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THE MAKING OF A GREENHOUSE POLICY

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When the media describe a scientific advance, they often focus on a particular individual or event, as if the advance derived entirely from that source. Scientists working in the field typically know the situation to be much different. Many steps are needed before a particular advance can occur, and much needs to be done for an insight to be integrated into an existing body of knowledge.

Similarly, in describing the formation of policy, it is often easy to overemphasize a particular incident: a clash of personalities, a pivotal document, the meeting at which everything becomes clear. I wish it were so simple. In fact, I have often found policymaking to be somewhat similar to scientific research, both in its rewards and its frustrations. Thomas Jefferson described science this way: "A patient pursuit of the facts, and cautious combination and comparison of them, is the drudgery to which man is subjected by his Maker if he wishes to attain sure knowledge." He might as well have been describing how you put together the fifth draft of a policy statement.

In a somewhat less solemn fashion, the making of policy has also been likened to the mating of elephants -- it takes place at a high level, it involves substantial trumpeting and thrashing about, and it takes a long time to produce any tangible results.

What I would like to do today is describe the process by which the Bush Administration has been forming a national policy -- and contributing to an international policy -- on global environmental change. You will be hearing much about that policy over the next few weeks, largely because of an international White House Conference on Scientific and Economic Research Related to Global Change that I will have the pleasure of cochairing next Tuesday and Wednesday. But that conference is just one step in the much larger process of trying to understand and respond to the possible adverse effects of global change. I have spent much of my time since coming to Washington last summer on this subject. And I believe that the actions the Bush Administration has taken -- and will be taking -- in this area amply demonstrate the President's commitment to dealing responsibly with this issue.

A POLITICAL AWAKENING

The term "global change" encompasses such diverse but interrelated issues as ozone depletion, greenhouse gas emissions, climate change, sea level changes, deforestation, levels of biodiversity, and energy demands. But much of the public's attention has focused on global warming. And I don't think that anyone can look at the possibility of global warming without being struck by an immediate paradox.

The enhancement of the greenhouse effect is one of the most long-term and global problems that we face. As such, it will require a long-term and global response -- not what might be described as slam dunk solutions.

Yet the political atmosphere surrounding global warming resembles nothing so much as a crisis. A remarkable number of pieces of legislation have been introduced on Capitol Hill, and the latest research results -- some emphasizing and some minimizing the potential impacts of global warming -- make the front pages of newspapers.

There are several quite understandable reasons for this widespread concern, including the fact that four of the warmest years on record have occurred in the 1980s. But I believe that much of the current ferment still derives from the summer of 1988. In that single season, a severe drought struck the Midwest, much of the nation sweltered under unusually high temperatures, forest fires scorched large areas of the West, and a particularly strong hurricane devastated the Caribbean. The greenhouse effect made the covers of Time and Newsweek -- even though scientists cannot yet, in any convincing fashion, connect these events of that summer to the greenhouse effect.

This political awakening has driven the greenhouse effect toward the top of the national and international political agendas. It should be remembered, however, that scientists have been speculating about enhancements of the greenhouse effect for decades and more. The Swedish chemist Svante Arrhenius predicted, in 1896, that the temperature of the Earth would go up 4 to 6 degrees Celsius if levels of atmospheric carbon dioxide doubled -- a remarkably prescient prediction given that, until the role of clouds were incorporated more accurately into global circulation

models, they estimated temperature increases of only slightly less. As early as 1957, Roger Revelle and Hans Suess wrote about the "large-scale geophysical experiment" that we are conducting by releasing carbon dioxide into the atmosphere.

Scientists know much more about the Earth and its components now than they did when these early predictions were made. General circulation models mimic global climate reasonably well. And we can observe the Earth from space, which has made a deep impression not only on our understanding of the Earth but on our sense of the planet as a unified, somewhat fragile home.

But what we do know about the Earth is still dwarfed by what we do not know. I know that journalists are expected to answer the four W's in the first paragraphs of their stories: who, what, where, and when. Suffice it to say that it would be very difficult to write a first paragraph describing the greenhouse effect.

There is a general consensus among scientists that continued loading of the atmosphere with greenhouse gases could lead to warming. However, the uncertainty and controversy center around the magnitude, rate, and timing of a warming.

In addition, there is a general consensus that the planet has warmed up by about 0.5 C during the past century. But very few scientists would claim that they are yet able to determine whether any of that warming can be attributed to a greenhouse effect or whether it represents a natural fluctuation. And although some climate models predict a warming of between 1 and 2 C from a doubling of atmospheric carbon dioxide -- although there is still large uncertainty as to whether this doubling will occur in 2050 or in 2200 -- it is also true that the historical record shows that the natural background temperature could, over this same period, go up or down by a similar amount, leaving us with no change or with twice the model predictions. We simply do not yet know.

We are also only beginning to understand what the impacts of a potential warming might be on agricultural productivity, sea level changes, biological productivity in the oceans, shifting vegetation patterns, storm patterns and severity, droughts, and the like. We are even further from any quantitative understanding of the corresponding economic impacts, as I shall discuss in a moment.

Two of the most severe difficulties involve the treatment of clouds and of oceans in general circulation models. Until recently, geoscientists did not even know if clouds warm or cool the Earth. We still do not know for certain whether the increased cloudiness associated with a warmer Earth will augment or counteract a greenhouse effect. It will depend on the nature and altitude of the clouds.

Regarding the oceans, we know that only about half of the carbon dioxide released through fossil fuel combustion and deforestation remains in the atmosphere. For years, researchers assumed that the rest was being sequestered in the oceans, but recent studies indicate that no more than a quarter probably ends up there. Where does the rest go? We still are not sure, although some suggest it is in temperate latitude biomass.

Uncertainties regarding the behavior of clouds and oceans also contribute to one of the most vexing difficulties of current atmospheric models: their inability to make accurate regional predictions. Models still disagree about such fundamental questions as whether the centers of continents will get wetter or drier if the Earth warms. Yet these regional predictions are essential to assess the possible impacts of global change.

Because of the limitations of models, we must remain aware of the potential for surprises. The development of the ozone hole over Antarctica was such a surprise. The hole develops through a mechanism that was not included in earlier models of ozone destruction, and as a result was found almost by accident. We need a careful program of observing and monitoring the Earth to detect any such surprises caused by our emission of greenhouse gases.

What the ozone hole has demonstrated beyond question, however, is that, contrary to long-held assumptions, our atmosphere is not so large, nor its inertia so great, that human activities cannot affect it on human time scales. Human release of chlorofluorocarbons combined with unique meteorological conditions has indeed created the ozone hole -- through well understood chemical mechanisms -- in only a few decades at most.

Lewis Thomas, among others, has compared the Earth to a living organism, and in particular to a single cell. The comparison is certainly apt in this regard: as

much as we still have to learn about the nature of life, about how it developed and where it is going, we have as much to learn about the nature of the Earth.

THE NATIONAL RESEARCH AGENDA

Bertrand Russell once wrote: "The most savage controversies are those about matters as to which there is no good evidence either way." Global warming comes dangerously close to falling into this category. As research reveals more about how human activities can influence climate, we will have a much less controversial basis on which to take actions.

The U.S. government is now engaged in a large-scale, integrated program to develop the understanding that will guide future policy decisions. That program is known as the U.S. Global Change Research Program, and it was established by the interagency Committee on Earth Sciences chaired by Dallas Peck of the U.S. Geological Survey. The Committee consists of directors of independent agencies and of assistant secretaries of cabinet departments doing research on the global environment. Working groups organized under the committee consist of the senior program managers working in a particular area. For example, the U.S. Global Change Research Program was organized by the committee's Working Group on Global Change, chaired by Robert Corell of the National Science Foundation and incorporate the programs of seven different agencies.

The FY 1991 budget that President Bush sent to the Hill at the end of January -- reflecting the compelling case made by the CES for its integrated, national program -- called for a 57 percent increase in funding for this program, to a total of over \$1 billion. The proposed funding would significantly expand research, data gathering, and modeling activities through a carefully balanced mix of ground-based and space-based research.

I might say, by the way, that the success of the Committee on Earth Sciences has acted as a model for similar efforts by the Office of Science and Technology Policy. We have recently reorganized and revitalized the Federal Coordinating

Council for Science, Engineering, and Technology -- the parent body of the Committee on Earth Sciences -- and have established a number of new interagency committees in such areas as education, the life sciences, and technology and industry. In this way, we hope to bring a much greater integration and coordination to a number of important areas of science and technology.

THE WORKING GROUP ON GLOBAL CHANGE

The Committee on Earth Sciences focuses on the research aspects of global change. The policy analog to the CES is the Working Group on Global Change, which President Bush established last fall under the Domestic Policy Council, one of two senior, Cabinet-level policy councils within the White House. The Working Group, which I chair, provides Cabinet-level coordination on global change issues and is an important source of information and advice for the President.

Shortly after it was established, the Working Group called for three specific studies of global change. The first looked at the economic costs of both global change and responses to possible change; it also considered the potential costs of inaction. The second considered private sector concerns and activities. The third reviewed the legal precedents for international agreements and conventions on the environment. The Working Group has also been briefed by top experts on the scientific and economic aspects of global change.

The Working Group on Global Change will continue to be the focal point within the White House in considering Administration policies toward the global environment. But at this point I would like to break my promise about sticking to process and discuss some of the policies themselves. The Bush Administration does not believe that further research is any substitute for action. It is clear that we are accelerating our research in the face of uncertainty; but what bears emphasis as being even more important is decision making in the face of uncertainty.

As such, this Administration has already instituted a number of policies that will reduce greenhouse emissions while being fully justified for other reasons. The

President refers to these as "no regrets" or "all weather" policies, because even if our concerns about the greenhouse effect turn out to be unfounded, these policies will have other benefits. I look on them as an insurance policy against possible adverse effects of global warming.

- o The United States is committed to phasing out the manufacturing and use of CFC's by the year 2000 to protect the stratospheric ozone layer -- ahead of the requirements of the Montreal Protocol -- provided safe substitutes are available. If not controlled, CFC's would account for as much as 25 percent of the greenhouse effect's increase in the next century.

- o The Clean Air Act now being debated in Congress will provide for substantial reductions in the emission of other greenhouse gases by fostering more efficient use of energy. The Environmental Defense Fund has estimated that the acid rain provisions of this act alone, if implemented, would have the same effect on our greenhouse gas emissions as would removing fully one fifth of our current automotive fleet (22 million cars!) from our highways for a period of 10 years.

- o The Department of Energy is developing a National Energy Strategy that will focus, in particular, on an aggressive commitment to energy conservation and to the development of non-fossil-fuel sources of energy.

These initiatives address the source component of the greenhouse gas question; turning to the sink component, the Administration is again taking concrete steps.

- o The Department of Agriculture is proposing to plant a billion trees on private land across America, trees that will eventually absorb 13 million tons of carbon annually.

- o Diplomatic discussions are being conducted aimed at protecting the remaining tropical forests through such mechanisms as debt-for-nature swaps.

An underlying theme in all of the Administration's global change policies is that they be based on the best possible science and that they be technically and

economically sound. These are criteria that we will continue to apply as we consider policies in the future.

THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

Thus far I have been discussing our national research and policymaking with respect to global change. But the greenhouse effect is no respecter of national or political boundaries, and its understanding demands information and analyses that span the globe. International cooperation will therefore be essential to continued progress.

The primary international forum through which these issues are being addressed is the Intergovernmental Panel on Climate Change (IPCC), which has been organized under the auspices of the United Nations Environment Program and World Meteorological Organization. The IPCC involves hundreds of scientists and government officials from a number of countries who are seeking to establish an international consensus on the likely causes and consequences of climate change.

The IPCC is conducting its activities through three working groups. The first, which is chaired by the United Kingdom, is seeking to develop a better scientific understanding of climate change. The second, chaired by the Soviet Union, is assessing the possible environmental and socioeconomic effects of climate change. And the third, chaired by the United States, is seeking to identify potential responses to global change.

These three working groups will produce reports by the end of the summer. Policymakers around the globe will then be able to draw upon these reports in formulating national and international policies. In addition, our conference being held next week on scientific and economic research relating to global change is designed to complement and support these IPCC activities.

The three working groups of the IPCC met here in Washington in February, and President Bush addressed their opening plenary session. He told them, "The United States is strongly committed to the IPCC process of international cooperation

on global climate change. We consider it vital that the community of nations be drawn together in an orderly, disciplined, rational way to review the history of our global environment, to assess the potential for future climate change, and to develop effective programs."

President Bush has also expressed his support for the next logical international step: a Framework Convention on Global Change to be negotiated among the countries of the world. At the Malta Summit, President Bush proposed that the United States host the first negotiating session of the Framework Convention, and he reiterated that offer to the IPCC.

In thinking about the goals of a Framework Convention, the Vienna Convention offers a useful analogy. In 1985, the United States and 20 other countries signed the Vienna Convention for the Protection of the Ozone Layer, which established a framework for international scientific and technical cooperation. However, the Vienna Convention did not set limits on emissions. Rather, it included provisions to establish protocols as further research developed.

A Framework Convention on Global Change could serve the same function. It would build cooperation among nations and establish the mechanisms by which future steps are taken. But the United States believes that a comprehensive approach should be taken to encompass all greenhouse gas emissions on the basis of a scientifically determined greenhouse equivalent index and that possible actions should employ market-oriented approaches.

THE WHITE HOUSE CONFERENCE ON SCIENTIFIC AND ECONOMIC RESEARCH RELATED TO GLOBAL CHANGE

The reports of the IPCC working groups will be an important input to the Framework Convention, but an important complement to the IPCC will be the White House Conference being held here in Washington next week. President Bush is hosting the conference and will open and close the proceedings. I am one of the

cochairmen of the conference, along with Michael Deland of the Council on Environmental Quality and Michael Boskin of the Council of Economic Advisors.

The conference will bring together the three senior officials in science, economics, and the environment from 17 countries, the Organization for Economic Cooperation and Development, and the European Community. The conference is designed to explore what we do know about the scientific and economic questions surrounding global change, what we do not know, and when remaining uncertainties might be reduced. In addition, the conference will examine ways to more fully integrate the results of scientific and economic research into the policymaking process.

I have already mentioned some of the scientific challenges, so let me focus here on the economic ones, since in many cases they are even greater than the scientific ones. For example, one recent analysis was able to conclude only that emissions of carbon dioxide in the year 2050 are likely to be between 1.5 and 12 times what they are today.

We need much better measures of the potential costs and benefits of limiting or adapting to global change. Preliminary studies show that the costs could be very high, but data and assumptions with which to make such estimates are riddled with uncertainties.

In general, the social sciences will be as important as the natural sciences in improving our understanding of global change. Even when the physical and biological aspects of a problem are understood, all too often agreement is lacking on the underlying social, behavioral, and economic causes and consequences of an action. The conference next week will be focused at least as much on these aspects of the problem as on the purely scientific aspects. We hope in this way to add a new dimension to the international dialogue on global change.

The Conference is expected to produce a Cochairmen's report, which will set forth common actions designed to expand research and cooperation among nations. The United States will also be making a number of concrete proposals during the conference, such as a proposal for an international global change research program comparable on the international scene to the U.S. national program described above. You will be hearing about those next week.

CONCLUSION

Let me conclude with a bit of history, which I hope to relate at the conference next week because I believe that it summarizes our current situation very well.

The year after next we will be celebrating the 500th anniversary of Columbus's discovery of the new world, an event of unsurpassed importance in the course of world history. As might be expected, Columbus was an astute observer of the natural world. While he was anchored off the coast of Jamaica, Columbus noted in his journal that it rained for about an hour every afternoon. Columbus also pointed out that the same thing used to occur in the Canary and Azores Islands, but that the rain had stopped since the trees on those islands were cut down. In other words, Columbus was one of the first people to observe the effects of human beings on climate.

I think it very appropriate that Columbus should have done so, because he was engaged on a great voyage of discovery, and today we find ourselves engaged on a similar voyage. We are changing the world in ways that it has never been changed before. And yet human beings, by their very nature, cannot help but change the world.

We have no reason to fear such changes. But we must keep our eyes open, and try to understand where we are going, and change course when we have good reasons to do so. We need not sail blindly into our future. But we must keep moving forward if we are to achieve the complementary goals of an economically healthy and environmentally sound world.

**EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
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**U.S. TECHNOLOGY POLICY:
CAN IT HELP MAKE AMERICAN COMPANIES COMPETITIVE?**

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It is always a great pleasure to return to Harvard, especially given the long history of friendly competition between Harvard and Yale, on the football field and elsewhere. Although I have to admit that when I think of Harvard, I tend to think more about the English department than with the football team. The reason is that several years ago I had a graduate student at Yale who had been a Harvard undergraduate, and who had presumably taken at least one English course here. He was extremely bright and is today an internationally known physicist. But the first sentence of his Ph.D. dissertation, when I received it in draft, read as follows: "This field of research is so virginal that no human eyeball has set foot in it."

I am not here, however, to talk about either physics or English but rather about something in between: the use that we make, here in the United States, of technology. Technology -- and the science from which much technology springs -- are of vital importance to this country, and they have received much attention in my office -- the Office of Science and Technology Policy -- and within the Bush Administration in general.

Over the last few months, we have seen the difference that science and technology can make on the battlefield. But science and technology are having an equally dramatic -- if less directly visible -- effect on our civilian economy and on our modern way of life. The past investments we have made in science and technology have paid great returns in economic growth and an improved quality of life, just as the investments we made in military systems paid off in outstanding fashion in the Gulf War. Nor is there any reason to think that this return from science and technology will be any less in the future.

Let me try a simple calculation to demonstrate these economic returns of R&D. Over the last 50 years, the size of the U.S. economy, after correcting for inflation, has increased about fivefold. Economists calculate that about a third of this growth has resulted from research and development. In other words, at least 25 percent of our national income today can be directly traced to science and technology.

Now let me make the very conservative assumptions that the economy grows at

*ACMR-Technology
not training*

only half this rate over the next fifty years -- so that it is two-and-a-half times today's size in the year 2031 -- and that today's R&D continues to account for about a third of that growth. In that case, the U.S. economy fifty years from now will be over \$3 trillion larger -- in today's dollars -- than it would be without the results of R&D. Given that the United States today annually spends about \$150 billion on R&D of all kinds -- public and private, defense and civilian -- we can calculate that an expenditure of \$1 today will yield a real return of at least \$20 fifty years from now. I do not know of any other investments that give that kind of return -- with the possible exception of a Harvard or Yale education.

I have been talking about the economic returns of research and development, but of course there are many other kinds of returns. Science and technology have immeasurably improved the quality of our lives through prevention and treatment of disease, greatly enhanced mobility, improved accommodations and food, and even new forms of recreation and entertainment. We tend to forget that just 100 years ago, a quarter of all people born in the United States were dead before their 25th birthday, and half of all people had died by the age of 50. Today the corresponding figures are 3 percent mortality by the age of 25 and 10 percent by the age of 50.

Finally, scientific discovery is one of the greatest adventures that we have available to us as a species. The quest for knowledge is a basic human drive and brings great intellectual and emotional satisfactions. Furthermore, as Francis Bacon put it in the famous quotation from his Religious Meditation: "Nam et ipsas scientia potestas est," which of course translates as "knowledge itself is power." I might add, by the way, that since coming to Washington I've heard that when Senator Everett Dirksen first heard this quotation, he immediately replied, "particularly if you know it about the right people."

Continued American Strengths

Much has been said and written in the last few years about how America is losing its edge in technology, and even in some areas of science. Personally, I believe

that much of this is talk is ill-informed at best. We in the United States continue to have, by a large margin, the strongest science and technology base that the world has ever known. This storehouse of facilities, equipment, knowledge, and trained personnel has come about largely because of the generous support provided by the federal government, and ultimately by the American taxpayer, for research and development since World War II. It is a tribute to the American people, and to the public policy process in this country, that investments of this magnitude have been made.

What is true is that a number of countries, by focusing their resources in particular areas, have moved up to equal -- and in a few cases surpass -- the position of the United States. That is not necessarily bad. In fact, it was to be expected as other countries recovered from World War II and began to follow the United States' lead. What we must do now is ensure that, in all areas of science and technology where our activities do not define the frontier, they are close enough to those frontiers so that we can exploit, without delay, new developments whenever and wherever they occur.

Let me mention a few other strengths of American science and technology, because it will be important to keep these in mind in considering U.S. policies affecting technology. First, this country continues to have the strongest research university system in the world. Especially at the graduate level -- but also if more selectively at the undergraduate level -- our universities continue to set world standards and typically attract the brightest young people from around the world.

These research universities also provide a double dividend. They generate the new knowledge that drives both science and technology, and at the same time they produce the young minds trained to use that knowledge in new and more productive ways. In no other country does this process work as effectively.

The United States also continues to have a business climate that encourages the formation of new companies and allows successful companies to grow quickly into major businesses. The rapid growth of the biotechnology industry is one example -- with over 400 firms founded in biotechnology in the 1980s -- but there are other examples throughout American business. These small and medium-sized firms

generate many of the most important new ideas in our economy, and they continue to generate most of the new jobs in this country. So long as adequate investment capital remains available for new start-ups, these companies will continue to contribute a dynamic quality to the U.S. economy that is not evident elsewhere.

Finally, the United States remains an open and restless society that prizes and rewards innovation. Our world is today changing at accelerating speed, and those companies that remain flexible and innovative are going to be the ones best able to take advantage of those changes. The massive production lines for which the United States became famous can no longer be looked on as the paradigm, though the advantages of scale will continue to be important. We need greater flexibility and agility in changing our production capabilities, both to reflect technological changes and to match customer demand. And we must develop much greater sensitivity to that demand, particularly in the international marketplace.

The FY 1992 Budget

These strengths -- and the opportunities they present -- are fully reflected in the budget proposal that President Bush sent to Congress in January. To take advantage of the countless scientific opportunities available to researchers at our nation's colleges and universities, the budget proposes an 18 percent increase in funding for the National Science Foundation and a 9 percent increase in funding for research project grants awarded to individual investigators at the National Institutes of Health.

Together, these two federal agencies support over 75 percent of the federal funded basic research done in universities; by focusing on them, the Administration is seeking to strengthen the individual investigator and small group research that remains the heart and backbone of American science and technology.

Yet basic research clearly cannot be the only component of a nation's R&D enterprise. Other nations such as Japan have R&D enterprises that bring great benefits to society yet include very little basic research. The difference is that these

systems are able to very efficiently and effectively exploit the results of basic research, no matter where it is done. This is the stage of the innovation process -- the stage between the generation of knowledge and its application in the marketplace -- that poses the greatest challenges to the United States.

To help strengthen the latter stages of the innovation process, the budget includes funding for many areas of applied research and technology development, including high performance computing and communications, energy technologies, biotechnology, advanced manufacturing and materials, and aeronautics. To take just one example, the budget includes a special Presidential initiative on high performance computing and communications, which is designed to sustain and extend America's preeminence in this critically important area of technology. This program, which was put together by an interagency committee organized through my office, focuses on the hardware, software, networks, and human resources that will be necessary to increase computing and communications capabilities by several orders of magnitude. In my view, these new capabilities could have the kind of catalytic effect on society, businesses, and universities that the telephone system has had during the twentieth century.

The budget emphasizes a number of areas of applied research and development. In fact, it goes so far as to state that it is providing increased funding "for all major civilian applied R&D areas." This is an important measure of the Administration's intentions.

In a speech to the recipients of the National Medals of Science and National Medals of Technology last fall, the President said, "Today, our government must help carry [basic] research forward and contribute to the development of generic technologies that build on basic discoveries. If America is to maintain and strengthen our competitive position, we must continue not only to create new technologies, but learn to more effectively translate those technologies into commercial products. In this way, we can help leverage the R&D of the private sector, helping whole industries advance in an increasingly competitive global market." As part of this commitment from the highest levels of government, applied research and technology development are going to be increasingly important federal emphases.

Technology Policy: The Narrow and Broad View

The question then becomes, will this support of technologies automatically boost the American economy? Or, to return to the title of my talk, can federal support for technology development help make American companies competitive? There is no question that in some cases it can, and history provides many examples of such success stories, from the airline industry to the computer industry.

But even though a strong technology may be a necessary condition of commercial success, it is by no means a sufficient condition. Our past strengths in technology have not prevented an erosion of market shares of U.S. companies in many industries. Nor should the federal government try to directly identify and develop technologies for commercial products and processes. That is the responsibility of the private sector, and past federal attempts to second-guess the marketplace have often produced dismal results.

The very real limits on the federal government's ability to mandate technological success can be seen in a recent poll conducted by the Industrial Research Institute of its members, who consist of the top-ranking R&D officials in many of America's leading companies. The members were asked to rank five major factors according to their contributions to the erosion of U.S. industrial technology. The two most important categories were "general management practices" and "external financial pressures." The last category in order of importance was "federal technology policy."

As the director of the Office of Science and Technology Policy, this ranking leaves me in a somewhat awkward position. I can sympathize with the story that Newton Minow used to tell, who was head of the Federal Communications Commission in the 1960s and coined the phrase "a vast wasteland" in describing television. He said that his mother once called him up and said, "Newton, since you've been in that job the television programs have really gotten much better. But can't you do anything about TV dinners."

The problem, I believe, is that we have had a tendency to define "technology

policy" much too narrowly -- as simply the federal government's support for technology. Last September my office put out a report entitled "U.S. Technology Policy," and in that document the issue is viewed from a much broader perspective. It considers such issues as technology transfer, the financial environment needed for longer-term investments, the legal and regulatory environment necessary for innovation, and the education and training of the workforce. What I would propose to do with the rest of my time is look at some of these issues and show how they fit into a comprehensive federal approach to competitiveness.

Technology Analysis

Turning to the issues most closely related to technology development, one of the most important needs is for solid information and analysis about the technologies of importance to our economy and national security. Some of this analysis has been and is being done by the private sector. I know, for example, that several groups here have looked at these issues, and I want you to know that we read those reports very carefully in our office, and they have been extremely helpful.

Another important activity is going on within the Office of Science and Technology Policy. Over the past year, the National Critical Technologies Panel within OSTP has been working to develop a list of the technologies that will be critical to our future economic prosperity and national security. The panel has 13 members -- six from the private sector and six from the federal government, plus the panel's chairman, Bill Phillips, who is the Associate Director for Industrial Technology within OSTP.

The first report of the panel will soon be released, and in that report the panel discusses 22 technologies that it believes will be critical in the 1990s and into the 21st century. The technologies fall into six broad categories: (1) materials, (2) biotechnology and life sciences, (3) manufacturing, (4) information and communications, (5) aeronautics and surface transportation, and (6) energy and the environment. The report describes each technology, highlights its importance and the

reasons for its selection, and discusses the current status of the technology, including the relative position of the United States versus other countries.

As the report points out, the development of technologies -- like the development of science -- is replete with surprises. Who would have guessed when the laser was developed that we would today be using it to play music and read prices from supermarket items? However, the panel has set forth the technologies in its report with confidence that they constitute the appropriate bases for exploitation to satisfy many of the nation's future needs. Also, the list technologies will be updated biennially to ensure that they remain current.

Once the appropriate technologies have been selected, careful thought must be given to how those technologies can be successfully developed and deployed. Again, considerable work on this subject is going on in the private sector, and OSTP is in the process of greatly increasing its involvement with this issue. The 1991 Defense Authorization Bill called upon OSTP to follow-up the work of the National Critical Technologies Panel by establishing a Critical Technologies Institute. This institute would give OSTP an analytical arm for developing strategies to promote technologies critical to both governmental and private sector needs. It would evaluate programs that are already in place in both the private and public sectors to see which programs are most effective. And it would work with other groups at evolving strategies for the optimum development and deployment of technologies.

This question of how best to develop technology applications is a critical one, yet it is often given scant consideration in either the public or private sectors. We in the White House frequently meet with representatives of U.S. industrial groups. Many believe that they were in some trouble in terms of remaining competitive; many would like to see some form of direct federal assistance. But all too few are prepared to lay out a strategic plan that demonstrates how such assistance would, in fact, put them on a new trajectory that in five or more years would leave them competitive and not in need of an additional transfusion.

This Administration is prepared to be helpful, and indeed looks on competitiveness as one of the nation's most pressing challenges. But we do not believe that we in government are as well-qualified to make these strategic plans and

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decisions for industry as is industry itself. Nor do we believe that economic transfusions in the absence of such strategic plans are any answer at all.

In addition to OSTP's work in industrial technology, the Department of Commerce has, of course, been heavily involved in this area. For example, very recently, the Department of Commerce, through the National Institute of Standards and Technology, announced the first set of awards under its new \$36 million Advanced Technology Program, which we in the Administration view as a pilot program.

In all, 249 proposals were received; 45 were joint ventures, 204 were single applicants, and 183 were from small businesses. They came from 38 states in addition to the District of Columbia.

These proposals were subjected to 678 technical peer reviews involving 395 individual reviewers from industry, universities, and government as well as venture capitalists and private consultants.

Out of this screening, 11 winners emerged; 5 are joint ventures, and 8 are single applicants. Eight of these projects are led by small businesses, and there is small business participation in all of the awards through subcontracting. The awardees span the entire range, from multinationals such as AT&T and IBM to very small companies with only a few hundred employees.

The total requested in the proposals was \$337 million, with \$112 million for the first year. Among the winners, \$9.2 million was requested from the federal government, with cost-sharing of \$9.4 million. The winning proposals address 10 different generic technologies, ranging from X-ray lithography through panel displays to machine tool control and nonvolatile computer memories.

By all measures, it would appear that this pilot program has been a great success, and I would anticipate substantial growth in it in future years.

Technology Transfer

Any consideration of how best to exploit federal development of technologies

must include an extremely valuable but often overlooked asset. In this country, in addition to our university researchers and those in industry, we have an enormous national resource in the professional personnel, expertise, and infrastructure resident in our over 700 federal laboratories. The federal government invests over \$20 billion a year in these laboratories -- almost a third of the total federal R&D budget. They embrace an astonishing breadth and depth of science and technology, including some of the best science and technology to be found.

Many of these laboratories were established in the immediate post-World War II period, and they originally had very specific missions and objectives. Many of these missions were satisfied many years ago, so that at least some of the labs lack clearly defined objectives, although many have been able to keep their programs in close touch with national needs.

Our challenge now is to involve these laboratories in a much-discussed but all-too-infrequently realized partnership with universities and industry so that they can play a more effective role in supporting U.S. economic competitiveness in the international marketplace. I believe, for example, that potential users must be more involved in the launching of laboratory programs than is now the case, where individual curiosity remains a dominant driver in the laboratories. I am convinced that groups of knowledgeable industrial and university scientists, meeting with laboratory management and senior scientists and technologists, can add a new dimension to the selection of program emphases and priorities -- at the outset -- with the laboratories. In so doing, this process will lead to significantly improved coupling throughout the research programs and in the use of their outputs.

The end result of new partnerships among the components of our research enterprise would be a much greater degree of technology transfer. But I must caution that the term "technology transfer" is one of the most misunderstood in the English language. It seems to imply that technology can be neatly identified, wrapped up, and transported with equal neatness to another organization, where it can be unwrapped and applied without significant change. Nothing could be farther from the truth.

In fact, there is only one way in which technology can be effectively transferred, and that is in the minds of people. I have become convinced that the only effective

transfer occurs when the technologies are carried in the minds of trained individuals moving from one organization to another. As a result, I believe that substantially increased mobility among our research personnel -- both basic and applied, both short- and long-term -- is essential.

Other countries are much more successful at these kinds of close working relationships than we are here in the United States. Our international trading partners have forged very strong links between government and industry. They have put public and private funds into targeted programs that reduce the risk of technology development, lower the cost to each participant, and make it easier to compete.

If the United States is to compete in such a marketplace, we cannot force each individual country to reinvent the technological wheel. Rather, the government must act as catalyst, with federal funding where appropriate, to combine the very real strengths apparent in each component of our R&D enterprise.

Mathematics and Science Education

In addition to these considerations of technology, there are many fiscal, legal, and even cultural factors that influence the competitiveness of American companies. Let me mention just a few of these and the actions that the Bush Administration is taking to influence them. On the economic front, the Administration has been working to reduce the cost of capital by controlling the federal budget deficit. The budget agreement reached last fall will save a half trillion dollars of federal spending that can now go into private capital markets, reducing interest rates rather than raising them.

In trade, the federal government is working to reduce trade barriers and better protect intellectual property. We must ensure that we receive a fair return on our investments in research and development rather than allowing those returns to flow predominantly to our trading partners.

In the area of regulation, the Competitiveness Council headed by the Vice

President is working on reforms to product liability laws to restore balance to the tort system. The Administration is also working to remove barriers to research, innovation, and development by eliminating unnecessary and unwarranted regulations.

These are all important elements of what might be considered a U.S. technology policy in its broadest sense. But I want to emphasize, in closing, perhaps the most fundamental element of our approach to technology, and that is the education of our young people and the training of our workforce.

American education is now suffering from some extremely serious breakdowns. Particularly at the precollege level, the education that many of our young people are receiving is scandalously poor. For the first time in American history, our children and grandchildren are now receiving a worse education than their parents and grandparents received.

As is the case through society, science and technology are becoming an ever more important of the educational enterprise. Jobs requiring high levels of scientific and technical training are the most rapidly growing segment of the labor market. But our schools are not producing nearly enough scientifically literate and technically training individuals to meet the demand. International comparisons show the United States at or near the bottom in scientific and mathematical achievement. If we cannot educate our young people properly, scientific and technological supremacy will inevitably pass from the United States to other countries.

The importance of science and technology is apparent in the National Education Goals established by the President and the nation's Governors last year. Of the six goals, three directly involve science and technology, including the most ambitious of the six, that American students be first in the world in science and technology by the year 2000.

All of us know that particular goal is a stretch goal. Yet it is already having its desired effect in driving some very significant reforms. At the federal level, an interagency committee under the leadership of Secretary of Energy James Watkins has put together an integrated, government-wide program designed to significantly advance science and mathematics education. As part of that effort, the committee produced, for the first time, an inventory of all of the activities in the federal government that

directly influence science, mathematics, engineering, and technical education. And in the budget sent to Congress last month, the President proposed a 13 percent increase for this interagency program, to a total of nearly \$2 billion.

We are now looking seriously at the next iteration in developing a federal program in mathematics and science education. Precollege education was the top priority to emerge from the past year's work. A strong candidate for high priority in the FY 1993 round is technician training, in the broad sense of the term. This is an area where the United States has fallen behind other countries, especially Germany and Japan, to the detriment of our high-technology industries. Your suggestions as to how we should meet this challenge would be greatly appreciated.

These are important first steps, but of course the federal government alone cannot guarantee the achievement of the National Education Goals. It is going to take all of us working together -- with the goals as a consensual statement of where we are headed -- to make the kind of progress they envision. We must get parents reinolved in the education of their children, in part by giving them a greater degree of choice about where they send their children to school. We must establish partnerships between universities and the surrounding schools so that the expertise available in universities can be applied to this serious national problem. We must substantially upgrade the training and abilities of our teachers and treat them with the respect and understanding that their importance to the nation's future warrants. And government and industry must work together to produce the trained technicians our country needs.

I'm talking, here, about some sweeping and fundamental changes in the cultural norms of our country, and those changes will not be achieved easily or quickly. But they can be achieved. Our country is one of the most dynamic that the world has ever known; it is one of our greatest strengths. Change is a way of life in the United States, and in a democracy change is almost always for the better. The challenge now is to marshal the collective will. As Benjamin Franklin once said, "In a democracy, the people rule -- if they want to."

Of course, some changes will be easier to achieve than others. Several years ago I was meeting with the Science Advisor to the Prime Minister of Japan and with

one of the most senior scientific entrepreneurs in the Japanese economy. After a day's detailed discussions about our different approaches to high technology, to engineering, to science, and to education, I asked the Japanese science advisor what, in his view, was responsible for the rather different success that our two countries have enjoyed over recent years in the development of high technology, industrial strength and economic competitiveness. His answer was simple. He said, "It may not be unrelated to the fact that in Japan, per capita, we produce five times more engineers than you do, one twenty-seventh the number of lawyers, and no MBA's whatever."

This may be a Japanese solution to the problem of competitiveness that is not appropriate for America. But it gives you an idea of the kind of issues that we must face.

SCIENCE, TECHNOLOGY, AND THE U.S. AIR FORCE

D. ALLAN BROMLEY

**Assistant to the President for Science and Technology
Executive Office of the President**

**Air Force Scientific Advisory Board
Fort McNair Officers' Club
October 24, 1990**

It is a great honor and a privilege for me to be able to present the U.S. Air Force Basic Research Award to Dr. Joseph Horner of the Rome Air Development Center at Hanscom Air Force Base, Massachusetts. The committee of the Science Advisory Board that judged this year's nominations expressed the conviction that the entries this year were competitive with research going on anywhere in the nation. This award is thus a mark of great distinction, as are the four honorable mentions and seven runners-up who were also cited. I congratulate all of the individuals so honored.

Dr. Horner has been singled out for his work on the optical processing for pattern recognition, which coincidentally has long been an interest of mine. Studies show that 75 percent of the fraction of your brain that is actually functioning is always engaged in processing visual information. Humans have a remarkable ability to sense patterns and form hypotheses on the basis of visual information, and learning how to perform these functions with computers is one of the challenging and important tasks facing computer science. The potential returns on this research are incalculable -- not only in defense but in education, in manufacturing, in basic research -- really throughout the range of science and technology. I commend both the board and Dr. Horner for your far-sighted recognition of the importance of this research.

The title you have been given for my talk today is "Science in America," and in a moment I plan to at least touch upon this rather all-encompassing theme. But first I wanted to talk more specifically about science in the Department of Defense. For decades following World War II, the Department of Defense was the dominant supporter of both fundamental and applied research in this country, and it originated mechanisms for federal support of academic research that remain the envy of the world.

Other federal agencies now support a proportionately much larger portion of federal R&D, but defense research continues to be crucial to not only our national security but our national prosperity. There are very few technologies developed for

the military that do not have some sort of civilian application. Prior to coming to Washington, I used to think that international competitiveness could be separated from national security. I no longer think that to be the case. There are so many dual-use technologies and such close links between the defense and commercial applications of technologies that we must consider economic competitiveness and national security as two aspects of a single problem. The challenge, as I'll be describing in a moment, is to find ways of transferring science and technology developed in within the Defense Department, including within the Air Force, into the private sector as quickly and as effectively as possible.

During the next few years, the United States is going to be restructuring and rethinking the goals of its armed forces. I am convinced that defense research and development -- and particularly basic and applied research -- will be a critical part of this process. The Greek historian Thucydides once said, "A nation that draws too broad a difference between its scholars and its warriors will have its thinking done by cowards and its fighting by fools." This nation cannot afford either of those possibilities.

During the last month or so, several members of the President's Council of Advisors on Science and Technology, which was established by President Bush last February, have begun to do an informal analysis of defense R&D expenditures, and some of the issues they have been focusing on are quite interesting ones. Just to consider the overall numbers for a moment, the point is often made that federal defense R&D exceeds federal civilian R&D, and in absolute terms it does. But a closer examination reveals a number of special considerations. The defense R&D budget actually includes research, development, and demonstration -- with the lion's share of the money in development and demonstration of specific weapons systems. Only about \$1 billion of the Defense Department's \$38 billion R&D budget proposed for FY 1991 is in basic research or 6.1 account; only about \$2.5 billion is in the exploratory development or 6.2 account; and only about \$2 billion is in the advanced technology development or 6.3A account.

The rest of the federal R&D budget goes predominantly to test and evaluation activities, including technology demonstrations; engineering development of defense

systems; management and support; and the development, testing, and evaluation of operation systems. Some portion of this money contributes to the technology base of this country, but it is undoubtedly a smaller proportion than is the case for research and exploratory development.

I might say, by the way, that this is one of the things that distinguishes my current position from my previous one. I used to talk in terms of millions of dollars; now I talk in terms of billions. Eventually, you get fairly nonchalant about discussing that kind of money. It reminds me of the story I've heard about David Bell, who was John F. Kennedy's budget director. One time before a Senate Appropriations Committee, he gave an estimate for a particular set of outlays totaling \$366 billion. But a week later the subcommittee called him back and said that his estimate was in error and that it should have been \$350 billion. Bell replied, "Well, give or take \$10 or \$15 billion, I was substantially correct."

Funding for the research and exploratory development, therefore, does not even fall within Mr. Bell's margin of error. Furthermore, that portion of the Defense Department's R&D budget has been shrinking over the years. In constant dollars, the 6.1 and 6.2 accounts were over twice what they are now in the middle-1960s. As a percentage of total defense R&D, basic research and exploratory development were over twice what they are now throughout the 1960s and 1970s.

In my view, this country will need to place more emphasis on these portions of defense R&D if we are to preserve a decisive edge in our military capabilities. These activities will also be essential to strengthen the interface between defense and civilian technologies.

I am glad to say that the President and the leaders of the Defense Department fully agree with me on this point. The President's 1991 budget called for military research and development to rise about 4 percent, compared with a 1.7 percent increase for total funding within the Defense Department. Even more important, basic research for defense was slated for a 6 percent increase.

Particularly at a time of lessened tension, it is important to maintain and strengthen research to avoid technological surprise and being blindsided. Perhaps there will be less development and testing of specific weapons systems. But support

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for the basic and applied research on which the weapons systems of the future will be based should increase.

If basic research and exploratory development were increased, it would serve an additional, very important purpose. Such increases would help rebuild some of the bridges between the Defense Department and academic community that were present in the immediate postwar decades. These bridges were important for both sides: they brought the Defense Department into contact with some of the best research and brightest minds in the country, and they supported the development of new knowledge and the training of young minds that were able to use that knowledge creatively in the universities. The task before us today is that of reintegrating our national security enterprise into the civilian research and educational system -- to the benefit of both.

There is another reason for looking to the Defense Department for an increased emphasis on basic and exploratory research and development. The budgetary agreement that is now making its way through Congress is very likely to hold discretionary spending by the federal government at a constant level, in real terms, for the next five years. That discretionary spending includes all of civilian research and development, and, needless to say, the competition for that money is going to be intense. Increased basic research within the Defense Department can help compensate for the limits placed on the expansion of civilian R&D.

Several years ago, I. I. Rabi said that the military "is the most important source that we have of new inventions, new applications, new science. And the reason is a simple one: the military ask for the impossible, [and] they can pay for it." Today, I think that both of those assertions might have to be qualified somewhat. But Rabi's point is well taken: military R&D remains a key determinant of our technological future.

Technology Development by the Defense Department

As such, the portion of defense R&D aimed at technology development warrants particular attention. This last summer the Defense Science Board conducted a summer study on the Defense Department's technology strategy, and I addressed a meeting of that study. As I pointed out to that group, a significant portion of the government's R&D budget, both civilian and defense, goes for technology development. For example, the budget points out that over \$1.5 billion of civilian and defense R&D is allocated to developing such advanced technologies as robotics, high-performance computing, and semiconductor technologies.

Furthermore, the Bush Administration has made a commitment to continue to support the development of generic, precompetitive technologies that are important in both the public and private sectors. In a speech to the American Electronics Association on March 7, President Bush pointed specifically to the importance of these precompetitive technologies. He said, "This Administration is committed to working with you in the critical precompetitive development stage where the basic discoveries are converted into generic technologies that support both our economic competitiveness and our national security. Here again we can help to level the international playing field on which you operate."

My office is now engaged in a major effort to identify and prioritize a set of these generic technologies. The FY 1990 Defense Authorization Act directed OSTP to set up a National Critical Technologies Panel, which is chaired by OSTP's Associate Director for Industry Technology, Bill Phillips. This is a panel of six government officials, plus Bill, and six private sector representatives. Their immediate task is to merge two lists of critical technologies developed by the Departments of Commerce and Defense into a single list of no more than 30 technologies that will be critical to our nation's future economic prosperity and national security. More broadly, the panel will be examining the pace of technological development in this country and in other countries and assessing the implications for international competitiveness. The Panel has so far held two meet

In addition to directly funding the development of technologies, the federal

government can make it easier for industry to develop commercial technologies. One way to do this is by catalyzing the formation of consortia or networks of industries, with or without government funding. SEMATECH is an example of the former; the large number of joint R&D ventures catalyzed by the 1984 National Cooperative Research Act are examples of the latter. Particularly for small and medium-sized businesses, such consortia make it possible to pool resources and specialize on problems, so that each individual firm does not have to reinvent the technological wheel.

Finally, the hundreds of laboratories funded by the federal government -- including those of the Air Force -- embrace an astonishing breadth and depth of the best science and technology to be found. This base of knowledge represents one of our most valuable national assets. Federal laws and policies now in place make it the responsibility of every federal technology manager -- defense or civilian -- to consider the commercial ramifications of the work they are supporting and to try to encourage its commercial potential. We in the Administration will be building on these previous laws and policies to develop mechanisms that will expedite the diffusion of the results of federally supported R&D to industry. These mechanisms include active licensing of inventions and further removal of barriers to commercial development.

Precollege Education

There is one last topic that I would like to discuss today that may seem less directly related to the matter at hand but is equally important -- and that is the education of our youth. After leading the world for decades in the quality and scope of the education provided to our youth, we are now falling far behind the rest of the developed world. The state of our precollege education can only be considered as scandalous. At the college level, despite wide variations in quality, we remain -- on average -- competitive. At the graduate level, we continue to set the standard for world activity; in fact, the graduate students we train who then return to their homes

abroad represent one of our most valuable exports.

You might ask how we can maintain this paradoxical progression, from a precollege system that is scandalous to a graduate system that is worldclass. The answer, at least for science and technology, is that we are willing to drop a very large fraction of our young people along the way, particularly minorities and women. This is a loss that this country can no longer afford.

The demographic trends for the future of science and technology in this country are one cause for concern. The numbers of 22-year-olds in this country have been dropping for almost ten years, and they will continue to do so well into the 1990s. Furthermore, students have been exhibiting less and less interest in science and engineering, both because they see other professions as more lucrative and because of the decrepit state of precollege education in this country.

The Bush Administration has made precollege education a cornerstone of its domestic policy efforts, and within that area it has given special attention to science and mathematics education. Of the six national goals in education that the President announced last January, no fewer than three deal in some way with science and mathematics, including the most ambitious of the six, that American students will be first in the world in science and mathematics by the year 2000.

Because a very large fraction of scientists and engineers make their career decisions during and before high school -- much earlier than is typical for other professions -- it is essential that we refocus our corrective efforts on a much earlier phase of the educational enterprise than in the past. Currently, at these important precollege levels, the quality of mathematics and science teaching is often too low to attract other than the most dedicated student. For these dedicated few, in many cases, both the quality and quantity of mathematics and science exposure are too low to prepare them adequately for careers in these fields. These problems are increasingly recognized, and a number of states have made important strides toward improvement in their K-12 programs. But much remains to be done.

As one of the largest training organizations in the country, one of the largest producers of new technologies, and one of the largest employers of scientifically and technically trained citizens, the Defense Department is increasingly dependent on the

same shrinking pool of young people that supplies both scientific and engineering talent and skilled technicians of every kind. The Department of Defense therefore needs to be equally concerned about the failings of our precollege educational system and needs to join in the national effort to reform that system.

**EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506**

SPACE, SCIENCE, AND THE AMERICAN FUTURE

D. ALLAN BROMLEY

**Assistant to the President for Science and Technology
Executive Office of the President**

**34th Annual Goddard Memorial Dinner
Washington, D.C.
March 15, 1991**

I am very pleased and honored that you would ask me to speak before you tonight at a dinner commemorating the pioneering accomplishments of Professor Robert H. Goddard. His dedicated career, often under difficult conditions, culminated in his 214 patents that truly laid the foundation for man's access to space.

Growing up in northern Canada I was of course blissfully unaware of Goddard's work. About the closest I ever got to space in those days was as an overly curious 9th-grader in the small village on the edge of the northern Canadian wilderness where I grew up. Having discovered one day that adding a little sulfuric acid to a little zinc in a small test tube liberated an interesting amount of hydrogen, I decided that adding a lot of acid to a large amount of zinc in a large Erlenmeyer flask would obviously yield even more interesting results. This is known formally as an extrapolation.

The resulting explosion did not send me into orbit, but it did blow out all the windows in the school and completely removed my trousers from my waist to my knees. I was immediately sent home, and to this day I can remember the tears welling in my mother's eyes when I presented myself to her -- I'm still not sure if it was because of my bleeding, burned legs or because, in those depression years, the trousers had been brand new ones.

Although I have not been directly involved with the space program, space has always been an intense interest of mine, and since joining the Bush Administration that interest has taken a much more active form. The President and Vice-President have made me a member of the National Space Council to provide guidance on the scientific and technical aspects of the space program. And my time as science advisor has coincided with one of the most intensive and far-reaching examinations of the space program ever done, an examination that I believe will leave the space program considerably strengthened.

From an historical perspective, it is also very appropriate that the Office of Science and Technology would be involved in this examination. Your organization

was formed on October 4, 1957, in response to the Soviet Union's launching of Sputnik. Two weeks later, my position, that of Science Advisor to the President, was created when President Eisenhower decided that he needed a source of scientific and technical advice close to the Presidency.

Shortly thereafter, the President's Science Advisory Council -- which today has evolved into PCAST, the President's Council of Advisors on Science and Technology (although its gestation period was 9 months, reflecting the increase in Washington's legal population) -- recommended that the old NACA be converted to NASA. And since that day the Science Advisor has been involved in almost all of the major decisions regarding space, from the decision to go to the Moon to the initiation of the National Aerospace Plane program.

It should be remembered, however, that the advice of the science advisor has not always been heeded -- nor should it. Nor is science the only or even necessarily a particularly important consideration in decisions involving space. Jerome Weisner, who was science advisor to President Kennedy, and the PSAC of the time were unanimously opposed to the Apollo program -- to putting man on the moon and bringing him back in the 1960's. They saw no scientific justifications for the project. President Kennedy, however, decided to go ahead with the project, for international and political reasons -- and in the end Weisner supported that decision, for political reasons of his own.

Despite the fact that science was tertiary to both engineering and political considerations in the Apollo program, some very good science was accomplished during Apollo -- a result largely of the good will, and substantial and creative bootlegging, demonstrated by distinguished members of the NASA family. At the same time, the engineering and political achievements of Apollo are unparalleled. As you might know, when the National Academy of Engineering picked the top ten engineering projects of the past quarter century, the Apollo program ranked first, ahead even of the microprocessor and communication satellites. And it bears emphasis that the Apollo program represented the first time in the history of our species where a quantum leap in both science and technology was accomplished without involving most of the civilized world of the time in a global war.

Space also remains an arena of ultimate importance to the security of the United States and of our allies. Our defense space capabilities are key to deterrence of conflict and to the accomplishment of essential duties of the President.

The United States has maintained an important, stabilizing presence in space ever since the deployment of the first early warning and reconnaissance satellites that would alert us in the event of a nuclear attack. Such capabilities as precise positioning, reliable communication, and timely surveillance support our armed forces in peacetime, as well as in the event of war. And under President Bush's initiative, the future holds the promise of global protection from the threat of ballistic missile attack.

In operation Desert Shield, space assets were ready and fully employed to support command and control links to forces in the Middle East. They provided vital communications between forward-deployed units and their base of operations both in Iraq and here in the United States. DMSP weather satellite information, adapted Space Command systems, a dedicated GPS satellite, and selective tactical exploitation of national capabilities -- all were essential elements of the operation's success.

The lesson is clear. U.S. presence, access, and control of space will be fundamental to America's ability to defend our freedom and preserve the peace.

Today, it remains the case that the space program is still not predominantly a science program. Only about 20 percent of NASA's budget is classified as space science, a percentage that the Augustine panel recommended should remain the same or increase as we move into the 1990s.

But we go into space for many of the same reasons that we do science, and that is why I believe the two are so often linked. First of all, we go into space because we know that it pays. As with basic scientific research, it may be impossible to predict when, where, how, and to whom the economic benefits of space exploration will flow. But the lesson of history is that the exploration of frontiers, whether physical or intellectual, offers returns far in excess of the original costs. These returns can be seen in the thousands of spinoffs from the Apollo program, or they can be measured in the rich legacy of scientific and technological progress that has transformed western societies and the modern world.

We also go into space -- and do scientific research -- because the adventures they offer are among the most profound ones available to us as human beings. They enrich us as individuals, they enrich us as nations, and they enrich us as a species. Again, history offers many examples of what happens when nations choose to grasp or shrink from frontiers. During the Ming dynasty in the 15th and 16th centuries, the Chinese were among the strongest, most technologically sophisticated nations on earth, and their seafaring emissaries traveled the world. For internal political reasons, the Chinese then decided to withdraw from the world oceans, and their power quickly ebbed. The same thing happened with the Portuguese in the 1600s, when a greater involvement with European issues sapped the strength of their global explorations.

Some have suggested that the United States is on the verge of such a decline, that we have lost our edge in technology and even in some areas of science. Personally, I think that this talk is ill-informed at best. The United States still has the strongest science and technology enterprise that the world has ever known. It is a tribute to the American taxpayer, and to the public policy process in this country, that the continued investments needed to build that strength have been made.

Over the last several months, we have seen some of the returns from those investments. No one who witnessed the success of the allied forces in operation Desert Storm would claim that the United States has lost its edge in technology. In a way, Desert Storm even accomplished something that has been eluding NASA for many years. People tend to forget that NASA, with its interplanetary probes and space launches, has been demonstrating a precision that makes some of the weapons used in Desert Storm seem like muzzle loaders. When Voyager 2 arrived at Neptune just 22 miles off its charted course, it was an accomplishment comparable to threading a needle in Paris with a thread fired from New York. And despite tragic events like the Challenger -- which is not adequately recognized by our public as still very much a technological frontier -- NASA, with its record of 37 successful shuttle launches, has achieved a measure of reliability that would be difficult to match in any comparably sophisticated technological undertaking.

NASA activities combine forefront activities in both science and technology, in both research and engineering, and my office is interested in the space program from

both perspectives. We at OSTP, for example, have recently been engaged in a review of the scientific elements of NASA's redesign of the space station. At the same time, the Office of Management and Budget has been looking at the proposed budget for the program, and the Department of Defense has been examining the technical aspects of the station. Our intent here is not to second-guess NASA but rather to work with NASA to make sure that as the Executive Branch takes to Congress the revised plan for proceeding with the space station, we do so from a common basis of understanding and strong support.

In the scientific review, we focused on the two primary scientific justifications that have been advanced for the space station: microgravity research, and life sciences research. Regarding microgravity, one point of view has been succinctly expressed by the Nobel laureate Nicolaas Bloembergen -- the current President of the American Physical Society -- who recently testified before Congress that, "Microgravity, to be blunt, is of microimportance to science." I do not take that viewpoint literally, nor, I suspect, does Nico. But he makes a point. While there clearly are studies where microgravity adds a new and important variable, the enthusiasm of a decade ago for possible industrial production of new materials and pharmaceuticals in space has waned as, in one case after another, with sufficient ingenuity, it has been found possible to achieve the desired results here on Earth using new technologies such as recombinant DNA and genetic engineering. But this does not mean that there are no worthwhile studies to be done in microgravity -- far from it. And many will be done during the period when the station is progressing from its man-tended to its fully manned configurations. But it is now generally recognized throughout the scientific community that microgravity science and technology does not, in itself, provide a compelling rationale for building the space station.

At this point, too, it is essential that I add the caveat that all scientists and technologists know all too well that in predicting the future, the surest prediction is that there will be total surprises. This may well turn out to be true in microgravity research. But in planning prudent expenditure of the taxpayers' dollars, we must proceed in the absence of sure knowledge and weigh relative claims on the basis of the best minds and evidence available to us.

A vastly more compelling rationale for the space station is that it is the first step in the great adventure that will take our species away from the home planet -- and eventually out toward the stars. We need to know how human beings can adapt to the unforgiving and harsh environment of space and to prolonged weightlessness. There are a host of problems, both physical and behavioral, that may well be consequences of weightlessness. We need to find out how to identify and minimize these effects and how to counteract them when they occur.

We need also to develop an enormous range of technologies and know-how if we are to become a truly spacefaring species. Clearly there are advantages to doing this as close to home as possible so that our access is both ready and quick both for routine and emergency situations. The space station will provide us with the base we need for the development of these technologies and this know-how.

And there are much more subtle effects. When astronauts -- among them my old student Joe Allen, the first physicist-astronaut -- went out into space to rescue ailing satellites, one of the things that initially confounded them was the fact that humans had never before had occasion to come to grips, personally, with the well-known Coriolis force of freshman physics. It takes time and repeated practice to teach an old species new tricks, and many will be required. The space station will make such practice possible.

It bears emphasis, too, that we must have experience with many humans in space so that individual human peculiarities do not mask, or simulate, real problems. This implies a lengthy program with many participants.

It is my firm belief that we need, and must build, a space station optimized for life science research as our first major step into the last great frontier and adventure. We should not accept compromises of this ultimate goal.

And it is here that I would part company with the report that the National Research Council has just completed and that, somehow, found its way onto the front page of this morning's Washington Post.

While I have great respect for the institution -- and for the members of the panel that produced this report under its distinguished chairman Louis Lanzerotti of AT&T Bell Laboratories -- I believe that we have started from different assumptions

and have arrived at recommendations that appear much more different than they really are.

In effect, the NRC group began with the question -- is the space station configured in such a way that the science that could be carried out justifies its construction? -- and they have arrived at a negative answer. I would agree with the answer, but I would also insist that this is not the right question.

I, rather, begin with the firm belief that the space station is our stepping stone to the stars. Given that, I ask, first, what science is needed to take us through the next step? What questions need to be answered to make humans spacefarers? My first answer, shared by the NRC panel, is that there are a whole series of life science questions. And the space station, properly configured, will provide answers to those questions.

Only then do I ask the parallel question, what can the space station do for science? And again, my answer -- in agreement with, and perhaps even stronger than, the NRC report -- is that it, to the best of our present knowledge, will not be expected to make revolutionary contributions to materials science or technology, certainly not contributions that in themselves provide a significant justification for the space station's construction.

So I would dispute the premise, rather than the specific conclusions, of the NRC's report. It concludes that science alone cannot justify the space station; I agree. But that was never the question. We agree that the space station will provide us with the new knowledge that will allow us to move into space with confidence. And if history has taught us anything, it is that the opening of so magnificent a new frontier will provide us with surprises, with new science, and with new technology beyond our wildest imagining.

This is the rationale that lies behind President Bush's proposing the Space Exploration Initiative, with its ultimate objective of a manned mission to Mars. The President sees such an initiative as a long-term goal that the American people will understand, accept, and support. The goal will not be embraced immediately. It took seven years for Columbus even to get an appointment with Queen Isabella. But I believe that a consensus is in the process of forming, and that the end point of that

consensus -- although in all probability I shall not be here to see it -- will be to send a manned mission to Mars.

Of course, the ultimate objective is not just Mars; it is also the world that we will make for ourselves here on Earth. As T.S. Eliot wrote, "The end of all our exploring will be to arrive where we started and know the place for the first time."

Len Fisk has already described how the manned exploration of the solar system could help turn around an educational system that poses perhaps the greatest threat to American preeminence in the 21st century. The past 30 years have been a time of unprecedented advances in science and technology, advances fueled by a generation of scientists and engineers who have been inspired by the example of Apollo. We need a new generation of young scientists who are driven by a vision of what is humanly possible.

The exploration of space can also help us understand the planet on which we live. Within this decade, as part of NASA's Mission to Planet Earth, the Earth Observing System (EOS) will begin returning data to earth from 12 to 14 sensors, each of them looking simultaneously at a single column of air and a single spot on the earth's surface. These data, returned at a rate equivalent to the entire Library of Congress every 4.8 days, will, once analyzed, be essential in giving policymakers the information they need to deal with issues ranging from climate change and ozone depletion to ocean productivity and the problems of tropical forests and world agriculture. A mission to the Moon and Mars will add greatly to this understanding, perhaps making it possible to know why life evolved in the first place, why only on earth in the solar system, and under what conditions it could evolve elsewhere.

But the most important benefit of the continued exploration of space will be a less tangible benefit. It will be the new perspective that space travel offers on the Earth and on the Earth's inhabitants. In his new book Mission to Mars, Mike Collins has written about his feelings as he watched the Earth recede into space. He says: "I couldn't take my eyes off it. It was exquisitely beautiful, bright and shiny in the sunlight. I could see no political borders, or even signs of life. It seemed pristine, which it is not, and fragile, which it is. I think I have an intensity of concern for this planet, and especially for its oceans, that I could not have generated

before."

I believe that in future centuries, when historians look back at the second half of the twentieth century, we will be most remembered for a single photograph. It is the photograph, taken by the Apollo astronauts on their way to the moon, of the Earth as a majestic blue and white ball suspended in the blackness of space. That photograph, more than anything else, emphasizes that this planet is mankind's common heritage. It is ours to preserve; it is ours to destroy. We are truly in this together.

In recognizing that photograph, I must also recognize the role of the National Space Club. You have helped to make that photograph possible, just as you have helped to make the space program possible. Like Robert Goddard himself, you have been visionary in your commitment to the future and in your optimism about human aspirations. Your efforts have incomparably enriched our society, and they will continue to do so in the future.

I want to conclude with a passage from a paper that H.G. Wells published in Nature, in 1902, in an article entitled "The Discovery of the Future." He wrote: "It is possible to believe that all the past is but the beginning of a beginning, and that all that is and has been is but the twilight of the dawn. It is possible to believe that all the human mind has ever accomplished is but the dream before the awakening. We cannot see, there is no need for us to see, what this world will be like when the day has fully come. We are creatures of the twilight. But it is out of our race and lineage that minds will spring, that will reach back to us in our littleness to know us better than we know ourselves, and that will reach forward fearlessly to comprehend this future that defeats our eyes. All this world is heavy with the promise of greater things, and a day will come, one day in the unending succession of days, when beings, beings who are now latent in our thoughts and hidden in our loins, shall stand upon this earth as one stands upon a footstool, and shall laugh and reach out their hands amidst the stars."

As we stand on the threshold of a new millennium, it is within our power to make at least the beginning of this dream a reality. Robert Goddard would certainly have approved.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

THE CHALLENGE OF THE FUTURE

D. ALLAN BROMLEY
Assistant to the President for Science and Technology
Executive Office of the President

Commencement Ceremony
Ohio State University
March 22, 1991

President Gee, Trustees, Distinguished Guests, Members of the Class of 1991,
Ladies and Gentlemen:

Let me begin by adding my congratulations to the Class of 1991. You have worked hard and have earned the recognition that is yours today. But this is not just your day. As the parent of two college graduates, I can tell you that your parents have looked forward to this day much longer than you have. In a very real sense, this is their day, too. So let me, both personally and on behalf of all of us who are honored to be joining the Ohio State family this morning, extend to you -- parents and students alike -- our warmest congratulations and best wishes on this most important day.

As I have prepared for this day over the last few weeks -- and again when I arrived in Columbus yesterday -- I have been struck by something that all of you have probably come to take for granted, and that is the sheer, overwhelming diversity and scale of The Ohio State University. This university -- whose first graduating class, the class of 1878, consisted of just six people -- now seems to do almost everything, and to do almost everything well. From your world-class faculty and programs, to your hospitals and College of Medicine, to the Cooperative Extension Service, to the Ohio State basketball team -- whose floor I understand I'm usurping today -- everything you do seems to be accomplished with great distinction and style. In fact, President Gee told me that if my talk could even approximate the eloquence of a Jimmy Jackson jump shot, then I would be doing very well indeed.

I recognize the speakers at commencements without number have told new graduates that the future was theirs. But the situation is now different. Because the world is changing so rapidly, and because the problems facing mankind are so important, Western civilization is at a crossroads. Either your generation will build on the wave of optimism that has accompanied the events of the last few months to address the problems we face, or those problems will once again rise to defeat us and spread a mood of pessimism across the country.

We are still a young country -- a frontier country. And because of the soaring

imaginations and dedicated toil of our forefathers and their open welcome to those of other nations who have chosen to join them, we have inherited one of the greatest societies that the world has ever seen and a quality of life unmatched in the history of mankind.

The challenge of the 1990s -- and of the new millennium to follow -- is that of continuing to improve our society and our quality of life, and of making it available to those in our own country who have been passed over and to as many as possible of those in the Third World. We will do this because of our regard for the elemental rights of humanity -- but it is also in our enlightened self-interest. Unless we do it -- and are perceived to be doing it -- we will face international turmoil.

The challenge is yours. Its magnitude is enormous -- but so also are the opportunities. They, too, are yours.

The Malthusian Laws

The problems that face us can very largely be summed up in two laws. The first of these was published early in the nineteenth century by the british philosopher Robert Malthus. The second, I am confident, would have been enunciated by him had he lived to our day, so let me be generous and call these the First and Second Malthusian laws:

1. Resources are limited, and unless controlled, populations will always grow beyond the resources needed to support them.
2. Man's ability to cope with information is limited, and if unable to cope with the explosive growth in information and complexity, people become alienated and withdrawn and our interdependent society can topple of its own complexity.

These laws are entirely valid, but unlike the laws of nature, with sufficient ingenuity they can be end-run. Take the first law. What Malthus did not and could not realize is that energy is the ultimate resource. Given abundant energy, we can

have unlimited pure water by desalinating the sea. With abundant energy, we can also fix nitrogen from the atmosphere, liberate phosphorus from the rocks, and have an agriculture that will feed the world's burgeoning population. Furthermore, with abundant energy, we can recycle elements indefinitely for human use.

We have the scientific and technological ability to provide this abundant energy now, using fossil fuels and nuclear energy for the short term. In the long term, I am hopeful that we will have the energies of the sun itself -- nuclear fusion -- with which we can burn seawater to yield essentially infinite energy.

The greatest challenge we face regarding the first Malthusian law is population. In 1950, we had 2.5 billion people on our small planet. In 1980, we had 4 billion. Today we are approaching 6 billion. This is exponential growth.

Very few people have the slightest concept of what exponential change means, so let me give you an example. Suppose that I take a single sheet of paper and fold it over on itself so that the thickness is doubled. Now suppose that I repeat this process fifty times. How high will the paper stack be? The usual answer is about 12 inches, although occasionally a particularly generous one of "the Empire State Building" or "Mount Everest" comes back for shock value. What most people miss is that this is exponential growth, and that the stack of paper would thrust outward far beyond Mount Everest, far beyond the Moon, to somewhere in the orbit of the asteroid between Mars and Jupiter. Such is the power of exponential growth.

In the nineteenth century, Malthus's first law was end-run by the Industrial Revolution, which was one of the great watersheds of human development. It is important to remember, however, that the Industrial Revolution was nothing more than the application of energy, and of machines, to amplify the capabilities of man's muscles. Not only could feats of strength far exceeding man's own powers be performed, but they could also be performed over and over without boredom, without tiring, and without error.

The Industrial Revolution happened very quickly -- in less than a hundred years -- but it profoundly affected all aspects of life. It changed the quality of life, of health, of religion, of politics, and even of human birth and death. Once started it could not have been stopped or deflected; and during its course almost no one

recognized what was happening.

The question facing us today is whether an analogue to the Industrial Revolution can end-run the prospect of a continued and massive increase in the world's population. It will be a race between the development of the science and technologies needed to feed and provide for that population and the inexorable increase of human numbers. Your generation is the one that will determine the outcome of that race.

The Computer Revolution

As an example of the technologies that will be needed, let me turn to my second "Malthusian" law -- that our ability to cope with information is limited. Here again a revolution, the Computer Revolution, is under way. It, too, will happen quickly, it cannot be stopped or deflected, and although few recognize what is happening, it, too, will profoundly affect the quality of our lives.

In the case of the Computer Revolution, we are again using energy and machines, but this time to amplify the capabilities of the human mind. Not only can feats of calculation and information handling, sorting, and retrieval far exceeding human powers be performed, but they, too, can be performed at speeds millions of times faster, without fatigue and boredom, and without error.

Progress in this field has been little short of fantastic. In 1960, we could put a single active electronic device on a chip of silicon a few millimeters in diameter. In 1970, we could put a thousand devices on such a chip. In 1980, the number is one million, and the number is now around a billion.

To put this in better perspective, if the U.S. automobile industry had witnessed the same changes as the U.S. semiconductor electronics industry, a 1990 Cadillac would not cost about 10 cents, it would easily achieve 10 million miles per gallon, and it would be unconditionally guaranteed for at least 10 hundred billion miles.

Unhappily, 20 of them would fit comfortably on the head of a pin!

The Computer Revolution is just beginning, but it, too, is moving very rapidly.

The human brain, to provide an example, can handle about 10 thousand billion bits of information -- though it rarely does! To duplicate this capacity in 1960 would have required a computer that would have occupied a cube one-third of a mile on a side, would have consumed as much power as New York City, and would have melted the second it was turned on. By about 2040, assuming an extrapolation of current trends, it will be possible to duplicate the capacity of the human brain in a volume smaller than the brain's and power it from the biological power sources now available in each of us.

The day when our descendants discover that their toaster is smarter than they are will mark social change with a vengeance.

Your university is now at the forefront of the Computer Revolution through your Ohio Supercomputer Center; in fact, the center was set up entirely with state funds guided by the vision of individuals here in Ohio who recognized the vital importance of this technology.

The budget that President Bush sent to Congress last month includes a special Presidential initiative in high performance computing and communications. The overall goals of the initiative are symbolized by a set of what are called "grand challenges," problems of important scientific and social value whose solution could be advanced by applying high performance computing techniques and resources. They include global climate modeling, mapping the human genome, understanding the nature of new materials, problems applicable to national security needs, and the design of ever more sophisticated computers.

What is interesting to me is that many of these problems have already been studied extensively in the Ohio Supercomputer Center. We in the federal government will therefore be looking at your experience and guidance in establishing our own program. Similarly, the National Research and Education Network envisioned under the federal program is a nationwide analogue of the Ohio Academic Resources Network, which has been a central element in your center's rapid growth.

I personally believe that high performance computing and communications could have the kind of catalytic effect on our society, companies, and universities that the telephone system has had during the twentieth century. Particularly in the area

of education, the successful implementation of this program could bring changes that are essential to the future prosperity of this nation.

Educational Reform

I mention this area of education, because I believe that it is one of the greatest challenges -- and, at the same time, one of the greatest opportunities -- that we face. I am on record as believing that the United States still sets the pace and style for the whole world in graduate education. In fact, the foreign students who come to this country to study and then return home constitutes one of America's most valuable exports.

At the college level, although our quality variations are more extreme than elsewhere in the developed world, we remain competitive.

At the precollege level, however, we have fallen far behind our international competitors. If we cannot educate our young people properly, scientific and technological supremacy will inevitably pass from the United States to other countries.

The importance of science and technology is apparent in the National Education Goals established by the President and the nation's Governors last year. Of the six goals, three directly involve science and technology, including the most ambitious of the six, that American students be first in the world in science and technology by the year 2000.

We in the Administration realize that this, among all the goals, is the stretch goal. But we feel that it was very important to establish that goal, and it is driving a number of important reforms in education.

For one thing, an interagency committee under Secretary of Energy James Watkins has been taking a close look at the federal government's efforts in science and mathematics education and has been organizing those efforts into an integrated, government-wide program. In their recently released report, entitled "By the Year 2000: First in the World," the committee lays out strategic priorities designed to meet the educational needs of the country in this area. For example, at the precollege

level, which the report identifies as the highest priority for action, the greatest need is to increase the supply of well-trained science and mathematics teachers.

These federal efforts are important, but of course the federal government cannot achieve the National Education Goals by itself. It will take all sectors of society working together -- with the goals as a consensual statement of where we are headed -- to make the kind of progress they envision.

This is where your own university is again leading the way. Through programs like your Young Scholars Program, you are reaching out to all levels of the educational system -- and to groups that have traditionally been underrepresented in our nation's college and universities. Your efforts are truly models for the rest of the country, as we seek to prepare all of our children for the challenges of the future.

Conclusion

Many of you may be thinking that there is nothing that you, as individuals, can do about the problems and issues that I have been discussing today. You could not be more wrong. Your generation is the critical one. Your generation will rekindle pride in being a citizen of this great country, will rebuild our economic and technological strengths, and will strengthen U.S. leadership in the world -- so that all of us can hold our heads a little higher.

If you fail, we may never get another chance. But I am convinced that you will not fail. Each of you can and will make a difference in whatever you do. And it bears emphasis that this is still the only country in the entire world where there are no artificial limitations on what you can do, what you can become, and how far you can go.

I want to conclude with a passage from a paper that H.G. Wells published in 1902, in an article entitled "The Discovery of the Future." He wrote: "It is possible to believe that all the past is but the beginning of a beginning, and that all that is and has been is but the twilight of the dawn. It is possible to believe that all the human mind has ever accomplished is but the dream before the awakening. . . . All this

world is heavy with the promise of greater things, and a day will come, one day in the unending succession of days, when beings, beings who are now latent in our thoughts and hidden in our loins, shall stand upon this earth as one stands upon a footstool, and shall laugh and reach out their hands amidst the stars."

It is essential that we not lose sight of this vision from the opening of this century as the century now comes to a close. These are the beliefs that we will need to deal with today's problems. They are problems that will demand all our vision, all our skills, all our wisdom, and all our experience, and only by working together can we hope to survive. But I, for one, remain optimistic about the outcome.

On behalf of those of us whom you may feel have received our Ohio State degrees today with considerably less work than was required of you, let me only say how honored and privileged we are to be able to join this very select group -- The Ohio State University Class of 1991.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

U.S. INDUSTRY ACCESS TO JAPANESE SCIENCE AND TECHNOLOGY

D. ALLAN BROMLEY

**Assistant to the President for Science and Technology
Executive Office of the President**

**Conference on U.S. Industry Access
to Japanese Science and Technology
Washington, D.C.
March 27, 1991**

It is a pleasure to be here to open this conference on "U.S. Industry Access to Japanese Science and Technology." International cooperation and competition in science and technology are issues of vital importance to this country, and that importance is only going to grow as markets and technology transfer become increasingly global.

In part, the increasing globalization of economies is a reflection of the widening influence of science and technology in our lives. Science and technology have always been among the most international of all human activities. It is frequently the case that scientists and technologists are on more intimate terms with colleagues on the other side of the globe than they are with those at the other side of the hall. What happens in Japan or Germany in biology is often of much more interest to a biologist than what happens across the campus.

At an even more fundamental level, the globalization of markets reflects a deeper transition from predominantly resource-driven economies to information-driven economies. As Walter Massey, the new Director of the National Science Foundation, has said, "The resources that are most critical to progress today are no longer mined from the Earth but are created in the mind."

Francis Bacon said much the same thing four centuries ago in his Religious Meditation. He wrote, "Nam et ipsa scientia potestas est," which translates as "knowledge itself is power." I might add, by the way, that since coming to Washington I've heard that when Senator Everett Dirksen first heard this quotation, he immediately replied, "particularly if you know it about the right people."

This morning I would like to begin by discussing the United States' general policies toward science and technology. I shall then turn specifically to international science and technology, which Bob White will then examine in more detail.

Importance of Science and Technology in Government Policy

Today, science and technology are integral elements of both domestic and international policy in the United States. One place where this can clearly be seen is in the budgets that President Bush has sent to Congress for the past two years. In both of those budgets, science and technology were among the very first items featured, second only to increasing the national savings rate (in the FY 1991 budget) and to education and preventive health measures (in the FY 1992 budget).

In general, the Bush Administration views science and technology as key investments in the future economic prosperity and national security of this country. The past investments we have made in science and technology have paid great returns in economic growth and in improved quality of life. These returns are going to continue, most likely at an accelerating pace, in the years ahead, and they must be made available to all of our citizens.

In the Fiscal Year 1992 budget, the President proposed a record \$75.6 billion for research and development, a 13 percent increase over the amount Congress appropriated for FY 1991. In a year when real growth in the domestic discretionary budget is essentially limited to the rate of inflation, this increase for R&D -- one of the largest in the federal budget this year -- marks a major commitment to science and technology. Furthermore, these funds came at the expense of other programs with strong constituencies.

An area of major emphasis in this year's budget is basic research. To take advantage of the countless scientific opportunities available to researchers at our nation's colleges and universities, the budget proposes an 18 percent increase in funding for the National Science Foundation -- with 16 percent required to be passed down to the fundamental sciences -- and a 9 percent increase in funding for research project grants awarded to individual investigators at the National Institutes of Health. By focusing on these two agencies, the Administration is seeking to strengthen the individual investigator and small group research that remains the heart and backbone of American science and technology.

Yet basic research clearly cannot be the only component of a nation's R&D

enterprise. Other nations -- such as Japan -- have R&D enterprises that bring great benefits to society yet include relatively less basic research. The difference is that these systems are able to very efficiently and effectively exploit the results of basic research, no matter where it is done. This is the stage of the innovation process -- the stage between the generation of knowledge and its application in the marketplace -- that poses the greatest challenges to the United States.

To help strengthen the latter stages of the innovation process, the budget includes funding for many areas of applied research and technology development, including high performance computing and communications, energy technologies, biotechnology, advanced manufacturing and materials, and aeronautics. To take just one example, the budget includes a special Presidential initiative on high performance computing and communications, which is designed to sustain and extend America's preeminence in this critically important area of technology. This program, which was put together by an interagency committee organized through my office, focuses on the hardware, software, networks, and human resources that will be necessary to increase computing and communications capabilities by several orders of magnitude. In my view, these new capabilities could have the kind of catalytic effect on society, businesses, and universities that the telephone system has had during the twentieth century. Moreover, perhaps the greatest impact of the program will be on college and precollege education.

The budget emphasizes a number of areas of applied research and development. In fact, it goes so far as to state that it is providing increased funding "for all major civilian applied R&D areas." This is an important measure of the Administration's intentions.

In a speech to the recipients of the National Medals of Science and National Medals of Technology last fall, the President said, "Today, our government must help carry [basic] research forward and contribute to the development of generic technologies that build on basic discoveries. If America is to maintain and strengthen our competitive position, we must continue not only to create new technologies, but learn to more effectively translate those technologies into commercial products. In this way, we can help leverage the R&D of the private sector, helping whole industries

advance in an increasingly competitive global market." As part of this commitment from the highest levels of government, applied research and technology development are going to be increasingly important federal emphases.

Science and Technology Policy in the Executive Branch

Let me describe for a moment the institutional structure within the Executive Branch that shapes science and technology policy, because it is important both in developing the budget numbers I have been describing and in considering international science and technology. As science advisor to President Bush, I wear several different hats. First, I am one of the 12 assistants to the President and therefore a member of the senior White House staff. In my role as Assistant, the President has also made me a member of the Economic Policy Council, the Domestic Policy Council, and the National Space Council, which are three of the senior policy-making bodies within the White House.

At the same time, I am the only one of the President's assistants who is Senate-confirmed and thus also reports to the Congress. I do this in my capacity as Director of the Office of Science and Technology Policy within the Executive Office of the President. This office, which was created in 1976, serves several functions. It helps me in the preparation of the information, analysis, and advice that I provide to the President in science and technology policy. It works closely with the Office of Management and Budget in reviewing and shaping R&D budgets within the federal government. And in general it monitors and acts as a source of information for the President and the rest of the Executive Branch on what might be termed policy for science and technology -- the influence of federal actions on the science and technology enterprise -- and science and technology for policy -- the influence of scientific and technological considerations on broader issues of national and international importance.

The same legislation that created OSTP also created an entity called the Federal Coordinating Council for Science, Engineering, and Technology, which goes by

the rather unfortunate acronym of FCCSET. FCCSET is a Cabinet-level entity that was established to review and coordinate activities in science and technology that cut across the missions of more than one federal agencies. The members of FCCSET now consist of the Secretaries and Administrators of the departments and independent agencies, respectively, involved with science and technology. With this level of representation, FCCSET is having a major impact on science and technology activities throughout the federal government.

Following its reorganization last year, FCCSET formed seven umbrella committees in science and technology. One of these is the Committee on International Science, Engineering, and Technology, which is chaired by Reggie Bartholomew, with Fred Bernthal of the National Science Foundation and Philip Schambra of the National Institutes of Health as Vice-Chairmen. That committee has initiated a number of activities in such areas as the intellectual property protection annexes in science and technology agreements and international cooperation on megaprojects in the basic sciences.

It is important to keep in mind when considering FCCSET, however, that all of its members, by law, must be government employees. Obtaining the private sector's input on matters of science and technology was one of the reasons why the President established his Council of Advisors on Science and Technology (PCAST). This is a group of twelve distinguished representatives of industry and academia that meets monthly with the President and with other high members of the White House staff to discuss a broad range of issues in science and technology. Furthermore, PCAST has been setting up panels in specific areas of science and technology, many of which parallel the FCCSET committee structure so that the private sector's views can be used to calibrate the activities of the federal government.

International Science and Technology

Having described the institutional structure that will be shaping science and technology policy, I want to spend some time addressing the question of international

research and development -- and particularly the concern of this conference, access to Japanese science and technology.

I believe very strongly in international access to basic science and basic technology, and particularly in the free flow of researchers and ideas. Unlike some other forms of international exchange, science and technology are positive sum games where international cooperation benefits all participants. The question is not whether a country gains or loses from such cooperation. The only question is the magnitude of the gains. To quote my friend and predecessor William Graham's version of an old adage, "Science is the rising tide that raises all ships."

There is no question that other countries are building on our basic research. But we unquestionably gain much more by maintaining an open system than we could by trying to build barriers. Rather than restricting access to our technology, we gain by developing capabilities greater than our competitors. Thus there is a very strong link between our domestic activities in science and technology and our international efforts. By further developing our own science and technology enterprise, we will inevitably strengthen our international standing in the marketplace.

Some individuals, recognizing the link between our national science and technology and international competitiveness, have called for restricting international access to U.S. science and technology. For basic research and the development of precompetitive technologies, I believe these calls to be misguided. After all, in the early years of our development, the U.S. technical community relied heavily on access to European science and technology.

But we do need to do a better job of monitoring and drawing on technologies from abroad, including Japan. The Commerce Department has mounted some ambitious, if still underused, programs in this area, and I know you will be discussing them later today and tomorrow. These and similar programs will continue to grow in importance as other countries become even more competitive in science and technology.

We must also work to ensure that individual researchers and private sector firms are able to participate in R&D endeavors in the other country's territory to the same extent that domestic researchers in that country can do. Although there may be

projects for which these rules do not apply, we should strive to achieve a level playing field for all parties.

Finally, we should continue our efforts to see that all countries share in the responsibilities of investing in basic research. Basic research is a "public good" in the economic sense that it is freely available to all. Thus, all countries who benefit from basic research have a responsibility to invest in that research.

The Protection of Applied Technology

At some point in the continuum between basic research and the development of commercial products, R&D moves from being precompetitive to competitive. Because this point is not always well defined, some countries tend to be overcautious in defining R&D as competitive.

I am convinced, however, that the line between competition and cooperation can be sharply drawn. The results of fundamental research are, by their very nature, public knowledge. What can and, in some cases, must be protected are the details of a particular application of the results of this fundamental research. This know-how, in the final analysis, is our only edge in an increasingly competitive world.

What this country needs to do is be much more focused on those aspects of technology that we want to protect. Rather than trying to protect a broad range of technologies, we have to focus on the particular technologies -- and particularly on the systems integration inherent in technologies -- and protect those things as firmly as we can.

As part of this effort, we have to be much more vigorous in enforcing intellectual property rights than we have been in the past. Of the three sectors of American industry that have remained most successful internationally during the 1980s -- the pharmaceutical industry, the chemical industry, and the aeronautics industry -- two of those have the strongest IPR protection of virtually any American industry. The protection of intellectual property has been a key element in their success.

We are reviewing our international science and technology agreements to ensure that research pursued in cooperation with foreign countries is subject to strong IPR protection. As many of you may know, IPR protection is also a major element of the Administration's objectives in the multilateral trade talks convened under the GATT.

We also have to identify much earlier than we have in the past exactly what we want to get in return for our technology. All too frequently in the past we have sent representatives to international negotiations without clear instructions on what we wanted to get and what we were prepared to give, and not surprisingly we have sometimes come out of those negotiations without the results that we might have wished. I will be doing my best to make sure that such lopsided negotiations do not happen in the future.

Future International Cooperation in Science and Technology

In general, I see international cooperation becoming an even greater feature of science and technology policy in the future. For example, we are about to design a program to determine future cooperation with the Japanese and others on Intelligent Manufacturing Systems, and the Japanese have proposed another program on advanced computing. In these efforts, we are taking a number of steps to ensure that openness and international cooperation strengthen the competitiveness of our economy and our nation's science and technology capabilities.

The reciprocal benefits of science and technology are the main reason for my being here today, and for OSTP being a cosponsor of this conference. Access to science and technology in Japan and in other countries is going to be vitally important to the continued vitality of American science and technology. If our own science and technology enterprise is to remain health, we must ensure that we know and appreciate what is going on internationally.

For many years the United States has had the strongest science and technology enterprise that the world has ever known, but the world situation is now changing. Our overall preeminence is not being challenged. But in specific areas, other

countries, by focusing their efforts into particular areas, have moved up to equal, and in some cases surpass, the scientific and technical achievements of this country.

We have nothing to fear from these international achievements. Rather, we should view them as opportunities. Still, to take advantage of these opportunities, we must have and take advantage of access to foreign science and technology. Those of you in this room -- as well as scientists, engineers, and managers throughout this country -- must make a concerted effort to look beyond our own borders to the renewed scientific and technological expertise of the world.

The development of this expertise should not surprise us. As I said at the beginning of my remarks, science and technology are inherently international activities, and other countries were bound to recognize and emulate the successes that American science and technology has brought to this country. But the great benefit of science and technology is that they can make the world better for everyone. As Louis Pasteur once said, "Science knows no country because knowledge belongs to humanity and is the torch which illuminates the world."

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

FEDERAL RESEARCH AND DEVELOPMENT
AND THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY

STATEMENT BY

D. ALLAN BROMLEY

DIRECTOR

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

BEFORE THE

SUBCOMMITTEE ON VETERAN'S ADMINISTRATION,
HUD, AND INDEPENDENT AGENCIES

COMMITTEE ON APPROPRIATIONS

U.S. SENATE

APRIL 24, 1991

Madam Chair and members of the Subcommittee:

It is a great pleasure to once again appear before you, as Director of the Office of Science and Technology Policy, to present testimony and answer your questions on the Administration's proposed Fiscal Year 1992 budget for research and development as well as the Administration's science and technology policies. I will also discuss the operations and accomplishments of my office during the past year and present our budget request for Fiscal Year 1992.

In continuing an approach adopted in the first budget submitted to the Congress by President Bush, research and development are given special emphasis in the Fiscal Year 1992 budget request. This is a reflection of the Administration's overall emphasis on investing in the future. Like spending on education, preventive health care, and our national infrastructure, our investments in research and development can be expected to return benefits many times over the expenditures.

These benefits can be measured not only in economic terms but in terms of enhanced national security, improved environmental quality, expanded intellectual and cultural vitality, and a widening international influence of our central political and social principles. It is no coincidence, I believe, that freedom of inquiry and expression, which are bedrock principles of both our political and scientific systems, are rapidly gaining strength around the world. Spurred on by the vastly increased communication capabilities made possible by technological advances -- primarily initiated here -- a dramatic shift in world outlook is occurring in what is a relatively short period of time in history.

While much has been said and written in recent years about our declining international economic competitiveness and a diminished role for the United States in the world, much of this has been overdone. I do not mean to gloss over real problems and the need to address them vigorously, but I remain an optimist and a deep believer in the fundamental strengths and values of this nation. From my own perspective as a scientist as well as an official of the Bush Administration, I see the opportunities before us as virtually boundless.

The essence of the collective decision that you in the Congress, we in the Administration, and the American people face is one of choice: whether or not to grasp these opportunities in defining and developing our role in what the President has called a "new world order." In the midst of rapid worldwide change, it is especially important to look beyond the present day and current problems to the potential for the future. As we approach the important psychological milestones of a new century and a new millennium, I see the decade of the 1990s as a precursor to a vast national and worldwide vigor and growth in the Twenty-First Century. And I fervently believe that science and technology will continue to play powerful and influential roles in these unfolding events.

In support of this broad theme, the President's Fiscal Year 1992 budget proposes to invest \$75.6 billion for research and development, including R&D facilities, an increase of 13 percent over the amount Congress appropriated for FY 1991. Civilian R&D would go up 9.5 percent, to \$28.8 billion; defense-related R&D would rise 14.5 percent, to \$43.3 billion. Funding for basic research is slated for an 8 percent increase, to over \$13 billion; support for R&D facilities would rise 15 percent, to over \$3.5 billion.

I will return to specific budget highlights and initiatives shortly. But first I would like to spell out important objectives of the Administration related to science and

technology and identify several criteria or policy rationales for investing in R&D in support of these objectives.

BROAD ADMINISTRATION GOALS AND POLICY RATIONALES RELATED TO SCIENCE AND TECHNOLOGY

A wide range of programs, activities, and organizational measures are included in the FY 1992 Budget. In general, these measures support the following objectives:

- o Ensuring that the United States continues to lead the world in science and technology.
- o Maintaining and enhancing the domestic science and technology base.
- o As part of the science and technology base, ensuring excellence in science and mathematics education at all levels.
- o Applying science and technology to the resolution of domestic social concerns.
- o Encouraging and supporting the application of science and technology in enhancing economic growth in the United States.
- o Enhancing national security through a strong capability for national defense.
- o Promoting increased international understanding through scientific cooperation and exchanges.

While each of you has a long familiarity with the arguments for federal support of research and development and this subcommittee has a decades-long track record of being in the congressional vanguard of supporting research and development, I would like to take a few minutes to review with you the basic policy rationales that were used to develop the FY 1992 budget in support of the above objectives. These rationales can be divided into four broad and partially overlapping categories: (1) investing for the future, (2) meeting national needs, (3) exploring intellectual, social, and physical frontiers, and (4) building on the fundamentally international character of science and technology.

Investing for the Future

In the first category, that of investing in the future, it has long been known that spending on research and development has a very high rate of return. Economists estimate that more than one third of the growth of the U.S. economy since 1930 has been due to research and development. Evidence from the past four decades suggests that industry-financed R&D alone accounts for about one third of the annual average

growth of productivity over that period.

Besides fostering economic growth, science and technology have helped to improve the quality of our lives. New vaccines and treatments for disease, greatly enhanced mobility, a wider range of foods and other products, improved accommodations, and new forms of recreation and entertainment have all made our lives more comfortable and more fulfilling.

The return from research -- particularly the basic research done largely at colleges and universities -- is not easy to quantify, but an initial attempt has been made by the distinguished economist Edwin Mansfield of the University of Pennsylvania. Looking specifically at academic research, he found an average social rate of return to past investments in R&D of 28 percent. Others have estimated rates of return from all R&D expenditures -- that is, basic and applied research and development -- ranging from 20 to 200 percent. In comparison, companies normally expect to receive returns on the order of 10 percent from investments in other areas such as plant and equipment.

Examples of research and development that lay the groundwork for future advances in both the public and private sectors can be found in many areas -- in agriculture, space science, economics, mathematics, biology, psychology, chemistry, engineering, earth science, physics -- indeed, throughout all of science and technology. However, returns from research and development -- and particularly basic research -- are not instantaneous. Depending on the type of research and the field in which it is done, the payoff may not come for many years. This time lag underscores the importance of R&D as an investment in the future, wherein a lack of investment now may result in diminished productivity in the next generation. Furthermore, these shortfalls cannot be instantaneously reversed by spending when the problem is noticed. It is our vigilance now that will make future technological growth possible.

Meeting National Needs

Another criterion applied to proposed programs in science and technology is whether they meet a pressing national need of immediate importance. The President's FY 1992 budget provides continued and, where appropriate, increased support for a broad range of federal R&D activities that address identified needs in areas such as energy, the environment, national defense, advanced technology, health, and education.

Many kinds of research and development are required to meet these needs. As an example, I might cite the U.S. Global Change Research Program, which has been organized by the Committee on Earth and Environmental Sciences under the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). The budget requests a total of almost \$1.2 billion for this program, an increase of 24 percent or \$232 million. This amount will virtually double the size of the program since it was started in fiscal year 1990. Much of this work is basic research designed to document, understand, and predict the functioning of the Earth system on a global

scale, yet it still meets an immediate and pressing need: that of producing the scientific knowledge that world leaders and the general public need to address such issues as global climate change and ozone depletion.

Another example of civilian R&D that meets important national needs can be found in the initiative in high performance computing and communications proposed in this year's budget. This initiative is based on a program put together under another FCCSET committee, the Committee on Physical, Mathematical, and Engineering Sciences. The program is organized around a number of "grand challenges" -- critical unsolved problems that can be addressed through the power of high performance computing. Furthermore, the provision in the initiative of a nationwide research and education network is designed to greatly increase the number of individuals with access to high performance computing and communications, including students throughout the country and at all educational levels.

National security is another example I might cite of a national need requiring both basic and applied research. The superiority of the current generation of U.S. military systems, as dramatically demonstrated by the Desert Storm campaign, is a direct result of decisions made in years past to harness American technical creativity in the development of military systems of unparalleled performance and quality. Costly though some of these systems were, they have been responsible for saving the lives of Americans, our allies, and our adversaries. As the United States enters the 1990s, the strength of our R&D in defense technologies must be sustained.

Finally, as I described to you in the hearing yesterday, a particularly critical national need in the United States today is the need to reform and revitalize education, particularly at the precollege level and particularly in mathematics and science. The nation is now recognizing the gravity of the problems affecting precollege education in science and mathematics. Within the federal government, a groundbreaking interagency effort under FCCSET's Committee on Education and Human Resources has been working to maximize the effectiveness of the federal contribution to science and mathematics education. I shall return to this effort below.

Exploring Intellectual, Social, and Physical Frontiers

By emphasizing the economic and social returns of R&D, I do not mean to imply that all research must have an immediately discernable payoff. We are by nature a curious and inquisitive species, and great nations thrive by fostering these basic human drives. When nations pull back from the frontiers -- intellectual or physical -- they tend to decline. If we are to prepare for what the President has called "the next American century," we must continue to pursue the frontiers, as we have throughout this nation's history.

Few frontiers have ever been as dynamic and as full of promise as science is today. The number of opportunities in science is unparalleled, partially because past funding for research and development has opened up a wide variety of new areas of inquiry.

For the past several centuries, the quest for scientific understanding has been one of the greatest adventures available to mankind. It is an adventure that has fundamentally changed our view of the world around us, and it will continue to do so in the future.

I would also emphasize the role of the social and behavioral sciences in this enterprise. The quest for new knowledge has altered our understanding of ourselves and of how we, as human beings, function in social and organizational contexts. The study of human behavior and social organization is as much a part of the grand adventure of science as are investigations in physics, chemistry, biology, geology, and astronomy.

The challenge of exploring new frontiers is also one justification for human expansion into space. Our standing as a world leader will continue to be measured, in part, through the commitment we make to exploring the space frontier. In addition, space exploration provides more tangible benefits in the form of new products and processes for industry and government, a stronger scientific and technological base, and a focus of attention for scientists and nonscientists alike.

Over the past year, the U.S. space program has been undergoing an intensive and very healthy review, and as a result the program is undergoing important changes. These changes, to which I shall return later, can be expected to produce a greatly strengthened space program.

Building on the Fundamentally International Character of Science and Technology

Scientific and technological research, whether funded directly by the government or by private industry or institutions, has always been among the most international of human activities. Science transcends national boundaries even when political differences restrict exchanges in other areas.

Because of the growing importance of science and technology and its transnational nature, the United States has been presented with a tremendous opportunity to better integrate science and technology into our foreign policy objectives around the world. Areas of particular promise and challenge include global environment change, large projects in the basic sciences, and the growth, use, and management of information and information technologies. Coordinating our planning and support of work in these areas with the activities of other countries is essential.

HIGHLIGHTS OF THE BUDGET

Having established some of the criteria applied in judging science programs, let me describe some of the areas of emphasis in the FY 1992 R&D budget and some of the issues that arise in considering the nature of that support.

Basic Research

The first area of emphasis in the budget is basic research. Basic research accounts for only about 15 percent of the total spent on all research and development done in the United States. But basic research -- and particularly the large fraction of basic research done in universities and colleges -- is an indispensable part of the nation's R&D enterprise. Indeed, it is the wellspring from which new knowledge and technical advances flow.

The federal government now supports more principal investigators at universities than ever before, reflecting real increases in the level of federal support for academic research. However, the number of such researchers competing for funds has increased even faster, which is largely a result of the emergence of exciting new scientific opportunities and of our past successes in training high-quality doctoral-level scientists and engineers. There has also been pressure to increase the size of such individual investigator grants -- reflecting the increased complexity of science (sophistication inflation) -- and to extend the duration of grants -- to promote stability of support and to reduce the fraction of researchers' time and effort devoted to paperwork rather than research. Both of these changes increase out-year mortgages. Such factors have caused the competition for available research funds at agencies such as the National Science Foundation and the National Institutes of Health to become so great that the situation has become a matter of serious concern in the research community.

Recognizing the many essential contributions of basic research, especially at universities, to our national future, the Fiscal Year 1992 budget proposes actions in several federal agencies designed to strengthen the individual and small group investigator component of the scientific enterprise. At the National Science Foundation, the President has reiterated his commitment to double the NSF's budget between 1988 and 1994. The budget proposes an 18 percent increase -- over \$400 million -- for NSF, bringing it to a total of \$2.72 billion. Support for the conduct of research, almost all of which is basic research in NSF, will increase by \$284 million, or 16 percent, to a total of \$2.1 billion. I sincerely hope that, this year, Congress will be able to sustain these increases, especially given that in recent years appropriations for research activities at NSF have fallen short of the increases needed.

In addition, the budget proposes a crucial \$50 million initiative at NSF -- matched at least 50:50 by nonfederal funds -- to improve the research infrastructure by providing state-of-the-art instrumentation to university researchers. As with research funding, support for this instrumentation will be distributed on the basis of a competitive, merit-reviewed process.

At the National Institutes of Health, the President has proposed an increase of \$334 million for basic research, or 7 percent, to a total of about \$5 billion. Total funding for NIH would go up 6 percent to about \$8.8 billion, and total funding for R&D

within the Department of Health and Human Services would also rise 6 percent to a total of about \$10 billion. These amounts would allow for an increase of 9 percent in NIH's funding for research project grants awarded to individual investigators, providing for a broad base of fundamental advances. In addition, within the NIH total, \$110 million is allocated to the Human Genome Program, with an additional \$59 million in funding from the Department of Energy, resulting in an overall increase for the program of 26 percent.

Together, NSF and NIH support over half of the federally funded basic research done in the United States, and over 75 percent of the federally funded basic research done in universities. By focusing special attention on these agencies, the Administration plans to strengthen the individual investigator and small group research that remains the heart and backbone of American science and technology.

In other agencies, the budget calls for the Department of Energy to fund \$1.76 billion of basic research into biological, environmental, and basic energy science and into nuclear and high energy physics. Funding for the Superconducting Super Collider is set at \$534 million for FY 1992. This total is \$291 million above the amount appropriated in fiscal year 1991 and will allow the SSC to proceed on schedule.

At the Department of Agriculture, the National Research Initiative, which is a merit-based competitive research grants program open to investigators across the nation, is proposed to increase by 71 percent, to \$125 million. This program will broaden the nation's science and technology base through research in such areas as food safety, water quality, global change, pest management, and farm income. In addition, the budget proposes a \$25 million facilities program at USDA necessary to support the National Research Initiative.

Finally, science research in the National Aeronautics and Space Administration is slated to rise by \$262 million -- to a total of \$1.96 billion -- largely reflecting increases in space and environmental science. These funds will support an exciting program of ongoing investigations, including studies using the Hubble Space Telescope, the Gamma Ray Observatory to be launched later this spring, and continued construction of the CRAF/Cassini probes and the Advanced X-Ray Astronomy Facility.

Research Infrastructure

One important consideration in the ability of universities to perform research efficiently and effectively is the adequacy of their research facilities and equipment. To sustain a strong national research capability and to expand the nation's research capacity, the R&D infrastructure must be maintained and replenished.

Since federal procedures were established for the support of R&D following World War II, the overwhelming majority of federal funds for research at universities has been allocated on the basis of excellence, as determined by a competitive process of

peer review. This approach serves to maximize the potential return on these investments by selecting only the highest quality research for support. Even programs that are more directed, such as the Experimental Program to Stimulate Competitive Research (EPSCoR), which is designed to bring geographically diverse research efforts to nationally competitive levels, are focused on excellence in that scientific merit remains a primary criterion for selection among eligible projects.

In recent years, the focus on excellence has been increasingly threatened by the practice of Congressional earmarking of funds for specific projects. According to an analysis of the FY 1991 budget conducted within my office, about \$427 million was appropriated for such projects at universities in 1991. Earmarked projects typically do not undergo merit review, and thus their potential for contributing to scientific advance is often unknown. In the present era of tight budgets and spending caps, earmarking has the effect of substituting projects of unknown scientific merit for ones that have had careful examination of their scientific merits and thus threatens to weaken the nation's R&D effort.

The budget sent to Capitol Hill each year for research and development represents the Administration's best judgment as to the proper balance in using scarce resources. Earmarking distorts this balance. The Administration looks forward to working with you on ways to reduce the perceived need for earmarking.

Technology Development

Applied research and development activities funded by the federal government fall into several broad categories. One category is applied R&D that supports agency missions in such areas as national security, health, energy, and space. Another is applied R&D aimed at generic or enabling technologies that have many applications in the public and private sectors. Because of the many benefits to be gained by supporting this work, the budget provides increased funding for major areas of applied research and development.

Many issues related to federal support for technology development are discussed in the publication "U.S. Technology Policy" released last September by OSTP. This document lays out the many ways in which the federal government influences technology development and, more broadly, economic competitiveness. It deals with the strength of the science and technology base, education and training, technology transfer, private sector incentives, and federal-state activities. Most important, it provides a baseline for future dialogue and discussion of technology issues, both inside and outside of the government.

An excellent example of technology development in the FY 1992 budget is the Presidential initiative in high performance computing and communications that I mentioned earlier. The President has proposed an increase of \$149 million or 30 percent -- to a total of \$638 million -- for an interagency effort designed to extend U.S. leadership in all advanced areas of high performance computing and networking.

Part of this program consists of basic research at the nation's universities designed to develop the hardware, software, networks, and human resources needed to ensure American leadership in all advanced areas of computing and networking. An additional and very important component of the program consists of applied research and development of technologies that will form the basis for tomorrow's computer and communications industries.

Another important example of federal applied research and technology development -- particularly given the events of the past few weeks and months -- is targeted high-payoff energy technologies. Guided by the National Energy Strategy, the budget proposes a major initiative to develop technologies that could increase the efficiency of energy use, provide alternatives to petroleum, and advance new electricity technologies. About \$900 million -- an increase of 34 percent in the targeted areas -- is proposed for this work.

In the area of advanced manufacturing and materials, the budget proposes to invest about \$1.3 billion, including over \$1 billion for research and development on advanced manufacturing technologies. About half of this manufacturing R&D supports the procurement needs of government programs, but the other half is focused specifically on generic manufacturing technologies. An increase of 15 percent is proposed for civilian manufacturing R&D. In the area of materials research and development, the budget proposes \$84 million for a new initiative in the National Science Foundation intended to strengthen the position of the United States in next-generation materials synthesis and processing. Initially, two high-payoff areas will be emphasized: electronic and photonic materials, and biomaterials.

Within the Department of Commerce, and specifically within the National Institute of Standards and Technology, the Administration proposes a 15 percent increase, to a total of \$248 million, to expand NIST's ability to perform generic applied research and technology development and to address a rapidly growing number of important standards and measurement issues. Long-term projections for NIST call for a budget that is approximately doubled by 1996. These increases will allow NIST to conduct research and provide laboratory support for manufacturing technologies, information technologies, and other emerging technologies that are extremely important to the U.S. economy. In addition, the FY 1992 budget includes \$36 million for the Advanced Technology Program to help fund industry-led high-risk R&D on generic, precompetitive technologies.

To extend U.S. leadership in aeronautics, the budget proposes \$543 million for aeronautics research and development in NASA, an increase of 13 percent. The program will address, among other items, high-temperature engines, issues associated with supersonic flight, and the aging of today's aircraft. In addition to this work, the budget proposes \$305 million for the National Aerospace Plane (NASP), a joint NASA-DOD program, for technology development leading to a 1993 decision on an experimental flight research vehicle. Investments in NASP and enabling technologies are vital to future generations of military and civilian aircraft and to U.S. preeminence in these critical areas.

Biotechnology has become one of the most exciting frontiers in science, offering enormous potential in medicine, agriculture, and industry. In the budget, the President has allocated \$4.1 billion to support biotechnology R&D. Over 80 percent of this amount is in the NIH budget, largely in the form of basic research, but 11 other agencies also support programs directly or indirectly related to biotechnology. The budget's emphasis in this area is designed to maintain America's lead in this rapidly growing field and, at the same time, generate fundamental advances in such areas as gene therapy, agriculture, and environmental cleanup.

Finally, let me mention a related item that does not directly involve federal outlays but has a key effect on our ability to secure R&D investments in the future. For the past several years, Congress has been renewing the research and experimentation tax credit on an annual basis, but it has never made the credit permanent, and this has greatly diminished the credit's effectiveness. The Administration is again calling on Congress to make the tax credit permanent this year to help reverse the recent leveling-off of corporate R&D investment and expand its scope.

The Organization of Applied Research and Development

In the government's support of applied research and technology development, an important factor is the way that it chooses to support that R&D. The technology initiatives cited above tend to be most effective when pursued through collaborative, cost-shared efforts among government, industry, and universities. Where appropriate, R&D should be industry-led with cost sharing and a division of research activities among industry, universities, and government labs.

The formation of industry R&D consortia is another way to encourage private sector-public sector cooperation. Examples of such cooperation are SEMATECH and a new venture involving the Department of Energy, Ford, General Motors, Chrysler, and EPRI on R&D on batteries for electric vehicles. By pooling resources, individual participants do not each have to reinvent the technological wheel but have access to the results of efforts that are several times the investment of any single company.

Together, these organizational arrangements are designed to foster a new, more results-oriented approach to technology development. They have the effect of building technology transfer into the process from the outset rather than attempting to weld it on at the tail end of a project.

The examination of technology development issues is now being pursued by the National Critical Technologies Panel, which was formed last year under the auspices of OSTP. This private sector-public sector panel, which is chaired by William Phillips, OSTP's Associate Director for Industrial Technology, has been examining a number of technologies important to the future economic health and national security of the United States, and the list of critical technologies developed by the panel will be released tomorrow at two Congressional hearings.

In addition, OSTP is now in the process of establishing the Critical Technologies Institute, as directed by the Congress, which will assist in the development of strategies that will follow up on the panel's work in these critical areas.

Expanding the Geographic Frontier: Space Exploration

This year's budget makes a very strong commitment to the scientific components of the space program, in keeping with the report of the Advisory Committee on the Future of the U.S. Space Program (the Augustine report). It proposes \$2.1 billion, an increase of 21 percent over FY 1991, for NASA's space science programs, including astronomy, life sciences, planetary exploration, Earth science, and materials research. This represents about 20 percent of NASA's total budget, which is also in keeping with the Augustine Report.

NASA's proposed \$15.7 billion budget also includes support for a Mission To Planet Earth and a Mission From Planet Earth. The Mission to Planet Earth is a vital component of the nation's overall integrated global change program. It includes initial support for the Earth Observing System (EOS), which, for the first time, will make simultaneous observations of the earth's surface by a whole suite of complementary instruments. EOS is an integral part of the U.S. Global Change Research Program coordinated by FCCSET's Committee on Earth and Environmental Sciences.

The Mission from Planet Earth -- which includes Space Station Freedom and the Space Exploration Initiative -- supports the goal of expanding the human presence away from Earth and into the solar system. Continued development work on Space Station Freedom is funded at about \$2 billion, taking into account the ongoing modification of the station to focus on life sciences and microgravity and reduce its operational complexity. The Space Exploration Initiative is funded at about \$250 million, including activities in the Departments of Energy and Defense, and as recommended in the Augustine Report is being planned on a "go-as-you-pay" basis.

The budget also recognizes the critical importance of space transportation as the foundation of all U.S. space activities. The budget proposes \$350 million (split evenly between DOD and NASA) to continue advanced rocket engine development and to initiate a program that will culminate in the development of a new space launch system. The program's goal is to provide new launch capability for a range of payloads, including heavy-lift, that is both more capable and more cost-effective than today's systems and that will benefit both unmanned and manned space activities.

Mathematics and Science Education

Over the past year, FCCSET's Committee on Education and Human Resources, which is chaired by Secretary of Energy James Watkins and vice-chaired by Ted Sanders of

the Department of Energy and Luther Williams of the National Science Foundation, has been examining the federal government's support of science and mathematics education. Guided by the National Education Goals established by the President and the nation's governors, the committee has developed a strategy to maximize the effectiveness of the Federal contribution to American science and mathematics education.

The recently released report of the committee, entitled "By the Year 2000: First in the World," lays out strategic priorities designed to meet the educational needs of the country in this area. At the precollege level, which the report identifies as the highest priority for action, the greatest need is to increase the supply of well-trained science and mathematics teachers. Other areas of emphasis include improving curricula, developing new educational technologies, and increasing student interest and performance in science and mathematics, particularly among women and minorities. Similar strategic priorities have been developed for undergraduate and graduate education. It is important that in our efforts to correct a dismaying series of problems at the precollege level we not lose sight of the importance of maintaining our world leadership in graduate education.

The committee also presents, for the first time, a comprehensive interagency overview of federal funding and programs that affect science and mathematics education at all levels -- precollege, undergraduate, and graduate. The federal investments in science and mathematics education are larger than previously recognized: in fiscal year 1991, for example, the federal government spent \$1.7 billion expressly for science, mathematics, engineering, and technology education at all levels.

The FY 1992 budget proposes that the federal government increase this amount by over 13 percent, to about \$1.94 billion, as part of an integrated interagency effort in science and mathematics education. Precollege education would receive the largest increase -- \$146 million, or 28 percent.

This report by Admiral Watkins' committee breaks new ground and will greatly influence our national strategy in science and mathematics education.

Setting Priorities in Science and Technology

The activities and projects I have been describing span a range of disciplines, types of research activities, and investments. But all are tools in meeting the goals listed at the beginning of my testimony. In meeting these goals, the Administration and Congress face the difficult problem of determining the best balance of activities and projects to include in the overall R&D portfolio.

Assembling the portfolio is often referred to as setting priorities. Although the idea of priorities captures part of the process, it is misleading, because it may leave the impression that we can simply rank all of the projects and work our way down the list, stopping when the money runs out. But in research and development, as in most

other endeavors, the whole is greater than the sum of its parts. It is thus necessary to obtain the optimal mix in the portfolio of R&D activities and projects.

One of the primary tasks of OSTP is to work with the agencies, with OMB, and with other interested parties to determine what combination of projects will provide the best balance and move us farthest toward our objectives. Along the way, many difficult choices must be made. Excellent projects in worthy fields may need to be delayed or abandoned because they do not contribute as much to the whole as some other project. Any one project may contribute to several of the objectives, or a project that may not be of "high priority" by itself may play a critical role in balancing the portfolio.

In presenting you with the FY 1992 budget, the Administration has set forth its vision of the most balanced portfolio of R&D projects for meeting our common goals in science and technology. We look forward to working with you to maintain this balance and achieve the goals we all desire.

OSTP ACCOMPLISHMENTS DURING THE PAST YEAR

During the past year, the Office of Science and Technology Policy has been involved with varying degrees of intensity in virtually every one of the areas discussed above. As a result, I believe that federal science and technology policy is now stronger, more cohesive, and more forward-looking than it was when I appeared before you a year ago.

Below I will review some of the many activities and accomplishments with which we have been involved over the past year. In addition, a much more comprehensive document, "Summary of Accomplishments: FY 1990, A Report to Congress," is enclosed as part of our budget justification to describe these activities and accomplishments in detail.

First, however, I would like to discuss two organizational initiatives that have had a very important influence on federal science and technology policy. One has been the reorganization and revitalization of FCCSET, which was initiated a little over a year ago. The members of FCCSET are now the Cabinet secretaries or deputy secretaries of agencies involved with research and development and the heads of the independent technical agencies. In turn, FCCSET has formed seven umbrella committees, with jurisdictions spanning the range of science and technology. Some of the committee activities are focused on budgetary and program coordination matters, as in the case of the three budgetary analyses leading to Presidential initiatives in the FY 1992 budget. Other activities are focused on subjects that affect the budget only indirectly. To take just one example, under FCCSET's Committee on Life Sciences and Health, the Biotechnology Research Subcommittee (formerly the Biotechnology Science Coordinating Committee) is identifying and reviewing national and international policy issues (such as public education) associated with biotechnology.

For many decades, observers of American science and technology have debated whether the United States should organize all of its federal research and development activities into a single agency or department to ensure coordination among various programs. The revitalized FCCSET offers a mechanism to provide that coordination while retaining the diversity and agency program authority that have contributed greatly to the strength of American science and technology. The effectiveness of the FCCSET mechanism is amply demonstrated by the three interagency programs that appear as initiatives in the FY 1992 budget. I hope and trust that the FCCSET process can be used much more extensively to bring greater cohesion and coordination to many areas of science and technology policy.

The other major organization initiative undertaken by OSTP has been the establishment of the President's Council of Advisors on Science and Technology, a group of 12 distinguished private-sector scientists, engineers, academicians, and industrialists. Since its formation in February 1990, PCAST has been meeting on an almost monthly basis with the President and with other senior members of the Executive Office. PCAST has helped to bring the private sector's perspective to the federal science and technology policy process at the highest levels, and the deliberations of this group are having an important influence on federal science and technology policy.

Status of Requested Reports

In your Senate Appropriations Report 101-474 of last year, you outlined a list of eleven studies and reports for OSTP to undertake. We have worked assiduously to satisfy your requests, and I am pleased to say that virtually all of the reports are on track. The report on rationalizing our relationships and sharing responsibilities with the Council on Environmental Quality has been delivered to you earlier this year. A report listing civilian R&D sectors by priority and identifying the top 20 science prospects in the country has also been delivered to you. A report that documents how the Administration expects to be first in the world in science and mathematics education by the year 2000 and that develops a multilevel priority setting framework that will focus, integrate, and where necessary reassign agency roles in science and mathematics education was completed and delivered to you in the form of the FCCSET report on science and mathematics education. The report developing a policy on academic research facilities modernization is now in the review process and will be ready shortly.

A report to review and respond to the National Academy of Sciences' report on the U.S. Global Change Research Program was delivered to you earlier this year. A report describing the establishment of education offices in each of the federal agencies with R&D activities and coordinating interagency activities toward developing laboratory-education partnerships was delivered to you earlier this week. A report on the establishment of the Critical Technologies Institute is still being prepared pending our remaining activities in this area. And the final report, addressing key issues in the global change arena, is now being reviewed and will be ready within a short time.

Other OSTP Activities

In addition to supporting the work of FCCSET and PCAST, OSTP has been involved with a number of major issues in science and technology. The following is a highly abbreviated list of these issues and activities.

Technology and Competitiveness OSTP has been involved during the past year in a wide range of technology-related activities. In September 1990, we released the "U.S. Technology Policy," which brings together the many facets of technology policy, describes what they are, and shows how they fit into a comprehensive framework. Working closely with Congress, OSTP has also organized and headed the National Critical Technologies Panel, which is publicly releasing its first report tomorrow, and is currently engaged in organizing a new Critical Technologies Institute.

Life Sciences During FY 1990, OSTP took the lead on a number of life science issues of importance to the Administration, including biotechnology, technology transfer in the biomedical sciences, the need for guidelines for handling misconduct in science, and the use of animals in biomedical research. A significant organizational effort has been the Working Group on Biotechnology under the Council on Competitiveness chaired by the Vice President. Another was an 18-member interagency group set up to examine current federal policies and procedures regarding misconduct in science and engineering, and to formulate guidelines for use by all federal departments involved.

Global Change OSTP has been the lead coordinating entity in developing a comprehensive U.S. policy on global change based on sound scientific principles and the need for strong economic growth. In cooperation with other federal agencies and offices in the Executive Office of the President, OSTP provides coordination on global change issues and is an important source of information and advice for the President through various forums, including the Domestic Policy Council and the Federal Coordinating Council for Science, Engineering, and Technology. OSTP has also been deeply involved, along with the Office of Management and Budget, in the evolution of the \$1.2 billion U.S. Global Change Research Program discussed earlier in my statement.

Space Through my membership on the National Space Council, OSTP has been involved with a number of space-related issues, including Landsat development and operations, the National Space Policy, the space station, commercial space policy, and the long-range goals of the space program. OSTP has also worked with OMB, NASA, and the scientific community to maintain a vigorous space science program.

Energy In FY 1990, OSTP worked directly with the Department of Energy in planning and participating in hearings on science and technology issues underlying the development of a National Energy Strategy. OSTP staff also worked closely with DOE and EOP staff on the Interim Report and on the interagency effort that developed the final strategy.

International Science and Technology In FY 1990, OSTP has been very active in the planning and implementation of a series of important bilateral science and technology initiatives, including those with the U.S.S.R., Japan, Brazil, China, and several Latin American nations, and has agreed to a framework for bilateral discussions with the European Community. Meetings of the U.S.-Japan and U.S.-U.S.S.R. Joint Commissions, which I chaired, were held in Washington, D.C. OSTP has sought in FY 1990 to review and strengthen the protection of intellectual property rights under U.S. bilateral science and technology agreements and to coordinate these agreements among the United States and other nations. Finally, I accompanied the President on his most recent visits to South American nations, where science and technology matters were high on the respective agendas.

National Security OSTP participates in interagency efforts aimed at resolving critical scientific and technical issues associated with national security and supports the National Security Council in matters concerning science and technology that are related to national security. Key OSTP concerns include the development and application of technology to support emerging defense and foreign policy requirements in such areas as defensive technologies to counter ballistic missiles and chemical and biological weapons; intelligence collection, analysis, and protection; and command, control, and communications capabilities. Also of concern is the maintenance and effective application, throughout the civilian sector, of the enormous national resource represented by the personnel, technology, and know-how currently available in the nation's defense industries and laboratories.

Science and Mathematics Education OSTP has worked closely with other EOP offices and Federal agencies in support of achievement of the National Education Goals relating to science, mathematics, engineering, and technology education. For example, OSTP worked closely with NSF and the Department of Education to improve coordination of science, mathematics, and engineering education programs between these two agencies.

OSTP BUDGET REQUEST

Before turning to the specific amounts and components of our budget request for FY 1992, I would like to summarize and highlight several organizational and personnel features of OSTP. In FY 1990, based on your understanding of the many new demands facing OSTP and the increasing scope and scale of various existing

responsibilities, we expanded both in budget and in staff. A limited number of new staff have been added, and we are currently in the final stages of staffing to our authorized budget levels. Also, the first phase of a new networked computer system has been installed to increase our effectiveness, and we have greatly improved our administrative procedures and controls.

Since I became Director of OSTP, the President has nominated and the Senate has confirmed all four Associate Directors called for in the OSTP organic act, P.L. 94-282 -- the first time in its history that OSTP has had all four Associate Directors. One of my colleagues is now awaiting Senate confirmation to be Associate Director of Life Sciences as a successor for Dr. James Wyngaarden. The President and I are exceptionally pleased that Dr. D. A. Henderson, former Dean of the School of Public Health at The Johns Hopkins School of Medicine and the leader of the World Health Organization program to eradicate smallpox, has decided to join OSTP.

As OSTP moves into a more stable organizational mode and no longer faces the problems of significant numbers of new people becoming adapted to the fast-moving pace of the Executive Office, we will be able to devote more and more attention to honing our agenda in terms of priority-setting. Less time will need to be devoted to institution-building and more can be focused on making things work better. For example, much time and attention has been devoted by me and by senior OSTP staff during the past year to organizing FCCSET, PCAST, the National Critical Technologies Panel, and the National Critical Materials Council. All are now working effectively, and only fine-tuning will be required as opposed to major organizational efforts. The major exception is that significant efforts lie ahead in establishing the Critical Technologies Institute that was mandated by the Congress in the Defense Authorization Act of 1991.

The total FY 1992 budget request of \$3,880,000 for the Office of Science and Technology Policy is intended to support 38 full-time permanent staff (including detailees) for OSTP, three staff for the President's Council of Advisors on Science and Technology, and two full-time equivalent personnel (consultants and premium pay). In summary, to better fulfill our mandate, OSTP is working to stabilize its work force of professional and support staff at the approved ceiling of 43.

The FY 1992 request provides for four Associate Directors and, as I noted above, all are on board or are in the midst of Senate confirmation. These senior people head four directorates responsible for policy and international affairs; industrial technology, including critical technologies and materials; the life sciences; and physical sciences and engineering. The request will, in addition, provide for an estimated six assistant directors and a number of policy analysts in key areas. The newest of these assistant directors has responsibility for the social and behavioral sciences. The budget assumes a moderate use of detailees. The professional staff are generalists, rather than narrow specialists, which is essential given the number and variety of the issues addressed by OSTP and the often-changing character of our priorities and agenda. I have been exceptionally pleased with the quality of the people who have joined me at OSTP. The extent of our achievements is a reflection of the expertise and judgment

they have brought to their jobs.

The requested level of \$3,880,000 is \$320,000 more than the FY 1991 appropriated amount, or an increase of just under 9 percent. I would note that the largest component of this increase stems from mandated pay increases (\$137,000); the second largest is from the build-up of PCAST to a reasonable operating level compatible with the President's interests (\$83,000); and the other large item is a noncontrollable increase in our rent charge by the GSA (\$56,000). Roughly another \$53,000 comes from increases in utility charges and the additional service costs for computers and other equipment. The precise details are shown in our budget justification book.

The FY 1992 request includes \$355,000 for support of PCAST. The maturation and evolution of PCAST during the past year and the establishment of several PCAST panels account for the above-mentioned increase. PCAST has become a very active group, with almost monthly plenary meetings, and with small panels to focus on more specific issues. Some of the issues being considered for review by PCAST panels include biotechnology, earth and environmental sciences, education and human resources, high performance computing and communications, and international economic competitiveness. Several PCAST panels will be developed during FY 1992. This increase in activity from the previous year will entail additional expenditures, but we believe that it is well worth the investment.

I might note for general comparison purposes that the Defense Science Board has a staff of nine and a budget of about \$3,000,000 annually -- nearly the size of the entire OSTP budget. The President's Foreign Intelligence Advisory Board has a staff of five. As I mentioned earlier, I have assigned three of OSTP's personnel allocation to PCAST, although I and others spend significant amounts of time on PCAST matters.

I would be less than grateful if I did not forthrightly acknowledge the generous action of this subcommittee in agreeing to an increase for PCAST in our FY 1991 budget. But I want to underscore that I have carefully reviewed this budget to ensure that it is prudent but lean. We are going to manage the budget as tightly as is possible with the assistance of the Financial Management Office of the Office of Administration in the Executive Office.

I have been examining very closely a variety of ways to delegate various tasks to agencies outside of the Executive Office and have been successful in doing so in a number of important areas. However, an important reality that I have had to come to terms with is that there is a growing set of responsibilities related to Administration programs and policies related to science and technology that I cannot delegate, that are highly labor intensive, and that require extraordinarily high levels of quality control because of the high stakes involved. To provide some flavor of this major observation, included are some key functions of OSTP:

- o Making recommendations to the President on current major issues of science and technology policy, and directing and participating in interagency coordination on a variety of issues. These tasks have required a very high level of

participation and interaction by OSTP in numerous coordinating groups within the Executive Office of the President and with all Federal government agencies.

- o Directing and coordinating the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) and its committees and subgroups. This requires an intensive level of participation, coordination, and guidance by OSTP staff of the various FCCSET committees and subgroups.

- o Coordinating with other Federal government agencies and departments of science and technology elements of the President's budget request to Congress.

- o Anticipating new science and technology issues, or issues with a significant science and technology component, especially those with a longer-range perspective; and initiating interagency coordination on such issues, including coordinating technical findings or other actions, as appropriate.

- o Developing, planning, and implementing international bilateral science and technology agreements with foreign countries. Interagency coordination, under FCCSET, of science and technology issues in negotiated agreements with foreign countries.

- o Directing, coordinating, and convening meetings of the President's Council of Advisors on Science and Technology and its various subpanels.

- o Preparing reports in accordance with legislative requests.

- o Other responsibilities assumed by OSTP.

The responsibilities of OSTP have grown in recent years with the growth in importance of science and technology in government policy and in the general affairs of the nation. In addition, the role of OSTP and of the Science Advisor has been upgraded in this Administration and will continue to involve a corresponding increase in workload. Specifically:

- o The OSTP Director is now a member of the Domestic Policy Council, the Economic Policy Council, and the National Space Council. The OSTP will, in addition, be taking a very active role in the Council on Competitiveness chaired by the Vice President, where OSTP has served as chairman of the Working Group on Biotechnology. Effective participation in these groups requires substantial staff involvement and support.

- o OSTP has assumed additional responsibilities in a number of areas, including science and mathematics education, the environment, and technology, particularly as its affects global competitiveness.

- o The upgraded role of the Science Advisor as the Assistant to the President for Science and Technology, the responsibility of the Science Advisor to chair FCCSET

and PCAST, and the expanded mission and augmented roles of PCAST and FCCSET have required greater demands on the staff and supporting resources.

- o An increasing number of Congressionally mandated studies and reports requiring substantial staff involvement, support, and resources.

Given the large workload expected for FY 1992 and beyond, the requested level of support is nevertheless in keeping with the current budgetary constraints. This request represents a judicious application of resources to meet varying and diverse needs and a very resourceful and effective use of funds, in view of the significant effect of science and technology policy coordination within the Executive Office on the overall coherence and effectiveness of the research and development conducted within this nation.

CONCLUSION

I have often said during this past year that the United States, in both the public and private sectors, is underinvesting in research and development. This belief is widely shared in the Administration, and I know that it is widely shared here on Capitol Hill, as demonstrated by the solid increases appropriated to science and technology by Congress last year.

The Administration's proposed FY 1992 budget for research and development continues to take steps to address this underinvestment in science and technology. In addition, it provides for a strong advisory, oversight, and coordinating function through its support of the Office of Science and Technology Policy. We strongly urge that you support these proposals, and we will work closely with you over the coming months to achieve these goals.

That concludes my testimony. I would be very happy to answer your questions.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

HIGH PERFORMANCE COMPUTING AND COMMUNICATIONS

TESTIMONY

OF

D. ALLAN BROMLEY

DIRECTOR

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

BEFORE THE

SUBCOMMITTEE ON SCIENCE

SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

MARCH 7, 1991

Chairman Boucher, Chairman Valentine, and members of the subcommittees:

Thank you for giving me the opportunity, as Director of the Office of Science and Technology Policy, to discuss with you the critically important issue of high performance computing and communications.

On February 4, 1991, the President announced his proposed budget for Fiscal Year 1992. Among the major new R&D programs in the budget is a Presidential initiative on high performance computing and communications, which is described in the report Grand Challenges: High Performance Computing and Communications. The report, which was released on February 5, 1991, was produced by a Working Group on High Performance Computing and Communications under the Committee on Physical, Mathematical, and Engineering Sciences, which is one of seven umbrella interagency committees under the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). A copy of the report is attached.

The overall goals of the high performance computing and communications initiative are symbolized by a set of what are called "grand challenges," problems of important scientific and social value whose solution could be advanced by applying high performance computing techniques and resources. These include global climate modeling, mapping the human genome, understanding the nature of new materials, problems applicable to national security needs, and the design of ever more sophisticated computers. Many such problems can be addressed through high performance computing and communications, including ones that are impossible to foresee today.

The initiative represents a full integration of component programs in a number of Federal agencies in high performance computing and computer communications networks. It integrates and coordinates agency programs and builds on those programs where appropriate. The initiative proposes to increase funding in these programs by 30 percent, from the \$489 million appropriated in FY 1991 to \$638 millions in FY 1992.

History of the Initiative

The high performance computing and communications initiative can trace its formative years to the early 1980s, when the scientific community and federal agencies recognized the need for advanced computing in a wide range of scientific disciplines. As fields of science progressed, the quantity of data, the number of databases, and need for more sophisticated modeling and analysis all grew. The Lax Report of 1982 provided an opportunity to open discussions on the need for supercomputer centers beyond those previously at the Department of Energy's national laboratories. Subsequently, the availability of such resources to the basic research community expanded -- for example, through the establishment of the National Science Foundation's and NASA's supercomputing centers.

In 1982 a FCCSET committee examined the status of supercomputing in the United States and reviewed the role of the federal government in the development of this technology. In 1985 this committee recommended government action necessary to retain technological supremacy in the development and use of supercomputers in the United States. Subsequent planning resulted in a series of workshops conducted in 1987 and in a set of reports that set forth a research and development strategy.

A synthesis of the studies, reports, and planning was published by OSTP in the report entitled The Federal High Performance Computing Program, which was issued on September 8, 1989. The initiative in the FY 1992 budget represents an implementation by the participating agencies of the plan embodied in that report, appropriately updated to recognize accomplishments made to date. The report described a five-year program to be undertaken by four agencies -- the Defense Advanced Research Projects Agency, the National Science Foundation, the Department of Energy, and the National Aeronautics and Space Administration. Four additional partners have since joined the program -- the National Library of Medicine within the

National Institutes of Health, the Environmental Protection Agency, and the National Institute of Standards and Technology and National Oceanic and Atmospheric Administration within the Department of Commerce -- and they have added considerable strength to the overall program.

The planning and implementation of the HPCC program have been the result of extraordinarily effective collaboration by the participating agencies using the FCCSET forum. It was developed after several years of discussions among the agencies and hundreds of hours of negotiating and interactions between all federal government agencies with an interest in computing. Agencies have realigned and enhanced their HPCC programs, coordinated their activities with other agencies, and shared common resources. The final product represents a complex balance of relationships and agreements forged among the agencies over a number of years.

These agencies have achieved a level of mutual trust, cooperation, and synergism that is remarkable in or out of government -- and not easily achieved. In addition, the success of this effort demonstrates the advantages to be gained by using the FCCSET process to coordinate areas of science and technology that cut across the missions of several federal agencies. The FCCSET interagency process maintains the necessary flexibility and balance of a truly integrated program as the science and technology evolve, and it allows additional agencies to identify opportunities and participate in a given program.

Description of the Initiative

The HPCC initiative is a program for research and development in **all leading-edge** areas of computing. The program has four major components: (1) High Performance Computing Systems, (2) Advanced Software Technology and Algorithms, (3) a National Research and Education Network (NREN), and (4) Basic Research and Human Resources. The program seeks a proper balance among the generic goals of technology development, technology dissemination and application, and improvements in U.S. productivity and industrial competitiveness. It incorporates general purpose advanced computing as well as the challenges ahead in massively parallel computing.

In the development of computing hardware, ambitious goals have been set. The program seeks a thousandfold improvement in useful computing capability (to a trillion operations per second). **The focus will be on the generic technologies that will prove valuable in many different sectors.** Where appropriate, projects will be performed on a **cost-shared basis** with industry.

In software development, the program will focus on the advanced software and algorithms that in many applications have become the determining factor for exploiting high performance computing and communications. In particular, software must become much more user-friendly if we are to provide a much larger fraction of the population with access to high performance computing.

The National Research and Education Network (NREN) would dramatically expand and enhance the capabilities of the existing interconnected computer networks called the Internet. The overall goal is to achieve a hundredfold increase in communications speed (to levels of gigabits per second). In addition, the number of "on-ramps" and "off-ramps" to the network would be greatly expanded, bringing the potential of high performance computing to homes, offices, classrooms, and factories. Such a network could have the kind of catalytic effect on our society, companies, and universities that the telephone system has had during the twentieth century. A new meaning will be given to communication, involving not just the transfer of knowledge but a full sharing of resources and capabilities that no single site possesses.

Finally, the HPCC initiative will add significantly to the nation's science and technology infrastructure through its impacts on education and basic research. It is my personal view that the successful implementation of this program will lay the foundation for changes in education at all levels, including the precollege level.

Of course, no plan is better than its execution, and the execution of the HPCC initiative will rely heavily on the synergy that has been carefully cultivated among the participating agencies. This synergy has been fostered by allowing each agency to do what it does best in the way that it does best. Each of the four founding agencies has national constituencies and historical strengths. DARPA, for example, will lead in fostering the development of breakthrough system technologies, as it has done in the past for time-sharing, network operating systems, and RISC architecture. DOE, through its historical ties with the national laboratories, has always led in the development and use of HPCC technologies and is applying them on the cutting-edge of scientific problems. NASA will continue to pursue a new wave of space-related and aeronautics problems, such as computational aerodynamics, as well as its strength in the collection, modeling, simulating, and archiving of space-based environmental data. And NSF's close ties with the academic community gives it a special expertise in both education and in the coordination and use of NREN.

Expected Returns of the Initiative

The high performance computing and communications initiative represents a major strategic investment for the nation with both economic and social returns. I personally believe that few technology initiatives have the potential to have a greater impact on the ways we live and work than does the high performance computing and communications initiative.

The high-performance end of the computer market is relatively small, but its influence far transcends its size. The high end is where leading-edge technologies and applications are developed. Recent history indicates that these developments diffuse so quickly throughout the overall market that "superminis" and "superworkstations" are no longer contradictions in terms. A federal investment in the leading-edge computing technology will speed the growth of the overall computer market and may catalyze investments on the part of U.S. industry. At the same time, supercomputers

are not the only important hardware component; we shall not forget the importance of the smaller, more widely distributed units and their role in the overall system.

In addition, the HPCC initiative will be a major contributor to meeting national needs. National security, health, transportation, education, energy, and environment concerns are all areas that have grown to depend on high performance computing and communications in essential ways. The dependence will grow as computers become more powerful, cheaper, more reliable, and more usable.

HPCC is also critical for the nation's scientific infrastructure. The electronic computer was born as a scientific tool, and its early development was driven by scientific needs. Business applications soon came to dominate its development, but recently there has been a renewed focus on computers as an instrument in science. Indeed, "computational science," which incorporates modeling, simulation and data rendition, is adding a third dimension to experimentation and theory as modes of scientific investigation. In field after field of fundamental and applied sciences, problems intractable for either theory or experimentation are being successfully attacked with the aid of high speed computation.

Diffusion of the Initiative's Benefits

If the HPCC initiative is to realize its full potential, it is not enough that it reach its technology goals. It is equally important that the technologies be deployed by the private sector in a timely way to result in an acceleration of market growth. It is likewise insufficient for applications to be developed and problems to be solved; in addition, the benefits accruing from those solutions must be disseminated so as to influence our everyday lives.

The continued development and use of government-funded high performance computing and communications prototypes can have a significant positive impact on the potential commercialization of these technologies. In addition, many organizations that cannot individually justify the hardware investments will be able to gain access to these new computing systems via the new network. Thus, the knowledge gained through the timely development and use of prototype systems and the access provided to them by the network will significantly improve the dissemination of the benefits of the initiative.

However, this wide diffusion is not possible by federal action alone. The Administration's HPCC initiative will serve the nation best as a catalyst for private actions. Some analysts have suggested that the HPCC initiative can spur several hundred billion dollars of GNP growth. If so, it will be because American companies, both large and small, are able to deploy the technologies in producing quality goods and services.

Similarly, some predict that NREN will lead to the establishment of a truly national high speed network that connects essentially every home and every office. If that

happens, it will be because private investments are stimulated by government leadership. Far from suppressing or displacing the focus of a free market, the HPCC initiative will strengthen them by providing the impetus for vigorous private action.

Congressional Initiatives in High Performance Computing and Communications

The breadth and balance of the high performance computing and communications initiative are critical to its success. The four components of the program are carefully balanced, and maintaining this balance is the most important priority in the program. For example, powerful computers without adequate software, networking, and capable people would not result in successful applications. A program that created only high performance networks would not satisfy the need for greater computing performance to take advantage of the networks and solve important problems.

Similarly, the Administration's initiative relies on substantial participation by industry and government laboratories to overcome barriers to technology transfer. Cooperative government, industry, and university activities will yield the maximum benefits derived from moving new technologies from basic discoveries to the marketplace.

The legislative proposals pending before the Congress, though well intended, do not fully recognize the comprehensive interagency effort brought about through years of collaboration. For example, H.R. 656 only specifies the program for two of the four major agencies included in the high performance computing and communications initiative. In addition, H.R. 656 incorrectly specifies the roles of the agencies; many of the requirements of the legislation have, in fact, already been accomplished; and the agencies have moved on to further scientific and technical challenges. The legislation, in effect, may detract from the existing programs by limiting the activities of the agencies and by causing an unintended revision of complex relationships forged between the agencies. For these reasons, I strongly believe that FCCSET activities should not be codified in law.

I am concerned that legislative action not limit the flexibility of what is by nature an extremely dynamic process. When research plans are developed to implement interagency programs, those plans are inevitably dynamic, just as the research efforts they describe are dynamic and evolving. If research plans are codified in law, it suggests that the research is static. This is particularly a concern with high performance computing and communications, where the pace of technological change is dramatic. As an example of a fast-moving research opportunity, I might mention a joint Los Alamos National Laboratory/DARPA effort that successfully applied an innovative massively parallel Connection Machine Computer system to a nuclear weapons safety code to gain new and valuable insights into the safety of the nuclear weapons inventory. Another example occurred in the last year at the National Library of Medicine's National Center for Biotechnology Information, where researchers developed a new fast algorithm for sequence similarity searches of protein

and nucleic acid databases. This was very helpful in the identification of a gene causing von Rocklinghausen's neurofibromatosis. This is a major breakthrough in the understanding of this bewildering disorder that affects about 1 in 3,000 people. On the networking front, significant achievements have also been made. For example, the NSFNET has increased in speed a thousandfold (from 56 kilobits per second to 45 megabits per second) since 1988.

H.R. 656 has as its focal point the issuing of a plan that would delineate agency roles and include specific tasks. However, the Administration's initiative and the accompanying FCCSET report satisfy these demands for items to be incorporated in the planning phase. H.R. 656 further calls for the establishment of an advisory panel to provide additional input into the plan. But many of the agencies already have current advisory panels, and private sector participation is fully anticipated in the Administration's initiative as agency programs move forward to implementation. Moreover, the oversight role of the Congress, including the hearings scheduled this week in the House and Senate, serve as important elements in the fine tuning of the program.

The National Research and Education Network described in the initiative addresses the need for greatly enhanced computer communications highlighted in the legislation. The initiative also seeks to be comprehensive in addressing the roles of the various R&D agencies -- for example, by allowing other agencies to join the effort as appropriate.

It bears emphasis that the Administration's initiative uses the existing statutory, programmatic, budgetary, and authorizing authorities of the agencies and departments involved in the initiative, including OSTP. The funding levels necessary to proceed with this effort have been transmitted to the Congress in the President's request and are clearly reflected in the budgets of each of the eight agencies involved in the initiative. The Congress already has the ability to positively affect the high performance computing program of the federal government through existing authorizations and appropriations.

FCCSET is a very important mechanism within the Executive Branch for reviewing and coordinating research and development activities that cut across the missions of more than one federal agency. Unlike the committees in the Legislative Branch, each of which has discrete authority for oversight, interagency committees within FCCSET are forums for discussion, analysis, collaboration, and consensus building. The member agencies then have the responsibility for implementing the program and proceeding with the necessary contracting, budgeting, and so on developed through the interagency process.

Several legislative vehicles, in addition to H.R. 656, have been introduced that seek to endorse and advance the Administration's initiative. I welcome the Congress's interest and intentions in high performance computing and communications. I am confident that by working together we can have a significant impact on the nation's future

through these efforts, and I welcome suggestions from Congress to improve the current initiative.

I might suggest that hearings to receive the views of all the various communities involved with this proposal and a positive endorsement of this program by Congress would be of great assistance in advancing high performance computing and communications in this country. Positive action on the requested appropriations will ensure that this extensive interagency program can go forward.

Chairmen and members of the subcommittees, let me conclude by saying that I look forward to working cooperatively with you on this initiative. We share the same goals, and I am confident that we can reach a consensus on how best to achieve them.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
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**U.S. TECHNOLOGY POLICY:
CAN IT HELP MAKE AMERICAN COMPANIES COMPETITIVE?**

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It is always a great pleasure to return to Harvard, especially given the long history of friendly competition between Harvard and Yale, on the football field and elsewhere. Although I have to admit that when I think of Harvard, I tend to think more about the English department than with the football team. The reason is that several years ago I had a graduate student at Yale who had been a Harvard undergraduate, and who had presumably taken at least one English course here. He was extremely bright and is today an internationally known physicist. But the first sentence of his Ph.D. dissertation, when I received it in draft, read as follows: "This field of research is so virginal that no human eyeball has set foot in it."

I am not here, however, to talk about either physics or English but rather about something in between: the use that we make, here in the United States, of technology. Technology -- and the science from which much technology springs -- are of vital importance to this country, and they have received much attention in my office -- the Office of Science and Technology Policy -- and within the Bush Administration in general.

Over the last few months, we have seen the difference that science and technology can make on the battlefield. But science and technology are having an equally dramatic -- if less directly visible -- effect on our civilian economy and on our modern way of life. The past investments we have made in science and technology have paid great returns in economic growth and an improved quality of life, just as the investments we made in military systems paid off in outstanding fashion in the Gulf War. Nor is there any reason to think that this return from science and technology will be any less in the future.

Let me try a simple calculation to demonstrate these economic returns of R&D. Over the last 50 years, the size of the U.S. economy, after correcting for inflation, has increased about fivefold. Economists calculate that about a third of this growth has resulted from research and development. In other words, at least 25 percent of our national income today can be directly traced to science and technology.

Now let me make the very conservative assumptions that the economy grows at

only half this rate over the next fifty years -- so that it is two-and-a-half times today's size in the year 2031 -- and that today's R&D continues to account for about a third of that growth. In that case, the U.S. economy fifty years from now will be over \$3 trillion larger -- in today's dollars -- than it would be without the results of R&D. Given that the United States today annually spends about \$150 billion on R&D of all kinds -- public and private, defense and civilian -- we can calculate that an expenditure of \$1 today will yield a real return of at least \$20 fifty years from now. I do not know of any other investments that give that kind of return -- with the possible exception of a Harvard or Yale education.

I have been talking about the economic returns of research and development, but of course there are many other kinds of returns. Science and technology have immeasurably improved the quality of our lives through prevention and treatment of disease, greatly enhanced mobility, improved accommodations and food, and even new forms of recreation and entertainment. We tend to forget that just 100 years ago, a quarter of all people born in the United States were dead before their 25th birthday, and half of all people had died by the age of 50. Today the corresponding figures are 3 percent mortality by the age of 25 and 10 percent by the age of 50.

Finally, scientific discovery is one of the greatest adventures that we have available to us as a species. The quest for knowledge is a basic human drive and brings great intellectual and emotional satisfactions. Furthermore, as Francis Bacon put it in the famous quotation from his Religious Meditation: "Nam et ipsas scientia potestas est," which of course translates as "knowledge itself is power." I might add, by the way, that since coming to Washington I've heard that when Senator Everett Dirksen first heard this quotation, he immediately replied, "particularly if you know it about the right people."

Continued American Strengths

Much has been said and written in the last few years about how America is losing its edge in technology, and even in some areas of science. Personally, I believe

that much of this is talk is ill-informed at best. We in the United States continue to have, by a large margin, the strongest science and technology base that the world has ever known. This storehouse of facilities, equipment, knowledge, and trained personnel has come about largely because of the generous support provided by the federal government, and ultimately by the American taxpayer, for research and development since World War II. It is a tribute to the American people, and to the public policy process in this country, that investments of this magnitude have been made.

What is true is that a number of countries, by focusing their resources in particular areas, have moved up to equal -- and in a few cases surpass -- the position of the United States. That is not necessarily bad. In fact, it was to be expected as other countries recovered from World War II and began to follow the United States' lead. What we must do now is ensure that, in all areas of science and technology where our activities do not define the frontier, they are close enough to those frontiers so that we can exploit, without delay, new developments whenever and wherever they occur.

Let me mention a few other strengths of American science and technology, because it will be important to keep these in mind in considering U.S. policies affecting technology. First, this country continues to have the strongest research university system in the world. Especially at the graduate level -- but also if more selectively at the undergraduate level -- our universities continue to set world standards and typically attract the brightest young people from around the world.

These research universities also provide a double dividend. They generate the new knowledge that drives both science and technology, and at the same time they produce the young minds trained to use that knowledge in new and more productive ways. In no other country does this process work as effectively.

The United States also continues to have a business climate that encourages the formation of new companies and allows successful companies to grow quickly into major businesses. The rapid growth of the biotechnology industry is one example -- with over 400 firms founded in biotechnology in the 1980s -- but there are other examples throughout American business. These small and medium-sized firms

generate many of the most important new ideas in our economy, and they continue to generate most of the new jobs in this country. So long as adequate investment capital remains available for new start-ups, these companies will continue to contribute a dynamic quality to the U.S. economy that is not evident elsewhere.

Finally, the United States remains an open and restless society that prizes and rewards innovation. Our world is today changing at accelerating speed, and those companies that remain flexible and innovative are going to be the ones best able to take advantage of those changes. The massive production lines for which the United States became famous can no longer be looked on as the paradigm, though the advantages of scale will continue to be important. We need greater flexibility and agility in changing our production capabilities, both to reflect technological changes and to match customer demand. And we must develop much greater sensitivity to that demand, particularly in the international marketplace.

The FY 1992 Budget

These strengths -- and the opportunities they present -- are fully reflected in the budget proposal that President Bush sent to Congress in January. To take advantage of the countless scientific opportunities available to researchers at our nation's colleges and universities, the budget proposes an 18 percent increase in funding for the National Science Foundation and a 9 percent increase in funding for research project grants awarded to individual investigators at the National Institutes of Health.

Together, these two federal agencies support over 75 percent of the federal funded basic research done in universities; by focusing on them, the Administration is seeking to strengthen the individual investigator and small group research that remains the heart and backbone of American science and technology.

Yet basic research clearly cannot be the only component of a nation's R&D enterprise. Other nations such as Japan have R&D enterprises that bring great benefits to society yet include very little basic research. The difference is that these

systems are able to very efficiently and effectively exploit the results of basic research, no matter where it is done. This is the stage of the innovation process -- the stage between the generation of knowledge and its application in the marketplace -- that poses the greatest challenges to the United States.

To help strengthen the latter stages of the innovation process, the budget includes funding for many areas of applied research and technology development, including high performance computing and communications, energy technologies, biotechnology, advanced manufacturing and materials, and aeronautics. To take just one example, the budget includes a special Presidential initiative on high performance computing and communications, which is designed to sustain and extend America's preeminence in this critically important area of technology. This program, which was put together by an interagency committee organized through my office, focuses on the hardware, software, networks, and human resources that will be necessary to increase computing and communications capabilities by several orders of magnitude. In my view, these new capabilities could have the kind of catalytic effect on society, businesses, and universities that the telephone system has had during the twentieth century.

The budget emphasizes a number of areas of applied research and development. In fact, it goes so far as to state that it is providing increased funding "for all major civilian applied R&D areas." This is an important measure of the Administration's intentions.

In a speech to the recipients of the National Medals of Science and National Medals of Technology last fall, the President said, "Today, our government must help carry [basic] research forward and contribute to the development of generic technologies that build on basic discoveries. If America is to maintain and strengthen our competitive position, we must continue not only to create new technologies, but learn to more effectively translate those technologies into commercial products. In this way, we can help leverage the R&D of the private sector, helping whole industries advance in an increasingly competitive global market." As part of this commitment from the highest levels of government, applied research and technology development are going to be increasingly important federal emphases.

Technology Policy: The Narrow and Broad View

The question then becomes, will this support of technologies automatically boost the American economy? Or, to return to the title of my talk, can federal support for technology development help make American companies competitive? There is no question that in some cases it can, and history provides many examples of such success stories, from the airline industry to the computer industry.

But even though a strong technology may be a necessary condition of commercial success, it is by no means a sufficient condition. Our past strengths in technology have not prevented an erosion of market shares of U.S. companies in many industries. Nor should the federal government try to directly identify and develop technologies for commercial products and processes. That is the responsibility of the private sector, and past federal attempts to second-guess the marketplace have often produced dismal results.

The very real limits on the federal government's ability to mandate technological success can be seen in a recent poll conducted by the Industrial Research Institute of its members, who consist of the top-ranking R&D officials in many of America's leading companies. The members were asked to rank five major factors according to their contributions to the erosion of U.S. industrial technology. The two most important categories were "general management practices" and "external financial pressures." The last category in order of importance was "federal technology policy."

As the director of the Office of Science and Technology Policy, this ranking leaves me in a somewhat awkward position. I can sympathize with the story that Newton Minow used to tell, who was head of the Federal Communications Commission in the 1960s and coined the phrase "a vast wasteland" in describing television. He said that his mother once called him up and said, "Newton, since you've been in that job the television programs have really gotten much better. But can't you do anything about TV dinners."

The problem, I believe, is that we have had a tendency to define "technology

policy" much too narrowly -- as simply the federal government's support for technology. Last September my office put out a report entitled "U.S. Technology Policy," and in that document the issue is viewed from a much broader perspective. It considers such issues as technology transfer, the financial environment needed for longer-term investments, the legal and regulatory environment necessary for innovation, and the education and training of the workforce. What I would propose to do with the rest of my time is look at some of these issues and show how they fit into a comprehensive federal approach to competitiveness.

Technology Analysis

Turning to the issues most closely related to technology development, one of the most important needs is for solid information and analysis about the technologies of importance to our economy and national security. Some of this analysis has been and is being done by the private sector. I know, for example, that several groups here have looked at these issues, and I want you to know that we read those reports very carefully in our office, and they have been extremely helpful.

Another important activity is going on within the Office of Science and Technology Policy. Over the past year, the National Critical Technologies Panel within OSTP has been working to develop a list of the technologies that will be critical to our future economic prosperity and national security. The panel has 13 members -- six from the private sector and six from the federal government, plus the panel's chairman, Bill Phillips, who is the Associate Director for Industrial Technology within OSTP.

The first report of the panel will soon be released, and in that report the panel discusses 22 technologies that it believes will be critical in the 1990s and into the 21st century. The technologies fall into six broad categories: (1) materials, (2) biotechnology and life sciences, (3) manufacturing, (4) information and communications, (5) aeronautics and surface transportation, and (6) energy and the environment. The report describes each technology, highlights its importance and the

reasons for its selection, and discusses the current status of the technology, including the relative position of the United States versus other countries.

As the report points out, the development of technologies -- like the development of science -- is replete with surprises. Who would have guessed when the laser was developed that we would today be using it to play music and read prices from supermarket items? However, the panel has set forth the technologies in its report with confidence that they constitute the appropriate bases for exploitation to satisfy many of the nation's future needs. Also, the list technologies will be updated biennially to ensure that they remain current.

Once the appropriate technologies have been selected, careful thought must be given to how those technologies can be successfully developed and deployed. Again, considerable work on this subject is going on in the private sector, and OSTP is in the process of greatly increasing its involvement with this issue. The 1991 Defense Authorization Bill called upon OSTP to follow-up the work of the National Critical Technologies Panel by establishing a Critical Technologies Institute. This institute would give OSTP an analytical arm for developing strategies to promote technologies critical to both governmental and private sector needs. It would evaluate programs that are already in place in both the private and public sectors to see which programs are most effective. And it would work with other groups at evolving strategies for the optimum development and deployment of technologies.

This question of how best to develop technology applications is a critical one, yet it is often given scant consideration in either the public or private sectors. We in the White House frequently meet with representatives of U.S. industrial groups. Many believe that they were in some trouble in terms of remaining competitive; many would like to see some form of direct federal assistance. But all too few are prepared to lay out a strategic plan that demonstrates how such assistance would, in fact, put them on a new trajectory that in five or more years would leave them competitive and not in need of an additional transfusion.

This Administration is prepared to be helpful, and indeed looks on competitiveness as one of the nation's most pressing challenges. But we do not believe that we in government are as well-qualified to make these strategic plans and

decisions for industry as is industry itself. Nor do we believe that economic transfusions in the absence of such strategic plans are any answer at all.

In addition to OSTP's work in industrial technology, the Department of Commerce has, of course, been heavily involved in this area. For example, very recently, the Department of Commerce, through the National Institute of Standards and Technology, announced the first set of awards under its new \$36 million Advanced Technology Program, which we in the Administration view as a pilot program.

In all, 249 proposals were received; 45 were joint ventures, 204 were single applicants, and 183 were from small businesses. They came from 38 states in addition to the District of Columbia.

These proposals were subjected to 678 technical peer reviews involving 395 individual reviewers from industry, universities, and government as well as venture capitalists and private consultants.

Out of this screening, 11 winners emerged; 5 are joint ventures, and 8 are single applicants. Eight of these projects are led by small businesses, and there is small business participation in all of the awards through subcontracting. The awardees span the entire range, from multinationals such as AT&T and IBM to very small companies with only a few hundred employees.

The total requested in the proposals was \$337 million, with \$112 million for the first year. Among the winners, \$9.2 million was requested from the federal government, with cost-sharing of \$9.4 million. The winning proposals address 10 different generic technologies, ranging from X-ray lithography through panel displays to machine tool control and nonvolatile computer memories.

By all measures, it would appear that this pilot program has been a great success, and I would anticipate substantial growth in it in future years.

Technology Transfer

Any consideration of how best to exploit federal development of technologies

must include an extremely valuable but often overlooked asset. In this country, in addition to our university researchers and those in industry, we have an enormous national resource in the professional personnel, expertise, and infrastructure resident in our over 700 federal laboratories. The federal government invests over \$20 billion a year in these laboratories -- almost a third of the total federal R&D budget. They embrace an astonishing breadth and depth of science and technology, including some of the best science and technology to be found.

Many of these laboratories were established in the immediate post-World War II period, and they originally had very specific missions and objectives. Many of these missions were satisfied many years ago, so that at least some of the labs lack clearly defined objectives, although many have been able to keep their programs in close touch with national needs.

Our challenge now is to involve these laboratories in a much-discussed but all-too-infrequently realized partnership with universities and industry so that they can play a more effective role in supporting U.S. economic competitiveness in the international marketplace. I believe, for example, that potential users must be more involved in the launching of laboratory programs than is now the case, where individual curiosity remains a dominant driver in the laboratories. I am convinced that groups of knowledgeable industrial and university scientists, meeting with laboratory management and senior scientists and technologists, can add a new dimension to the selection of program emphases and priorities -- at the outset -- with the laboratories. In so doing, this process will lead to significantly improved coupling throughout the research programs and in the use of their outputs.

The end result of new partnerships among the components of our research enterprise would be a much greater degree of technology transfer. But I must caution that the term "technology transfer" is one of the most misunderstood in the English language. It seems to imply that technology can be neatly identified, wrapped up, and transported with equal neatness to another organization, where it can be unwrapped and applied without significant change. Nothing could be farther from the truth.

In fact, there is only one way in which technology can be effectively transferred, and that is in the minds of people. I have become convinced that the only effective

transfer occurs when the technologies are carried in the minds of trained individuals moving from one organization to another. As a result, I believe that substantially increased mobility among our research personnel -- both basic and applied, both short- and long-term -- is essential.

Other countries are much more successful at these kinds of close working relationships than we are here in the United States. Our international trading partners have forged very strong links between government and industry. They have put public and private funds into targeted programs that reduce the risk of technology development, lower the cost to each participant, and make it easier to compete.

If the United States is to compete in such a marketplace, we cannot force each individual country to reinvent the technological wheel. Rather, the government must act as catalyst, with federal funding where appropriate, to combine the very real strengths apparent in each component of our R&D enterprise.

Mathematics and Science Education

In addition to these considerations of technology, there are many fiscal, legal, and even cultural factors that influence the competitiveness of American companies. Let me mention just a few of these and the actions that the Bush Administration is taking to influence them. On the economic front, the Administration has been working to reduce the cost of capital by controlling the federal budget deficit. The budget agreement reached last fall will save a half trillion dollars of federal spending that can now go into private capital markets, reducing interest rates rather than raising them.

In trade, the federal government is working to reduce trade barriers and better protect intellectual property. We must ensure that we receive a fair return on our investments in research and development rather than allowing those returns to flow predominantly to our trading partners.

In the area of regulation, the Competitiveness Council headed by the Vice

President is working on reforms to product liability laws to restore balance to the tort system. The Administration is also working to remove barriers to research, innovation, and development by eliminating unnecessary and unwarranted regulations.

These are all important elements of what might be considered a U.S. technology policy in its broadest sense. But I want to emphasize, in closing, perhaps the most fundamental element of our approach to technology, and that is the education of our young people and the training of our workforce.

American education is now suffering from some extremely serious breakdowns. Particularly at the precollege level, the education that many of our young people are receiving is scandalously poor. For the first time in American history, our children and grandchildren are now receiving a worse education than their parents and grandparents received.

As is the case through society, science and technology are becoming an ever more important of the educational enterprise. Jobs requiring high levels of scientific and technical training are the most rapidly growing segment of the labor market. But our schools are not producing nearly enough scientifically literate and technically training individuals to meet the demand. International comparisons show the United States at or near the bottom in scientific and mathematical achievement. If we cannot educate our young people properly, scientific and technological supremacy will inevitably pass from the United States to other countries.

The importance of science and technology is apparent in the National Education Goals established by the President and the nation's Governors last year. Of the six goals, three directly involve science and technology, including the most ambitious of the six, that American students be first in the world in science and technology by the year 2000.

All of us know that particular goal is a stretch goal. Yet it is already having its desired effect in driving some very significant reforms. At the federal level, an interagency committee under the leadership of Secretary of Energy James Watkins has put together an integrated, government-wide program designed to significantly advance science and mathematics education. As part of that effort, the committee produced, for the first time, an inventory of all of the activities in the federal government that

directly influence science, mathematics, engineering, and technical education. And in the budget sent to Congress last month, the President proposed a 13 percent increase for this interagency program, to a total of nearly \$2 billion.

We are now looking seriously at the next iteration in developing a federal program in mathematics and science education. Precollege education was the top priority to emerge from the past year's work. A strong candidate for high priority in the FY 1993 round is technician training, in the broad sense of the term. This is an area where the United States has fallen behind other countries, especially Germany and Japan, to the detriment of our high-technology industries. Your suggestions as to how we should meet this challenge would be greatly appreciated.

These are important first steps, but of course the federal government alone cannot guarantee the achievement of the National Education Goals. It is going to take all of us working together -- with the goals as a consensual statement of where we are headed -- to make the kind of progress they envision. We must get parents reinvolved in the education of their children, in part by giving them a greater degree of choice about where they send their children to school. We must establish partnerships between universities and the surrounding schools so that the expertise available in universities can be applied to this serious national problem. We must substantially upgrade the training and abilities of our teachers and treat them with the respect and understanding that their importance to the nation's future warrants. And government and industry must work together to produce the trained technicians our country needs.

I'm talking, here, about some sweeping and fundamental changes in the cultural norms of our country, and those changes will not be achieved easily or quickly. But they can be achieved. Our country is one of the most dynamic that the world has ever known; it is one of our greatest strengths. Change is a way of life in the United States, and in a democracy change is almost always for the better. The challenge now is to marshal the collective will. As Benjamin Franklin once said, "In a democracy, the people rule -- if they want to."

Of course, some changes will be easier to achieve than others. Several years ago I was meeting with the Science Advisor to the Prime Minister of Japan and with

one of the most senior scientific entrepreneurs in the Japanese economy. After a day's detailed discussions about our different approaches to high technology, to engineering, to science, and to education, I asked the Japanese science advisor what, in his view, was responsible for the rather different success that our two countries have enjoyed over recent years in the development of high technology, industrial strength and economic competitiveness. His answer was simple. He said, "It may not be unrelated to the fact that in Japan, per capita, we produce five times more engineers than you do, one twenty-seventh the number of lawyers, and no MBA's whatever."

This may be a Japanese solution to the problem of competitiveness that is not appropriate for America. But it gives you an idea of the kind of issues that we must face.