the NSF the first thing they did was separate each of the chapters and send out each one to different reviewers.

The squeeze on resources, combined with the inherent nature of some science and technology projects that drives up their cost and complexity, also forces us toward greater internationalization of science and technology projects, particularly "Big Science" but all of science to some extent. It grows harder and harder for any single nation to justify projects such as mapping the human genome, developing fusion power, exploring space, or rooting out the mysteries of the "Big Bang." At the same time, financial and political barriers limit any one nation's ability to deal with complex comprehensive problems for which science and technology can offer important contributions, such as global climate change or human population growth. We require better mechanisms for multinational planning, cooperative decision-making, and decade-length commitments. We intend to explore efforts in joint planning for one-of-a-kind research facilities, creation or more formal international networks in selected fields, networks capable of negotiating agreed divisions of labor, and development of more multinational research mechanisms.

Internationalizing science holds great promise for decreasing the huge economic disparities that exist among nations. Yet issues such as who pays, who participates, and location, among others, can be so difficult to resolve that the ill-will threatens accords outside the S&T arena. There is an inherent tension between scientific cooperation and economic competition as science grows ever closer to economic performance. Improving our ability to manage such complexities, including the ability to make longer term commitments of resources, will be an important focus of the National Science and Technology Council and my office which will be a part of it.

Many scientists fear the political tide has turned on them. They sense a sea change, driven by hard economic times, the end of "evil empire," and, perhaps, some disillusionment about the golden promise; and they know of no safe harbor. However discomforting all this may be, I believe we should accept these changes as challenges, not as threats. The emphasis of strategic paths for science and technology does not deny the importance of basic research. Rather, it encourages scientists to join the national attempt to articulate the proper role for S&T in achieving the goals implicit in those values.

People want a sustainable future. They want a growing economy with more high-skill, high-wage jobs; a cleaner environment where energy efficiency enabled by technological ingenuity increases profits and reduces pollution; a stronger, more competitive private sector able to maintain leadership in critical world markets; an educational system where every student is challenged to reach his or her full potential; national security reflecting a world that has been made safe for diversity; and an inspired scientific and technological research community focused not just on ensuring our national security but also on increasing our intellectual capital and improving our quality of life. Scientists and engineers can help enunciate the vision that replaces Cold War dominance and chart the course for science and technology in realizing that vision. The challenge is daunting, it makes the defense business look simple by comparison. But challenge is the very sustenance of innovation and research, so we should welcome it.

As I noted in my opening, I have reviewed Realizing Our Potential, and find it parallels, in many respects, the Clinton/Gore Administration's first publication on science and technology policy, Technology for America's Economic Growth: A New Direction to Build Economic Strength, which was released in February, 1993. Both nations have identified a need for government to work more closely with industry in establishing the public's S&T agenda; and recognized the need to restructure the priority-setting, funding, administration, and management apparatus for science and technology policy and investment.

We have chosen similar paths for accomplishing our shared goals, and we are all treading new ground. We will learn by doing, and I know that we will continue to learn from each others experience. Shakespeare knew the difficulty of predicting the future when he said:

> If you can look into the seeds of time,
> And say which grain will grow and which will not...
> Speak then to me... .

However, our task is not to predict the future, but to enable it to unfold in ways that can take fullest advantage of the contributions that science and technology have to offer.

National Security Writ Large: A New Role for Science and Technology in a Changing World

The Clinton administration faces three immediate and pressing problems demanding international scientific cooperation and technological innovation. Daunting as it seems:

- we must manage the restructuring of military forces and associated industries, while helping the former Soviet Union to do the same;
- we must strengthen efforts to prevent the proliferation of advanced weapons, while working to integrate formerly Communist states into the industrialized world; and
- we must reinvigorate our own economy—for our security as a nation will derive in large measure from our global economic strength.

To start, we have been guided—and constrained—by commitment to reducing the federal deficit's "theory of holes." That is, if you find you're in one, the first thing to do is stop digging. And we have put forward a tough deficit-reduction budget. But we also have to climb out of the hole, so our new approach also strongly emphasizes investment. Despite our freeze on discretionary spending, the President's budget for fiscal 1995 increased our high-priority research and development (R & D) investment by four percent. The civilian and dual-use share of that R & D budget is up to 47 percent. And we want to bring that share to at least 50 percent by 1998.

We believe that this shift of resources toward dual use and commercial technologies will promote our national security—which brings me to the question of defense restructuring.

Paper presented before the Council on Foreign Relations, New York, March 1, 1994.

The end of the Cold War has not meant the end of conflict. Regional wars and civil strife dominate the headlines. And the proliferation of sophisticated weaponry is raising the risks and human costs—to us, and to others. In this era of shrinking defense budgets, we need to emphasize both sound technological investment geared to the post-Cold War environment, and the aggressive pursuit of nonproliferation policies.

We will rely increasingly on mobile, highly trained forces, equipped with advanced conventional weapons, which proved their capabilities in the Gulf War. To build the forces we need with the resources we have, we need to cut our investments in the technologies and machinery once needed in the Cold War, and we need a fundamentally different approach to defense acquisition.

During the Cold War, we built two industrial bases—one military and one civilian. The requirements of military contracting often prevented the Pentagon from buying cutting-edge commercial technology. And our military contractors were hamstrung in commercial competition. That is, our civilian economy could not fully benefit from our military technology base, and vice versa.

We will integrate the defense industrial base and the commercial industrial base into a single, globally competitive national industrial base. Our military forces must have the benefit of the rapid advances in commercial technology—particularly in information systems—to produce affordable and effective weapons faster, and with smaller budgets.

We are also reducing our reliance on nuclear weapons. If it was not clear before, it is clear now that their value is limited to deterrence of their use by others. For example, we are moving our weapons labs away from nuclear weapons testing, so that they can engage in more productive scientific enterprise.

In downsizing our forces, we will face the problem of excess capacity. As we consider our options, we must bear in mind that the weapons we may be tempted to sell have a way of being used against us. Balance-of-power-politics helped Saddam Hussein amass a great arsenal of weapons made in the U.S., the Soviet Union, and Europe. If we are serious about preventing future Iraqs, we will need to take a new approach to security, based on cooperative restraint in the sale of provocative weaponry. It is ironic that despite our commitment to nonviolent conflict resolution, the U.S. remains a leader in exporting arms.

In September 1993, President Clinton announced his nonproliferation initiative, including a commitment to a negotiated comprehensive test ban and a global convention banning all production of fissile materials for nuclear weapons. He offered to place our excess fissile materials under safeguards, to make clear to the world that our nuclear arms reductions will not be reversed. He submitted the Chemical Weapons Convention for ratification, proposed new transparency measures to strengthen the Biological Weapons Convention, and expanded the Missile Technology Control Regime.

That package goes a long way toward controlling the flow of weapons of mass destruction. But we must get control of the conventional arms trade as well. We plan to take on the intellectually and politically challenging task of designing a regime for controlling the spread of advanced conventional weapons, including those technologies over which we have a monopoly. My office is presently working with National Security Council, the Pentagon, ACDA, the intelligence community, and others on ways to contain the spread of increasingly lethal conventional weapons. I am personally committed to progress in this area.

As part of our nonproliferation effort, we have stepped up our assistance to the nations of the former Soviet Union in dismantling their nuclear and chemical weapons, and converting their military industries. We plan to Defense Secretary Perry , Commerce Secretary Brown, and I will send teams to Russia, Belarus, Kazakhstan, and Ukraine to work with these independent states on converting their defense enterprises to civilian pursuits.

As Russia and the United States dismantle their nuclear weapons, hundreds of tons of highly-enriched uranium and plutonium will become military surplus commodities. As a recent National Academy of Sciences study warned, these materials pose a particular danger in the FSU, where economic turmoil is fostering an aggressive criminal underground, and guards are living in poverty. At their January 1994 summit, Presidents Clinton and Yeltsin signed an agreement in which the United States will buy 500 tons of highly enriched uranium (HEU) from Russia, in order to remove HEU from this uncertain environment, and blend it down for peaceful use in power reactors.

However, surplus weapons plutonium poses a more difficult problem—and one that must be addressed in the context of the far larger global stocks of civilian plutonium, which also pose proliferation risks. The President has created an interagency group, co-chaired by OSTP, to devise options for meeting this challenge.

None of the options for plutonium disposition—from fabricating it into reactor fuel to mixing it with high-level waste now scheduled to be melted into glass logs—can begin for the better part of a decade. So the priority today is to build safeguards and secure storage for these materials.

Most urgently, we must help Russia ensure adequate security and accounting in its far-flung nuclear complex, so that tomorrow we don't find that several bombs' worth of plutonium or HEU has wound up on the black market or in terrorists' hands. No single issue is more central to the success of our nonproliferation effort, or more urgent in ensuring that we secure the peace, now that we've won the war.

The plutonium study and defense conversion efforts are just two examples of U.S.-Russian science and technology (S&T) cooperation. President Clinton has made it clear that helping former Soviet states on their rocky road to reform is a key national security priority. Trade, investment, and technical cooperation will be essential for economic revitalization, and will provide desperately needed support for the scientific community in the former Soviet states—once one of the strongest pillars of political reform, but now impoverished and underemployed.

Under the leadership of Vice-President Gore and Prime Minister, Chernomyrdin, we have agreed to a broad cooperative agenda in S&T—from fundamental science to energy conservation to space exploration. Our historic joint endeavor on the space station, for example, will mean a better and cheaper station for us, and a new future for hundreds of talented scientists and engineers for them. I co-chair the joint Science and Technology committee with Science Minister Boris Saltykov. Together we have successfully negotiated the first U.S.-Russia Science and Technology Umbrella Agreement. That agreement and its annex on intellectual property rights provide access for our scientists to a wealth of talent, information, and special resources. And they help provide Russia's scientists and engineers with improved means to contribute to the transformation of Russia's political economy and system of governance. Now that the International Science and Technology Center has finally begun its vital mission of engaging former weapons scientists in peaceful challenges, we are contemplating a civilian R & D foundation as well, to further address the "brain drain" problem.

Our international S&T cooperation is not limited to the former Soviet Union. From global climate change to fusion power, from exploring space to pursuing the mysteries of particle physics, we are encouraging international science and technology cooperation on a broad front. In the Middle East, for example, we've sought to develop new habits of cross-border cooperation on shared technical problems—such as regional water management—which might undergird the fragile peace process. I will soon convene the U.S.-China Joint Commission on Science and Technology—which we hope will be a vehicle for more productive relations, potentially allowing us to effectively address sensitive areas such as encouraging defense conversion as an alternative to arms sales. As we consider the possibilities for S&T cooperation, we must bear in mind that China is the world's fastest growing economy and India is the fifth largest. At the same time, both those countries are contestants in a dangerous regional arms race. Simply put, we cannot afford to be Eurocentric in our approach.

Just as science and technology can support economic reform abroad, so can they bolster our economy at home. Cutting-edge science and technology is essential to a cutting-edge economy. When we took office a year ago, our commitment was to grow the economy, regain lost market share, and create American jobs.

Here are a few of the things we have done so far:

- With NAFTA and GATT, we have opened markets, while protecting our federal R & D initiatives in new partnerships with the private sector. Freer trade is good for us, and essential for moving the developing world out of poverty.
- We are trimming outdated export restraints, while strengthening those that are key to nonproliferation. For example, we've liberalized export controls on computers, telecommunications, and other technologically sophisticated equipment, freeing up 35 billion dollars in high-tech exports, and that's only a start.
- We've developed an action plan for the National Information Superhighway. Linked to this telecommunications network will be high-speed computers—another critical area where our Administration has already initiated major new investments. Yet to call this information highway "national" is a misnomer: We are working toward an integrated *global* network that will be a critical catalyst for trade and ideas. We are working actively to link up the newly emerging democracies. Access to information is a tool of democracy: The role that the simple fax machine and the samizdat it produced played in fostering reform in the former Soviet Union provides a hint of the free expression the new information technologies can unleash.
- We've created the Technology Reinvestment Project, to stimulate the transition from strictly military technologies to "dual use" technologies that also have civilian applications. Already, four rounds of rigorous, peer-reviewed competition have resulted in awards worth $605 million; and industry will match these dollar-for-dollar.
- At the NIST (DOC) we've proposed a seven-fold increase, compared to just two years ago, in the budget for the Advanced Technology Program, a government-private partnership to promote industry's development of high-risk, high-payoff commercial technologies—again, on 50–50 cost sharing. And we're developing major new initiatives in science and technology education and training.
- We have targeted environmental technologies in particular—which we expect by the year 2000 will be a 600-billion dollar a year global market in emissions controls/management and pollution reduction. We have put forward a Climate Change Action Plan for the United States, and are increasing spending on research on global climate change by 24 percent.

- We renewed U.S. support for international family planning efforts. We forged the "Clean Car Initiative," to build the competitive low-emissions, high-efficiency cars of the future. Overall, we are increasing spending on environmental technologies by 11 percent this year, on renewable energy by 15 percent, and on energy efficiency R&D by 42 percent.

In all this, we are working in partnership with the private sector—particularly in targeting our applied science and technology investments. We need to insure that our manufacturers can use technology flexibly, responding quickly to a fast-moving market place while minimizing costs and wastes—what I like to call "lean, green" production.

In short, we are determined to make our Nation's preeminent scientific and technological capability truly the engine of economic growth: the ladder we can use to climb to long-term national security, economic resilience, and environmental quality.

To enable us to carry out this S&T agenda, we are reinventing the way government does business. For example, we have dropped the word "defense" from the Defense Advanced Research Projects Agency (DARPA), renaming it ARPA: (where we center our work on dual use research co-jointly with DOE, DOC, NSF, NASA, DOT). We are reforming our defense acquisitions system, and we have launched an interagency review of how the national laboratories of DoD, DOE, and NASA can best meet our new national needs.

To more effectively harness S&T for the nation's military and economic security goals, President Clinton has established the National Science and Technology Council—a virtual government-wide S&T agency. Like the National Security Council, the National Science and Technology Council is chaired by the President, and includes the Vice President and the relevant cabinet secretaries and agency directors. OSTP serves as its secretariat and I am the Assistant to the President responsible for its coordination.

The Council is structured to make science and technology policy across agency boundaries. The President will also establish a revitalized science and technology advisory committee President's Committee of Advisors on Science and Technology (PCAST) with a new emphasis on government-private partnership in promoting our science and technology objectives. Let there be no doubt: President Clinton and Vice President Gore recognize science and technology as the key to the kind of future we yearn for.

In the last half-century, science and technology have produced amazing accomplishments in the free world. We have unraveled the mysteries of our chromosomes, doubled the efficiency with which we use energy, transformed the world with information technology, and built the finest fighting force our nation has ever seen. Though the challenges we face now are dangerous and daunting, I am full of hope that science and technology, correctly applied, can help us meet them.

The French mystic, pilot and author, Antoine Saint-Exupery wrote: "As for the future, your task is not to foresee, but to enable it." This government hopes to pursue science and direct technology to that end. But, ultimately, science and technology can only provide options. It is the purview of governance and the market to transform options into actions for as Victor Hugo observed, "... science says the first word on everything and last word on nothing ...".

Envisioning the Future of Science and Technology

Goals for Investment in Science and Technology

As enunciated by the President in his first month in office, our science and technology policies and programs are directed toward three basic goals:

- Long-term economic growth that creates jobs and protects the environment.
- Making government more efficient and more responsive.
- World leadership in basic science, mathematics, and engineering.

Government is an essential actor in making sure science and technology help us reach our goals. Many of the benefits science and technology confer are in areas that are either outside the market or imperfectly subject to market forces—such things as a strong national defense, first-class education and training, improved environmental quality, and fundamental scientific research. In these areas, a strong government presence in R&D investments is essential.

A government role is also vital in promoting technologies that are critical to economic growth, the creation of good jobs, and meeting the common needs of the nation, but that cannot attract adequate private investment. In our partnerships with business for pre-commercial technology development, our cardinal rule is to use government funds only where they are essential and where the payoff to society as a whole is large. We invest government

Statement before the Committee on Science of the U.S. House of Representatives, January 6, 1995.

funds, on a cost-shared basis, where private sector investment is not adequate to the job because of unacceptably high technical risks, prohibitive cost, long payback horizons, or where the returns cannot be captured by the investing firm but spill out to competitors, other firms, or society at large.

Experience teaches us that the likelihood is that the payoff on government investments in science and technology, if judicially made, will be enormous. It is our steadfast belief that thoughtful federal spending on science and technology is simply good economic policy. Many economic studies have shown that federal money invested in science and technology brings, on average, a 50 percent rate of return to U.S. society.

Anticipating the Results of S&T Investments

The record of the past half-century clearly shows a high average rate of return on public and private investments in science and technology. Of course, we can only make educated guesses about which investments will catalyze revolutionary developments in science and technology, and we must expect some failures. One of my early mentors, Alvin Weinberg, always said "Never make a prediction until you're very old; otherwise you might live to see it not come true." But if the past is any predictor, our expectations for an excellent return on our investments are not misplaced.

In 1975, it was theAdministration's belief that for instance, emerging computer and telecommunications technologies would soon change the conduct of warfare; that continued funding of molecular biology would yield revolutionary advances in medical diagnosis and treatments; that progress on environmental pollution required major additional Federal research attention; and that technology could both quiet the noise and cut fuel consumption in airplanes. Decisions made at that time to invest taxpayer dollars in those areas turned out to be wise, for predictable as well as for unforeseen reasons.

- Public investments in fundamental research and development on information technologies did, in fact, revolutionize the conduct of warfare—both the weaponry deployed and the tools used to prevent or to prepare for war. Just as importantly, those investments changed the nature of commerce, indeed the nature of everyday life in this country. Early investments in ARPANet, the first national computer network, have brought us to the 25th anniversary of the Internet, a prototype of the Global Information Infrastructure. When it started out, ARPANet could transmit only 56,000 bits of data per second. Today, networks using technology several generations more advanced routinely transmit 45 million bits a second—almost a thousand times faster. The Federal government provided a relatively small catalyst (a few tens of millions of dollars annually) that has been matched more than a hundred times over by private-sector investment in the Internet. Today, dozens of companies are investing millions of dollars and competing to provide Internet connections and new services to the tens of millions of Internet users around the world.

- Public investments in biomedical research have, as we expected 20 years ago, improved our understanding of the root causes of many diseases, leading to better preventive and treatment techniques. What we could not predict, but benefit from nonetheless, is the multi-faceted biotechnology industry that did not exist 20 years ago. Biomedical research spawned this industry that already accounts for 100,000 jobs and $8 billion in annual sales. We owe incredible advances in agriculture and in chemical and pharmaceuticals processing, as well as our ability to capture billion dollar markets in health care and other industries, to fundamental research in molecular biology and development of advanced instrumentation funded by the U.S. government.
- Investments in environmental research and development have improved air quality, moved us toward our goal of "fishable, swimmable" waters, and, as science often does, revealed unanticipated impacts of human life on the natural systems that support us. Twenty years ago, for instance, we determined a need to understand the impacts of emissions of anthropogenic chlorine, bromine, and fluorine on stratospheric ozone. Today we know unequivocally that the ozone layer is being depleted because of human activities. This knowledge has led to international agreements that limit the production and use of ozone-depleting chemicals. At the same time, advances in technology have resulted in cost-effective substitutes that do not degrade the ozone layer. Because of the research and early detection of stratospheric ozone depletion, technological response has enabled us to largely avert a major global health problem while still providing the benefits of air conditioning, refrigeration, and other necessities and amenities that once depended on ozone-destroying chemicals.
- Twenty years ago, civilian jet airliners were powered by fuel-guzzling turbojet engines that polluted the environment and disturbed people living near airports and under airline flight paths. Today, thanks to NASA research in combustion, turbomachinery, lubrication, aerodynamics, acoustics, and materials and structures, those airliners are 50 percent quieter, 25 percent more fuel efficient, and emit less than half the atmospheric pollutants. Many NASA-developed technologies have been incorporated directly into the current commercial turbofan

engines, helping U.S. manufacturers attain world leadership in technology and market share.

One could reasonably say that we got even more than we bargained for from the government's S&T investments of 20 years ago. They were strategic, meaning they were thoughtfully directed toward goals such as national security, high quality health care, and environmental quality. And, in hindsight, they were more than fully successful.

Administrative Investments in the Future

I am confident our successors in governance in 2015 will be able to say the same about many current S&T investments—if, that is, they receive adequate financial support, both public and private. The Administration's science and technology investments are focused on six priority areas:

- A healthy, educated citizenry.
- Job creation and economic growth.
- World leadership in science, mathematics and engineering.
- Improved environmental quality.
- Harnessing information technology.
- Enhanced national security.

I would like to describe a few of the initiatives we believe will ensure long term economic growth, a broader knowledge base to support that growth, and a better quality of life for Americans.

Technology for Economic Growth

The Administration has made a major commitment to work with the private sector on the development and deployment of advanced civilian industrial technologies, both here and abroad. Environmental technologies—technologies that enable delivery of goods and services with less environmental pollution and technologies that trap pollutants or clean up pollution—receive special emphasis in our investments. They will allow us to pursue our dual goals of economic development and environmental protection because we will be producing higher value goods and services with less energy, less waste, and less environmental harm.

During the next 20 years, U.S. industries can significantly expand their share of what is presently a $300-billion global industry in environmental technologies. The potential public and private returns on investments in environmental technologies are tremendous.

This vision of economic growth combined with protection of the environment is not unfounded fantasy. Over the past 15 years, for example, the Intel Corporation (at their Portland, Oregon, plant) has more than doubled its production of semiconductors with no increase in emissions, and no new investments in pollution emissions control technologies. Instead, they have redesigned their entire production process to make higher quality chips with less environmental impact.

Also over the past 15 years, research into more efficient wind turbines and expanding markets have reduced the cost of wind-generated electricity by a factor of eight (from over $.40/kilowatt-hour to less than $.06/kilowatt-hour) and made the U.S. the leader in global wind energy production. These changes are indicative of what can happen within a time span of twenty years and give us a sense of what is possible as we look forward to the year 2015.

Alan Kay at Apple Computer was right when he said, "The best way to predict the future is to make it happen." For this reason, it is necessary for us to create strategic alliances with industry, to set long-term goals, to stimulate innovation, and to make sure our industries move significantly beyond their global competitors. We are doing this, for example, with the Clean Car Initiative and our work with the U.S. construction industry.

The Partnership for a New Generation of Vehicles, also known as the Clean Car Initiative, is one of our premiere ventures into cooperative civilian industrial technology development. In it, we are tackling a technological challenge as tough as putting a man on the moon—that is, to develop within 10 years a car with 3 times the efficiency of today's automobiles with no sacrifice in cost, comfort, or safety. If the project succeeds, the payoff to the public will be huge in terms of less dependence on foreign oil and lower emissions of greenhouse gases. The project also holds the promise of an extremely attractive car for world markets in the twenty first century and a thriving U.S. auto industry to produce them. The government (in this case, a consortium of Federal agencies) and industry (the Big 3 automakers and many suppliers of materials and equipment) are working closely together here to break highly challenging technological bottlenecks where the benefits are as much societal as commercial.

In our Building and Construction Initiative, our goal is to develop better construction technologies to improve the competitive performance of the U.S. industry, raise the life cycle performance of buildings, and protect public safety and the environment. The initiative responds to a high level of industry interest and combines government and industry goals. Construction is one of the nation's largest industries, with employment of 6 million and a total yearly value of close to $800 billion, yet U.S. building technology lags behind that of foreign countries and the incidence of injury in construction work is among the highest of all industries. We are determined, in full cooperation with industry, to realize, by 2003, the following future:

- *Better constructed facilities*, meaning: a 50 percent reduction in delivery time; a 50 percent reduction in operation, maintenance, and energy costs; a 30 percent improvement in productivity and comfort; 50 percent fewer occupant-related injuries and illnesses; 50 percent less waste and pollution; and 50 percent more durability and flexibility.
- *Improved health and safety of construction workers*, meaning a 50 percent reduction in construction work injuries and illnesses.

This initiative is dedicated to removing nontechnical barriers to innovation, as well as putting greater emphasis on research and development and aligning government programs appropriately with industry needs.

Investing in Fundamental Knowledge

America's future demands investment in expanding our knowledge base, in other words, in our people, institutions, and ideas. Science is an essential part of that investment—an endless and sustainable resource with extraordinary dividends. The nation's investment in world leadership in science, engineering, and mathematics has yielded a scientific enterprise without peer, whether measured in terms of discoveries, citations, awards and prizes, advanced education, or contributions to industrial and informational innovation. Our scientific strength is a treasure this Administration intends to sustain and build on for the future.

We have pledged (as described in Science in the National Interest) to:

- maintain leadership across the frontiers of scientific knowledge;
- enhance connections between fundamental research and national goals, such as economic prosperity, national security, health, and environmental responsibility;
- stimulate partnerships that promote investments in fundamental science and engineering and effective use of physical, human, and financial resources;
- produce the finest scientists and engineers for the twenty-first century; and
- raise scientific and technological literacy of all Americans.

Broad investment in basic research is essential to our national defense strategy. A strong domestic science base supporting a robust national security S&T program is critical to preserving the technological superiority that characterizes our military advantage. The Administration's strategy is to apply resources broadly at the basic research level and make further investment decisions as emerging technologies reveal the most effective payoff areas. Through these investments in fundamental science, we can continue our science and technology advances, position ourselves to take advantage of maturing technologies, and minimize our vulnerability to surprise.

We have given particular emphasis in the first two years of this Administration to a human resources development strategy aimed at producing the cadre of experts necessary for the scientific enterprise of the future; for research and development; for applied fields and industries; and for competing in a global marketplace. We are reevaluating the breadth and nature of graduate training—recognizing that we are not training our scientists merely to work in laboratories and universities. We are projecting the workforce needs of our future economy and developing methods for fostering the basic skills necessary for all workers.

I cannot predict the science success stories of 2015. But our strong investment program for basic research sets the stage for the equivalent of:

- Fiber optics—which were a germ of an idea in 1966 but now carry most U.S. long-distance telecommunications.
- The Hubble Space Telescope—which has opened our eyes to distant galaxies in the same way the early space program opened our eyes to the wonders of our small planet and solar system.
- Global positioning system—a confluence of basic research in physics, software, communications, and high-speed electronics first tapped for military purposes and now rapidly expanding into commercial markets for navigation and air safety and monitoring Earth's large scale ecosystems.
- Severe weather prediction—which has emerged from the integration of space platforms, large computing power, and continued atmospheric science research.

I am sure we will see equally impressive and revolutionary developments in the coming years—provided we maintain our strong commitment to basic research. My confidence stems, at least in part, from the fact that the process of good science inherently contains a healthy degree of skepticism and willingness to weigh new evidence. For example, over the past two decades, researchers in the United States and other countries, particularly Brazil, have debated the rate of deforestation in the Amazon rainforest. The answer affects calculations of the amount of carbon dioxide present in the atmosphere. In a NASA-sponsored study using Landsat data, this debate was effectively resolved, with the study showing that the rate of deforestation was, in fact, lower than many thought.

Our polar-orbiting satellites also provide information about the atmospheric cooling effects of volcanic emissions, specifically from the eruption of Mt. Pinatubo in the Phillipines. The extent and the duration of the effects of such natural phenomena on global warming must be considered in trying to understand fluctuations in the climate record. As a nation, we should take great pride in our ability to undertake policy-relevant scientific investigations designed to provide information necessary to, but not driven by, the policy debate.

Space and Aeronautics

The commitment the Administration has made in space and aeronautics technologies reflects the critical role these technologies play in advancing U.S. economic, national security, and foreign policy interests.

The international space station is perhaps the Administration's most visible commitment to US leadership in aerospace technology. As you know, early in the Administration we undertook a redesign of the space station to reduce its cost, to improve its performance and safety, to accelerate its schedule, and to make it more relevant to today's economic and political climate. The inclusion of Russia as full partners in the station program reflects not only the benefits we believe can be derived from the incorporation of Russian space technology, but also the importance of broad international cooperation in the pursuit of fundamental scientific research. We expect that research on board the space station will provide important new scientific and technical insights and will lay the groundwork for mankind's next steps into space.

This Administration is also committed to making investments that will allow industry to dramatically reduce the cost of space transportation. In August, the President directed NASA to begin development of a new generation of launch vehicle technologies that could eventually replace the expensive Space Shuttle. The President also directed the Department of Defense to develop a strategy for evolving the existing launch vehicles into a fleet of vehicles that is significantly more cost effective. These government actions, combined with the energy and creativity of the private sector, not only holds out the possibility for much less expensive access to space for science, exploration, and national security, but lays the foundation for a reemergence of US industry as the dominant player in the commercial space launch market.

The Administration's commitment to space technology research has not lessened its commitment to space science and applications. Through its Global Change research program—including NASA's Mission to Planet Earth program—we will gain new insights into the fundamental processes of our planet. These insights can have a positive effect on our economy as we benefit from new knowledge of weather prediction, agriculture, disaster prediction, and other complex processes.

Besides exploring out own planet, NASA is planning a new generation of small, low-cost spacecraft that will provide new opportunities for exploration and discovery elsewhere in the solar system. These new programs, combined with our sustained commitment to important facilities such as the Hubble Space Telescope, will expand our already significant efforts to understand the nature of the universe in which we live.

The U.S. aeronautics industry has benefited greatly from its strong research and technology partnership with the Federal government. U.S. firms lead the world in the manufacture of aircraft, engines, avionics, and air transportation system equipment. This leadership role has translated into hundreds of thousands of high-quality jobs and a significant contribution to our balance of trade—more than $28 billion in 1993 on exports of $40 billion. The Administration's continued support for aeronautics technologies will help to ensure that U.S. industry remains a world leader in the development of new aircraft and engines. Federal R&D will also play an important role in helping to ensure the development and implementation of a new, efficient, safe, and affordable global air transportation system. In particular, new technologies such as the Global Positioning systems (GPS) will play a significant role in this process and may result in billions of dollars in annual saving to the airlines and a significant global market for new U.S. products and services. Finally, Federal R&D will help to ensure the long-term environmental compatibility of the aviation system. New technologies hold the promise of even greater increases in energy efficiency and further significant reductions in noise and potentially harmful chemical emissions.

Principles of the Federal S&T Enterprise

Science and technology are essential to the various missions of the Federal departments and agencies. Looking to the future, our agencies must have a research and development base that will continually refresh and improve the ways in which we carry out our responsibilities.

Coordination and Streamlining

In order to confront the budgetary, scientific, and technological challenges of the twenty first century, the Administration recognized that significant changes were needed in the way we plan and fund Federal R&D. The traditional single-agency, single-discipline approach to problem solving must be supplanted by a coordinated, multi-agency, interdisciplinary approach. Multi-dimensional problems can only be addressed by bringing together natural and social scientists, economists, engineers, and policymakers. For too long, science has been decoupled from informing policy decisions. Fixing this disconnect has been one of our highest priorities.

Over the past two years, the Administration has been working to improve the Federal R&D enterprise in many ways. For the first time, the United States has a comprehensive, coordinated Cabinet level body devoted to the Federal R&D enterprise. In November 1993, the President created the National Science and Technology Council (NSTC). The principal purpose of the NSTC is to:

- identify national goals that require concerted R&D efforts;
- identify the high-priority R&D needed to meet those goals; and
- coordinate R&D government wide to make sure that adequate attention is given to high-priority areas, and to avoid wasteful duplication.

Although each agency, to accomplish its missions, must have R&D directed to its particular needs, there are some commonalities in the science and technology needs of all the agencies. Put another way, overarching national goals typically cross agency boundaries. This is particularly true because of the highly interactive nature of research and development with its many feedback mechanisms. The NSTC provides a structure in which to prioritize the many legitimate demands on the public's R&D dollar. It assures a forum where critical national needs cannot be pushed aside by urgent and parochial agency needs. It can sensitize agencies to the advantage of symbiosis over isolated pursuit of objectives.

Through its nine standing committees, the NSTC has identified R&D priorities that link our S&T activities to critical national goals. Unprecedented cooperation among the member agencies plus a great deal of hard work in 1994 enabled these committees systematically to prepare research and development strategies to meet the goals. OSTP then worked with the Office of Management and Budget to ensure the priority areas received adequate attention—all within a level R&D budget. The result is a coherent, efficient R&D agenda.

To meet the nation's goals in the years ahead—and to continue meeting them as the goals themselves evolve—requires that we set priorities for R&D now, with a farsighted vision for the future because most of the S&T enterprise is inherently a multi-decade process. Even within the science community, it can take decades to recognize the significance of a scientific discovery. The NSTC provides the mechanism for providing the vision and deriving priorities. By creating a "virtual" S&T organization, the NSTC enables the Administration to maintain a productive research and development activity in each S&T-dependent agency while simultaneously achieving the efficiencies of a cross-linked system.

In addition to its beneficial impacts on the R&D budget, the NSTC has several important policy directives to its credit. For instance, the President has issued policy directives that will ensure continuity and efficiency in the Landsat and polar-orbiting satellite systems and ensure the appropriate agencies focus on the Nation's long term space launch needs.

All of the NSTC's work is undertaken in cooperation with the private sector. One of our key links to the private sector is the President's Committee of Advisors on Science and Technology whose members include eminent industry leaders and academic researchers, including Nobel Prize winners. Issues ranging from technology development to education and training to prevention of deadly conflict require close interaction between government and private sector experts to ensure ultimate success in our efforts.

Cooperation with the Private Sector

Technology is a powerful driver of economic growth. Over the past 50 years, at least a quarter of U.S. economic growth—possibly as much as half—came from new technology. These advances created millions of good new jobs, a cleaner environment, better health and longer lives, new opportunities for individuals, and enrichment of our lives in ways we couldn't imagine half a century ago. Superior technology, moreover, is vital to U.S. national security. In a world of ever tougher global competition, U.S. prosperity depends as never before on our ability to master new technology in areas like information, biotechnology, and advanced materials and to build on S&T advances made in other countries.

Private businesses are the principal actors in converting technology to goods and services, to profits and jobs, and they have supported much of the research needed to develop new technologies. But the public (government) has three indispensable roles to play in advancing technology: 1) ensuring a strong base of fundamental science; 2) providing a business environment that encourages innovation and investment; and 3) investing in research that is critical to the economic and social needs of the nation, but cannot attract adequate private support.

The accelerating pace of technological advance, ever shorter product cycles, and rapid worldwide diffusion of technologies mean that many companies are finding it harder to justify investment in risky or lower yield R&D than in the past. Today, the payback to the investing company is often less than half the spillover, or "social return," to society at large.

This means that government R&D partnerships with industry in growth-enhancing technologies are more important than ever. Without government to share the risk at the pre-commercial stage, individual companies are reluctant to take the plunge, especially where a substantial fraction of the total return cannot be captured by a company. The government partnership fosters technology advance that otherwise might not be made—or would be made in foreign countries, with most of the benefit going to their citizens.

In general, where there are technological risks, R&D projects with a strong combination of potential public and commercial benefits merit a mix of government and industry support. For example, education and training technologies that challenge and reward all our children and bring lifelong learning within reach of everyone have multiple public and private benefits: a better educated citizenry, a world-class work force, opportunities for people to retrain themselves in response to changing technologies and jobs, and a rich commercial market for the learning technologies themselves. Government's role in creating the National Information Infrastructure is not only to share the costs of R&D for basic advances in computing and telecommunication. It is also to make sure that privately financed information superhighways are accessible to all Americans.

The problem of capturing returns on private sector R&D investments is especially great in widely dispersed and fragmented industries such as agriculture or building and construction. Government must support technology advance in these industries, at least on a cost-shared basis, or it won't get done. This has been long recognized in agriculture, where government support of R&D goes back to 1862, with the foundation of land grant colleges across the nation.

Today, many in industry are taking a new, forward-looking view of their R&D programs. Corporate cost-cutting drives have led to focusing in-house research on technologies that are close to commercialization, at the expense of more basic, longer term, or riskier research. The new model of best practice that is taking form is to create partnerships for riskier, generic, pre-commercial R&D—teaming with other companies, with universities, and with the government.

We have re-invented these partnership programs to make sure that they are:

- market-driven, with industry leading the joint research agenda;
- cost-shared, with the private sector putting up half or more of the money, as a quasi-market test to make sure the technological risk is worth taking;
- competitive and peer-reviewed, to guard against pork in the selection of research projects; and

- evaluated periodically and rigorously to make sure that the projects are having the intended effect.

With the assistance of wise government policies, U.S. companies have recently regained a competitive edge in critical technologies, such as semiconductors, once thought lost to Japanese and other competitors. We must not return to the days when American scientists and inventors made breakthrough innovations, only to see the jobs and profits growing out of discoveries and inventions flow to overseas competitors. In a fiercely competitive world market place, it would be unwise to rely solely on those programs and policies that worked during the Cold War but are unsuited for today's needs.

The Link Between Science and Technology

The Clinton/Gore Administration's science and technology initiatives are based on a recognition that science and technology are linked in a multitude of ways, each building constantly on the gains in the other domain. It is certainly true that all technological advance ultimately depends on fundamental science, and the highly trained people educated at our universities and colleges. But old distinctions between "basic" and "applied" science no longer make sense in today's laboratories, where, for instance, newly derived fundamental understanding of molecular biology quickly yields ideas for new products and manufacturing processes—which, in turn, not only raise questions for further fundamental research but also give rise to new technologies that enable more effective research. And where progress in such fundamental fields as astronomy or elementary particles depend upon technological breakthroughs in optics, computing, or superconductors.

The relationship between basic research, applied research, technology development, and commercialization is not a linear progression. Rather, it is full of feedback loops. Often a technical or engineering advance will stimulate or enable scientific inquiry. For example, cars powered by internal combustion engines were running on the road before scientists began to understand, even imperfectly, some fundamental principles of combustion. Magnetic resonance imaging was founded on basic research in nuclear physics—but it could not have been put to practical use in medical diagnostics without the separate but parallel development of a number of sophisticated technologies, especially the microprocessor, the "computer-on-a-chip" that could be built directly into the instrument. The cancer treatment drug taxol is derived from the yew tree of the Pacific Northwest, and without the research to classify and study the natural plants and animals it might never have been found. And most of today's experimental science has become totally dependent on the most recently developed technology.

The search for something practical often forces a new look at the scientific principles that underlie new phenomena; the prepared mind is ready to take a leap into the practical application. Ernest Shockley, an AT&T Bell Laboratory physicist, invented the transistor while engaged in a lab program to develop better switches—but the scientific work of previous decades on solid state physics and quantum mechanics was absolutely essential to the invention. The early age of science provides equally interesting examples. Galileo, who developed fundamental astronomy, was also an inventor who spent much of his time and energy demanding payment for his practical inventions.

The blending of discovery and application is repeated across virtually all science and engineering—from biomedicine to environment to space exploration and aeronautics to materials and manufacturing. Basic research on materials results in stronger, long lasting roads and bridges and lighter, but safer airplanes and cars. Today's wonder drugs and tomorrow's bioremediation of chemical wastes are direct products of our continuing investments in biology, chemistry, physics, and earth science.

The fundamental point is that basic science, applied science, and technology, though different in approach, motivation, and scale, are profoundly interdependent.

Conclusion

There has been and will continue to be strenuous debate about the appropriate role for government in science and technology. Some people believe that fundamental science—basic research—is the only area in which government belongs. As I have already said, this Administration does not believe it benefits the American people to try to draw that line in the sand. The Clinton/Gore Administration believes government has an essential role in technology development as well. Economic growth, quality of life, national security—all these things depend on a comprehensive science and technology investment program. For our children and grandchildren to succeed in the knowledge-based, highly competitive global economy, the Federal government must maintain a strong commitment to investment in the future, in other words, to investment in science and technology linked to long-term goals.

We are convinced that *technology is the engine of economic growth* that will ensure good jobs and a higher quality of life. We know that *scientific knowledge is the key to the future* . . . it is the fuel for the engine.

The Cabinet Secretaries and Agency Heads here today will all agree that the Federal Departments and Agencies are working together in unprecedented cooperation to provide essential science and technology services to the American taxpayer in an efficient and cost-effective manner. The "virtual agency" created by the NSTC eliminates duplication and waste and gets maximum advantage from each investment dollar. Budgetary constraints have made the workings of the NSTC absolutely essential, and we have succeeded in shifting resources to enable the S&T portion of the budget to be maintained and even slightly increased in key areas.

We know from your record, Mr. Chairman, that you, too, support science and technology and recognize the vital role they play in the future of our economic, environmental, and national security. But in looking at the Contract With America, along with the FY '94 and FY '95 Republican budgets and other proposals for paying for the Contract, we are concerned. The Clinton/Gore Administration shares your commitment to reduce budget deficits and the inefficiencies in government. We have worked, with great success, to bring the budget deficit down, to cut government employment and spending. But we have also taken great care not to sacrifice our investments in the future—in the well being of our children and grandchildren—in the process, by commiting ourselves to sustained support of science and technology.

Our initial interpretation of proposals to fund the Contract With America raises our concerns that we will *not* be able to develop and disseminate the education technologies our children will need to compete in the global, knowledge-based economy; that we will *not* be able to invest in research that could ensure this nation's continued preeminence in industries dependent on biotechnology or information and communications technologies; that, in fact, between now and the end of the century this nation may find itself in wholesale, devastating retreat from the investments on which our future depends—investments in science and technology. This Administration will stand against that retreat because it cuts to the core of our guiding premise: we must invest in our children's future in ways that promise the highest payoff.

We are a nation of explorers. We need science and technology to nurture our national soul as well as our economic well being. The Clinton/Gore Administration wants to work with the Congress to achieve the goals of the American people, including long-term economic growth, an efficient and responsive government, and world leadership in science, engineering, and mathematics.

The New Frontier: Space Science and Technology in the Next Millennium

A new millennium is nearly upon us. The next few years mark the transition between the twilight of one age and the dawn of the next. During this transition, we will have the opportunity to reflect upon the great and dynamic changes that are taking place around us:

Here at home, Americans are asking fundamental questions about the social contract that binds them to each other and to their government.

Around the world, new forms of cooperation between governments are reducing barriers to commerce, science, and culture, enhancing the prospects for new forms of collaboration, and defining anew the meaning of neighbor, community, and national boundaries.

Dramatic and unparalleled advances in technologies for information, health, transportation and the environment are fundamentally transforming the way we live, play, and work.

We continue to struggle with the problems of environmental degradation and overpopulation; with violence and famine caused by centuries-old ethnic and religious conflicts; and, with an increased threat of proliferation of weapons of mass destruction.

I would like to reflect upon both the role that the space program has played, and continues to play, in enabling technological and societal change and how these changes have, in turn, altered our perception of space research and exploration. I would also like to share with you a vision for the future of US and international space activities. A vision that is simultaneously optimistic and affordable; practical and, I believe, exciting.

Wernher von Braun Lecture, National Air and Space Museum, Smithsonian Institution, Washington, D.C., 22 March 1995.

Why We Go to Space

Space technology has been one of the defining forces of this century. The Soviet launch of Sputnik in October 1957 and the ensuing space race to the moon came to symbolize the conflict between the competing world views of communism and democracy. Space became the symbolic ideological battlefield upon which each country sought to demonstrate its prowess and win global influence.

This titanic struggle yielded dark moments—such as the Cuban missile crisis—where it seemed to many that technology would ultimately be the undoing of mankind. But there were also bright moments, such as the Apollo moon landing, where space technologies seemed to light a clear path to the future. In following this path, we have come to recognize several unfolding discoveries.

Space Applications Are Now a Practical and Essential Part of Our Daily Lives

Satellites provide essential communication services to both the developed and the developing world. Whether it is the global distribution of news and entertainment, or the regional delivery of health care and educational programming, satellites constitute a critical component of the emerging Global Information Infrastructure.

Space also provides a unique vantage point from which to analyze and monitor our complex planet. Satellites have dramatically increased our ability to predict the weather and its many consequences. Multispectral imagery from space has provided unprecedented advances in regional and global resources management; and, satellites for treaty verification have helped us to keep the peace.

Diverse scientific, military, and commercial applications of the Global Positioning System are revolutionizing how we work, play and travel. Although this multi-satellite system was originally developed for military use, the United States has welcomed the global use of GPS for a wide range of peaceful purposes, including the pivotal role that GPS could play in the global air traffic management systems of the future.

Space Research and Technology Can Enable Us to Be Better Stewards of Our Planet

The very first images of the Earth from weather satellites and from the Apollo missions literally changed our view of the planet. In those pictures—particularly the one known as the "Blue Marble"—the Earth, hanging in empty space, seemed, for the first time, small and fragile.

Astronaut Bill Anders, remembering his first view of Earth from the Apollo 8 command module, said: "Looking at the Earth and seeing it floating like—since it was Christmastime—a little Christmas tree ornament against an infinite black backdrop of space...it seemed so very finite. It was this view of the fragility and finiteness of the Earth that is the impression, frankly, that I hold more in my head than any other."

It was Dr. Sally Ride, the first American woman in space, who later pointed out that although we had sent highly sophisticated spacecraft to study other planets, we had not taken a similar interest in our own planet. She led a study group that recommended a program to accomplish this task and dubbed it, somewhat ironically, "Mission to Planet Earth."

The simple truth is that we still don't understand well enough how our planet works and how human activities are affecting the biosphere. Space technology can play a pivotal role in this research. For example, we learned more about ocean circulation from a single US/French satellite than in the whole previous history of ocean research. Satellite measurements also played a critical role in monitoring and understanding ozone depletion in the upper atmosphere, thereby averting a major health and biological catastrophe.

And we are just getting started. Some two dozen missions to study the global environment will be flown by the year 2000. NASA's Mission to Planet Earth, and its companion programs in the US and other nations, are building the knowledge base that is a critical prerequisite for achieving a sustainable future.

Space Exploration Is Providing Phenomenal Insights into the Nature of the Universe

1994 was an absolutely outstanding year for space science. Indeed, astronomer John Bahcall has called it—perhaps with only a little exaggeration—the most important year to be alive for astronomers since the dawn of man. The Hubble Space Telescope is simply wowing the world. Most recently, it has given us striking evidence that the universe may be billions of years younger than we thought. It has found conclusive evidence that massive black holes exist at the cores of active galaxies. And, it's brought us the first views of infant galaxies, which formed only about two billion years after the Big Bang.

And That's Not All

Hubble data have confirmed the existence of protoplanetary disks around newborn stars. This is the strongest evidence yet that the same basic process that formed the planets in our Solar System may be common throughout the galaxy.

Looking Earthward, the Compton Gamma Ray Observatory contributed to the discovery of a strange new phenomenon known as upper atmospheric flashes that may provide a link between phenomena in the Earth's lower atmosphere and events in the upper layers of our atmosphere.

Comet Shoemaker-Levy"s collision with Jupiter in July 1994 was a seminal event for astronomers. Such events may occur in the solar system only once every thousand years or more. The early detection of the comet by the Near Earth Object Program allowed unprecedented preparation to observe this event from ground and space-based observatories, sparking worldwide interest from the scientific community and the public. And millions of Americans could find the pictures on the Internet!

Cooperation in Space Offers Us a New Vision of Global Cooperation

International cooperation in space offers a rare opportunity for nations to pool their interests and resources in exciting and challenging ventures. Such cooperation is a laudable successor to the dark conflict that characterized the birth of the space program. The Apollo moon landing was assuredly an American victory, yet it seemed then, as now, "a giant leap for all mankind."

But the Cold War did not end with Apollo. For years, the US and Russian space programs continued along their separate paths, not really competitors, not yet partners. In 1984 the "Fire World partners"—US, Canada, Europe, and Japan—and close allies joined to build a Space Station, partly in response to a similar initiative by the USSR. Then the Berlin Wall came down. The Soviet Union fell apart under its own weight, and the world changed dramatically. In that light, gradually, we came to see the space program as a tool for building peace and international understanding rather than as a weapon of the Cold War.

This is why the Clinton Administration, in its first year, took the bold step of inviting the Russians to be full partners in the International Space Station.

Visions of the Future

But what next? Are the glory days of the space program in front of us or behind us? I feel confident in predicting that the best years of the space program are yet to come. In the future, space will play an increasingly important role in our daily lives, in our science, our adventures, and the security of this nation. I would like to examine some of the ways in which space technology will continue to change the world in which we live.

Today, we are in the midst of a digital revolution that promises to transform the way we use and share information. Satellites, including the new generations of hand-held mobile devices and broad-band communications satellites, will play a critical role in this revolution. They will provide affordable links to the global network from the most remote corners of the planet. And they will help link existing terrestrial networks as well. The result will be more open markets, more freedom of information, stronger democracies, more productive workers, and a higher quality of life for billions of people around the globe.

Satellites will help communications and computer companies to develop ever-more sophisticated products and services. "Information appliances" will replace today's computers, cellular phones, and televisions; appliances such as wallet-sized, wireless, personal digital assistants will help you organize your life and keep in touch with your office; newspapers, magazines, and books will be delivered directly to your laptop computer, and new learning tools using virtual reality or providing access to huge digital libraries of information will be a few key-strokes away. These new tools will enable users to access and manipulate data in ways that we cannot even imagine today.

We can see examples of what will be possible in the future in the research community today, particularly among scientists using remote sensing data and computer models. Because their work is so data-intensive and because it requires interdisciplinary collaboration, researchers have developed software and networking technology that enables people around the country to access, manipulate, and share huge data files of imagery. Experiments currently being conducted by NASA and industry on the Advanced Communication Technology Satellite are demonstrating that satellites will play an important role in networked, high data rate communications.

The New Explorers—Putting Our Minds Where Our Feet Won't Go

In the future, we will continue our exploration of the solar system and beyond. However, this exploration will proceed in ways that would have surprised, and, I know, fascinated Wernher von Braun.

The von Braun paradigm—that humans were destined to physically explore the solar system—which he so eloquently described in Colliers Magazine in the early 1950s was bold, but his vision was highly constrained by the technology of his day. For von Braun, humans were the most powerful and flexible exploration tool that he could imagine. Today we have within our grasp technologies that will fundamentally redefine the exploration model. We have the ability to put our minds where our feet can never go. We may soon be able to take ourselves—in a virtual way—anywhere from the interior of a molecule to the planets circling a nearby star, and there exclaim, "Look honey, I shrunk the Universe!"

Today, the great challenge of space exploration and utilization is making it affordable and efficient; that's exactly what Dan Goldin and NASA are trying to do. The Jet Propulsion Lab, for example, is now developing concepts for a ten-pound spacecraft that is no bigger than your fist.

The next century will likely see the flowering of a new manufacturing revolution, enabling an armada of tiny, intelligent machines to travel outward from Earth to explore new worlds. These small spacecraft will require less power and smaller, lower-cost launch systems. They will take advantage of next generation onboard intelligence capabilities and will have little need for elaborate terrestrial control and operation centers. The result will be to greatly increase the science output while reducing the physical and human resources required to develop and operate a mission.

There will even be occasions when we conduct dramatic new exploration missions without ever sending spacecraft to distant worlds. In the not-too-distant future, we may have the technology needed to image planets that may be orbiting nearby stars. It might be possible to infer through spectroscopic analysis of their atmospheres or the color of their oceans whether they are life-bearing. What a revelation that would be!

All of these options will greatly enhance our research into the human role in exploration. We are firmly committed to the space station, not only because it opens a door to new research, but because it is an essential step in understanding how humans react to the space environment. Early in the next century we will hopefully solve the difficult problems of bone loss and blood chemistry that currently beset astronauts spending long periods in space. With this knowledge and the knowledge obtained from our robot explorers, we will be prepared to answer the important questions about the next destination for humans in space.

A New Understanding of the Planet Earth

But of course, even as we set out to explore new worlds, we must also be better stewards of the one world in which we all live—and the only world we can count on.

One of the space program's most important contributions is to increase our understanding of our planet so that we may preserve and enhance life on Earth.

As the century ends, the United States and its international partners will have an array of sensors in Earth orbit measuring the atmosphere, oceans, biosphere and land surfaces, as well as the interactions among these elements. These sensors will be linked by sophisticated information systems providing data to scientists and researchers. This work will produce answers to fundamental questions about the Earth, how its systems interact, and how and why it changes.

We will have powerful new tools for analyzing weather, for the longer-term prediction of floods, drought, violent storms and the dynamics of biological change, such as disease and the migration of flora and fauna. We will have a complete survey of the Antarctic ice sheet, and we will be making the first assessments of changes in thickness of the Greenland ice sheet and the first global rainfall assessment. In the future, routine forecasting of El Niño occurrences and consequences will be possible with enormous potential for economic savings.

Soon we will be able to perform repeated global inventories of land use and land cover from space, evaluate the consequences of observed changes, and analyze the consequences of different preventative and adaptive practices. We will use satellites for the first global assessment of air pollution in the lower atmosphere, leading the continual assessment of changes in global air quality.

In short, space technology can give us the information we need to understand the role that human activities play in this complex cycle as well as the influence of natural phenomena. This knowledge is absolutely essential if we are to be responsible stewards of this planet.

How We Will Get There

Space science and exploration has inspired and enriched us. What more could we ask? Well, as they say, "happiness can't buy money." The current review of budgets and programs both in the Administration and in Congress implies that even high priority programs, such as space science and exploration, will be coming under increased scrutiny. That's the bad news. The good news is that much of what we must do to develop an aggressive space program for the future has already been started.

First, we are truly reinventing NASA. This means that we must take an organization established during the Cold War as a federally mobilized response to Sputnik, and transform it into an agency that is more relevant to today's economy and today's world, an agency that will once again define excellence in space science and technology. This task will be difficult and it will not be done without some legitimate pain.

However, reducing the size of NASA is not an end in itself. We must also work with NASA to change the way it does business. The aerospace industry has matured considerably since the days of Apollo. As a result, the private sector can now accomplish many of the tasks formerly handled by the government. Satellite communications, space launch, and remote sensing were all originally government programs but are now being offered successfully by the private sector. In the future, we must continue to ensure that NASA does only those things that it does best.

NASA's 1996 budget contains a number of programs that already incorporate this new approach. For example, the Reusable Launch Vehicle (RLV) program will focus on developing low-cost, next-generation launch vehicles, while the Discovery program will seek to advance the state of the art of spacecraft for space exploration. Both of these programs have sought, from the beginning, to include significant industry participation, management, and funding.

Finally, we must seek creative ways for the space programs of the world to combine their talents, resources, and facilities to accomplish goals that are beyond the reach of any one country. Space Station and Mission to Planet Earth provide us with early examples of this trend. In the future, we must seek other opportunities to build durable links between our individual efforts in space science and exploration.

In 1965, President Johnson asked: "As (man) draws nearer to the stars, why should he not also draw nearer to his neighbor? As we push even more deeply into the universe, we must constantly learn to cooperate across the frontiers that really divide the earth's surface."

We can all look forward to participating in this important adventure.