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Series:	Sununu, John, Files
Subseries:	White House Offices Files

OA/ID Number:	29183
Folder ID Number:	29183-008

Folder Title:
Science and Technology (Bromley) (1990) [3]

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Withdrawal/Redaction Sheet

(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
01. Memo	From D. Allan Bromley to John Sununu Re: Letter from Miro Todorovich (1 pp.)	2/13/90	P-5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff to the President, Office of the
Series: Sununu, John, Files
Subseries: White House Offices File
WHORM Cat.:
File Location: Science and Technology
 (Bromley) (1990) [3]

Open on Expiration of PRA
 (Document Follows)
 By JP (NLGB) on 10/28/05

Date Closed:	12/16/2004	OA/ID Number:	29183-008
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AR Disposition:		MR Disposition:	
AR Disposition Date:		MR Disposition Date:	

RESTRICTION CODES

Presidential Records Act - [44 U.S.C. 2204(a)]

P-1 National Security Classified Information [(a)(1) of the PRA]
 P-2 Relating to the appointment to Federal office [(a)(2) of the PRA]
 P-3 Release would violate a Federal statute [(a)(3) of the PRA]
 P-4 Release would disclose trade secrets or confidential commercial or financial information [(a)(4) of the PRA]
 P-5 Release would disclose confidential advice between the President and his advisors, or between such advisors [(a)(5) of the PRA]
 P-6 Release would constitute a clearly unwarranted invasion of personal privacy [(a)(6) of the PRA]

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 (b)(3) Release would violate a Federal statute [(b)(3) of the FOIA]
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 (b)(8) Release would disclose information concerning the regulation of financial institutions [(b)(8) of the FOIA]
 (b)(9) Release would disclose geological or geophysical information

THE WHITE HOUSE
WASHINGTON

Talking to Gary & Bob

THE CHIEF of STAFF
has seen

DATE: February 13, 1990

TO: Dr. Allan Bromley
FROM: GOVERNOR JOHN H. SUNUNU

Your comments, please.

Dear John:

Miro is a good guy - and
an activist with the right
instincts - but I am concerned
that through a revitalized
FECSET and the new PEAS we
can respond to your needs and
the President's for expert advice. I
would not recommend further
ad hoc advisory groups
Allan.

THE WHITE HOUSE

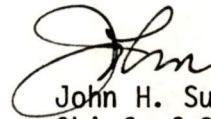
February 13, 1990

Dear Miro,

Thanks for the note.

I will be talking to Allan Bromley about your recommendation. I appreciate you taking the time to write and will follow up next time we meet.

Regards,



John H. Sununu
Chief of Staff

THE WHITE HOUSE

WASHINGTON

Dr. Miro M. Todorovich
410 Riverside Drive, Apt. 82A
New York, New York 10025

bcc: Dr. Allan Bromley

MIRO M. TODOROVICH
410 Riverside Drive, Apt. 82A
New York, New York 10025

February 9, 1990

Dr. John H. Sununu
Chief of Staff
The White House
Washington, DC 20500

Dear John:

In quick succession, the New York Times and other media noted (1) the toning down of the President's speech on global atmospheric concerns, (2) wetland's regulation relaxation, and (3) the one nuclear engineer in the White House allegedly responsible for these deeds.

While in more than full agreement with what was decided, I worry about your exposure to attack (remember Bork, etc.).

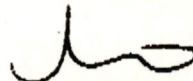
For more than a year now, I have held the belief that impeccably-crafted groups of prominent scientific experts (à la Seabrook panel) whom you would ask for council on specific issues could remove the lightning rod from above your head and guide hostile electricity to harmless neutralization.

You should be seen as a skillful executor of the best scientific/economic understanding held by competent people -- not portrayed as a capricious individual imposing his idiosyncratic predilections, via the President, onto a docile society.

Fred and I could assemble fully believable panels in support of any scientifically defensible decision. I strongly believe that it would be politically very wise that you lean visibly on such scientific validation.

Waiting to hear your reaction.

Cordially,



Miro M. Todorovich

J

Swain ✓

DRAFT LETTER TO CONGRESSMAN GINGRICH

May 21, 1990

Dear Mr. Congressman:

I am writing to convey the views of the Administration on the question of how best to finance the costs that developing countries stand to incur in meeting their commitments under the Montreal Protocol for phasing out production of chlorofluorocarbons (CFCs).

The Administration supports making financial assistance available to help developing countries phase out the production of CFCs. The scientific basis for action is unmistakable. Developing countries must be encouraged to become partners in the effort to phase out CFCs, and should not be asked to bear the full costs of compliance themselves. A solid partnership requires that developing countries participate in the marshalling of global resources needed to sustain this effort. This is essential if we are to achieve our CFC objective at the least cost to other priority objectives, notably achieving rapid and sustainable economic growth.

While the costs to developing countries of complying with the Montreal Protocol may appear to be relatively modest, the costs of addressing similar environmental concerns in future years will be substantial. As these costs grow, resource trade-offs will be inescapable. Industrial and developing countries alike must face this fact. The sooner we face it, the lower will be our adjustment costs.

The Administration believes that we must put in place now an effective system for making decisions on competing uses of resources. Therefore, a mechanism for providing increased funding for phasing out CFCs should contain the following elements:

- o World Bank role. The mechanism should be administered by the World Bank, the leading international development institution.
- o Resources. The World Bank's mechanism should draw upon existing resources. Additional funding for the Bank should be considered in the normal process of replenishing the Bank's resources.

- o Trade-offs. Funds for this activity should be administered in a way that encourages potential recipients to consider choices among competing demands for resources.

The United States was a leader in identifying the need for phasing out CFCs and in drafting the Montreal Protocol. This strong commitment remains. In our view, compliance with the goals of the Montreal Protocol is a clear and tangible sign of international good citizenship. We must meet these goals in a way that offers the best prospect for successfully resolving the world's environmental problems in the future.

Sincerely,

NUCLEAR THERMAL PROPULSION FOR SPACE EXPLORATION

Sending men to Mars adds new dimensions to the challenge of space travel. The long times involved in transit from Earth orbit to Mars, and the return, result in added risks to the health and safety of the astronaut crew. Prolonged periods of weightlessness, the cosmic radiation environment, the dangers of bursts of radiation from sunspot or solar flare events, the performance of life support systems over long time periods and the psychological issues associated with long-duration sequestering of humans all contribute to the hazards of the mission. The minimization of these hazards provides strong incentive to keep the transit time in free space to an absolute minimum.

Nuclear rocket engines, such as were developed and demonstrated in the Rover/NERVA program of the 1960s and early 1970s provide a low risk approach to short travel times to Mars. Nuclear rocket propulsion development, based on solid-core reactors, was begun in 1955 as the Rover Program. The program was expanded in 1961 by the addition of the NERVA (Nuclear Engine for Rocket Vehicle Application) program to develop a prototype of a flight-rated engine. The NERVA program successfully designed, developed, built and tested a number of reactors, culminating in the NRX-A6 which operated for greater than 60 minutes at its rated power of 1100 MWt (equivalent to 55,000 pounds of thrust with a specific impulse over 800 seconds and fuel element exit temperatures of 2550K). The XE-prime engine system demonstrated 28 startup and shutdown cycles. The design of the prototype flight-rated engine was well underway, having successfully passed the equivalent of an Air Force Preliminary Design Review, when the program was terminated in 1972.

Between 1955 and 1972 the United States government invested some \$1.4 billion (\$4 billion in 1990 dollars) in the Rover/NERVA program. The technology developed and demonstrated, through 20 operating reactors, represents the current reactor state-of-the-art. The technology is now being used by both national laboratories and industry in studies of space nuclear power and propulsion systems.

The Rover/NERVA program examined propulsion systems in the thrust levels of 15,000 to 250,000 pounds, specific impulses of greater than 800 seconds, and operating lifetimes up to 10 hours of equivalent full power operation. State-of-the-art materials and advanced fuel technology can boost the NERVA engine specific impulse to over 1000 seconds. The specific impulse is the mission driver. It is the specific impulse of the engine that drives down the initial mass in low earth orbit (IMLEO). It is the specific impulse which allows the transit time to be as short as possible. Although one always tries to reduce the mass of the propulsion engine, it has been shown that thrust-to-engine weight (T/W) ratios of greater than 5 have little effect on IMLEO. In fact, moving from a T/W ratio of 7 to a T/W ratio of 30 decreases the IMLEO by only about 3%, whereas increasing the specific impulse from 850 seconds to 1000 seconds decreases the IMLEO by about 30%. Thus, the driver for improved performance is increased specific impulse.

There are many reactor concepts being actively promoted that promise performance capabilities, measured in specific impulse, ranging from the mid-800 seconds to over 10,000 seconds. These include the NERVA system demonstrated in the 60's (Isp = 850 sec), NERVA systems with advanced fuels (Isp = 925-1020 sec), Particle Bed Reactors (NERVA based fuel bead with 100K higher temperature capability and greater compactness), Low Pressure Disassociating Hydrogen Solid Core Reactors (Isp = 1000-1250 sec), Gas Core Reactors (Isp up to 5,000 sec), and Fusion and Anti-matter systems (Isp in excess of 10,000 sec). It is abundantly clear that the technology status of the newer concepts is well behind the demonstrated NERVA technology and that the risk of failure, as well as the cost and time for development and testing, grows rapidly as the performance level of the system escalates.

A reasonable nuclear propulsion program should therefore include elements that address the complete spectrum of potential performance. For instance, the use of the well developed technology and design base from the Rover/NERVA program would permit the flight qualification of a nuclear propulsion unit with an Isp of perhaps 850 seconds prior to 2004, in time for trial use in lunar missions prior to the manned voyages to Mars. Using the NERVA technology, one would have a low risk approach that can offer a system ground test (public "show and tell") in about 5 years after program restart. Moreover, the early availability of the nuclear propulsion system makes it a viable contender for transportation between Earth orbit and the moon. Although a reduction in transit time is not an issue for lunar missions, the ability of the nuclear system to substantially reduce the amount of propellant mass launched from Earth to LEO could result in significant mission cost savings. Even more important, the initial use of nuclear propulsion in less stressful flights than Mars transit will provide an experience base that will make NASA and the Nation more confident in the widespread application of nuclear propulsion to space exploration.

In parallel with the qualification of the NERVA-type system would be a development program directed not only towards the improvement of fuels for the NERVA system, but the development of fuels, systems, and components for more advanced reactor concepts that hold promise for major improvements in performance. The effort devoted to these programs would be apportioned such that more money and attention would be paid to those systems and/or components whose payoff could be realized earlier than those which were either of very long term potential or extremely speculative.

In total, however, one would have a program plan which provides a near term product, as well as an evolutionary path that will incorporate improvements in performance into the nuclear propulsion system for as long as needs for improvements exist. It is a program in which the users, e.g., NASA, can gain both the advantages of early availability of nuclear systems, as well as the attention to the technologies that will provide improved performance. It is a program that is success oriented for all participants.

A National Strategy for the Technology Base



Summary:

Government must play a larger role in ensuring that the United States has the technology necessary to support our economy. The Administration should redirect existing R&D spending, especially support for government laboratories, to support pre-competitive research in technologies such as semiconductor manufacturing, biotechnology, information systems, materials, robotics, and artificial intelligence.

The Need for Government Action:

The Bush Administration has moved aggressively to increase the savings rate and lower taxes; to keep international markets open, flexible and dynamic; to improve education across the board, and to support basic research. These policies are critically important to maintaining international economic competitiveness.

But they are not enough. Although the Administration has adopted the goal of maintaining the strategic technology base, it has not yet taken the actions necessary to accomplish this.

Why is Action Necessary?

1. **Declining Reliance on Military Support:** For nearly forty years after World War II, "strategic technology" was developed mainly in the context of military and space programs supported by DOD and NASA. This gave us world leadership in integrated circuits, advanced computers, aerospace, lasers, nuclear energy, metallurgy, and many other fields. But two recent developments have undermined this system of supporting strategic technology:

- o The strategic technologies of the future will be increasingly developed in civilian contexts rather than in military or space programs. Biotechnology, semiconductor manufacturing, robotics, artificial intelligence, high definition displays, and materials technology are all being developed for and finding applications today in the civilian sector earlier than in the military sector. This is the reverse of the situation that existed prior to about 1980.

- o The fundamental shift away from U.S.-Soviet military confrontation is likely to reduce R&D budgets available to the military, and make it less possible for military agencies to develop important dual-use technologies.

2. **Increasing Cost of New Technologies:** In the 1970's it cost a company about \$3-5 million to develop a new generation of semi-

conductor manufacturing technology, at a feature level of about 10 microns. In the 1980's the feature level was down to 1-2 microns, but it cost about \$30-50 million to develop a new generation of technology. In the 1990's the feature level will be down another order of magnitude, to about .1-.2 microns. But the cost will be up another order, to about \$300-500 million.

Investments of this magnitude are beyond the capability of any American semiconductor company. Without government support, they may well be beyond the capability of the entire American semiconductor industry. And the same is true of other important industries, such as biotechnology, many materials areas, and high temperature superconductivity.

Strategic technologies are "pre-competitive" and underlie entire industries. It should always remain the responsibility of individual companies to turn them into products for the competitive marketplace. Strategic technologies are inherently high risk, and take sustained investment over a long period before they are ready to produce returns. When the costs were low enough, some companies were willing and able to make these investments as a bet on the future. But in most cases this is no longer possible. Today, an industry decision to stay competitive in these technologies depends on partial support by government if it is to succeed.

Actions:

The Administration should develop a plan, together with industry, to ensure American leadership in strategic technologies in the 21st century.

New funds are not necessary. Federal support for R&D is large enough already. But the funds must be redirected. In particular, at least some government laboratories must be assigned to support industrial coalitions directed towards creating leadership positions in strategic technologies. As military budgets decline, many government laboratories must find new missions or go out of business. Many already have no well-defined mission.

Government support for strategic technologies must be closely coupled with industry participation and industry money. SEMATECH in this country and JESSI in Europe provide possible models for organizing such an effort, although the best method of linking government and industry cooperatively must emerge to some extent from trial and error. But the important thing is to take action, for failure to do so will imperil our industrial future.

DRAFT

EXECUTIVE ORDER

ESTABLISHING GOVERNMENT-WIDE
POLICY IN SUPPORT OF SCIENCE, MATHEMATICS
AND ENGINEERING EDUCATION

This nation's commitment to realizing the National Education Goals, including the ambition to be first in the world in science and mathematics education, requires the mobilization of the Federal government's significant and often unique resources. We have an obligation to assist in providing mathematics and science education fundamental to the production of qualified mathematicians, scientists, engineers and technicians and fundamental to actualizing an informed and literate citizenry capable of meeting increased demands for skilled technological personnel in our nation's labor force.

By the authority invested in me as President by the Constitution and laws of the United States, including [cite authority], it is hereby ordered that each Federal department and agency that employs significant numbers of scientists, mathematicians, engineers and technicians add to their missions specific educational objectives promoting science, mathematics, and engineering education.

To advance this generation of American students, the departments and agencies should endeavor to reach out to the nation's youth -- from kindergarten through high school -- and to

its women, minority, disabled and disadvantaged students.

The Federal Coordinating Council for Science, Engineering and Technology (FCCSET) will provide the forum for coordination of this policy.

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

DATE: May 16, 1990

TO: Gov. Sununu

ADDRESS: West Wing

TELEPHONE NUMBER: 6797

FAX NUMBER: 2397


FROM: D. Allan Bromley

TELEPHONE NUMBER: 7116

FAX NUMBER: (202) 395-3261

NUMBER OF PAGES, INCLUDING COVER SHEET 6

SPECIAL INSTRUCTIONS:

World Commission on Environment and Development - Regional Cooperation Committee, Organized
by the Government of Norway in Cooperation with the Economic Commission for Europe



**ACTION FOR A
COMMON FUTURE**

BERGEN • NORWAY • MAY 8 - 16 1990

TELEFAX

TO: *DR BROMLEY*
FROM: *DR KNAUSS*
Date: *10 MAY 90*
TELEFAX NUMBER:

Our telefax number is *47-5-23 35 82*

Number of Pages (Front page included):

SUBJECT:

THE TEXT AS ADOPTED!

*John:
And have this
for
Ann*

Ministerial Declaration

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operation is needed.

7. In order to achieve sustainable development, policies must be based on the precautionary principle. Environmental measures must anticipate, prevent and attack the causes of environmental degradation. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

8. Environmental problems require greater and more systematic use of science and scientific knowledge. Environmental science activities must therefore be strengthened nationally and internationally. We invite the international science community to contribute towards the advancement of sustainable development policies and programmes. Scientific analyses and forecasts are especially needed to help identify longer term policy options.

9. The evolving political and economic processes in Europe will provide new opportunities for member countries of ECE to co-operate more actively in implementing the provisions of the Helsinki Final Act of the Conference on Security and Co-operation in Europe (CSCE) and in particular the conclusions and recommendations of the concluding documents of the Vienna Meeting of the CSCE (1989), of the CSCE Meeting on the Protection of the Environment held in 1989 in Sofia and of the Bonn Conference on Economic Co-operation in Europe (1990) as well as the ECE Regional Strategy for Environmental Protection and Rational Use of Natural Resources.

10. We believe that the attainment of sustainable

Ministerial Declaration

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CO₂

(d) To recognize the need to stabilize, while ensuring stable development of the world economy, CO₂ emissions and emissions of other greenhouse gases not controlled by the Montreal Protocol. The industrialized nations have agreed at Noordwijk that such stabilization should be achieved by them as soon as possible, at levels to be considered by the IPCC and the Second World Climate Conference. To fulfil this need, and

- noting with appreciation that some countries have already committed themselves in advance to stabilize CO₂ emissions at present levels or to reduce them by the year 2000;

- recognizing that countries with, ~~as yet,~~ relatively low energy requirements, which can reasonably be expected to grow in step with their development, may need strategies or targets which can accommodate that development;

Delete
Brackets !

- also recognizing that strategies or targets could be based, for example, on total emission levels, per capita emissions, climatic conditions or other equitable considerations.

We urge all ECE countries to take action now, and we agree to commit to establish national strategies and/or targets and schedules following the report of the IPCC and no later than the start of the negotiations of a framework convention on climate change to limit or reduce CO₂ emissions and other greenhouse gas emissions as much as possible and to stabilize them. In the view of most ECE countries, such stabilization at the latest by the year 2000 and

Ministerial Declaration
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(d) To work towards a coordinated approach to the use of economic instruments which would be facilitated by guidelines and studies by international organizations, particularly the OECD, ECE and EC. In this context, we welcome the OECD's work on preparing principles and international guidelines which will be presented to its meeting of Environment Ministers in 1991.

 (e) To support, in addition to present development assistance, programmes to increase the flow of capital and environmentally sound technology to developing and East European countries to assist the efforts by the receiving countries on high priority resource and environmental management projects and to meet their international obligations to protect the global environment. In particular it will be necessary to identify new ways and means of providing such resources to developing countries. We welcome the decision of the Development Committee of the World Bank and the International Monetary Fund on May 8, 1990, which urges the Bank, in close collaboration with UNEP and UNDP and other interested parties, to proceed expeditiously with the development of proposals for a pilot global environmental mechanism.

(f) To urge donors and multilateral agencies to take into account the relationship between debt service burdens and the ability of countries both within and outside the ECE to carry out measures to ensure the protection of the environment. We will also urge bilateral and multilateral partners and financial institutions to take full account of environmental considerations and

Ministerial Declaration

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21. We recommend the establishment or continued use of Round Tables or Committees or comparable processes to promote the integration of environmental considerations in all economic and social activities and thereby contribute to sustainable development with a view to improving the accountability of all participants in decision-making. Such bodies should take account of the Bergen model.
22. We will continue to improve national and international processes within the ECE region in the light of the important multisectoral dialogue among Governments and non-government sectors which was initiated by the Bergen process.
23. We will aim for the early completion, if possible in 1991, of the ECE Convention on environmental impact assessment in a transboundary context and to promote the further development of international environmental law.
24. We call on those ECE members who have not already done so to ratify or accede to the Montreal Protocol. We also call on the meeting of the Parties to the Montreal Protocol in London in June 1990 to strengthen international action to protect the ozone layer including, for example, through additional resources and technology transfer. It will be necessary to contribute to the fulfilment of the financial and other conditions to be agreed by the Parties to encourage a broader participation in the Protocol. In the ECE region we are prepared to do so.
25. We will consider strengthening international programmes, existing institutions and law leading up to the 1992 United Nations Conference on the

THE WHITE HOUSE
WASHINGTON

THE CHIEF of STAFF
has seen

February 9, 1990

MEMORANDUM FOR MEMBERS OF THE DPC WORKING GROUP
ON GLOBAL CHANGE

FROM: D. ALLAN BROMLEY

SUBJECT: UPDATE ON PLANS FOR THE 1990 WHITE HOUSE
CONFERENCE ON SCIENCE AND ECONOMICS RESEARCH
RELATING TO GLOBAL CHANGE

The DPC Working Group on Global Change, at its meeting on Tuesday, January 30, 1990, made several decisions with regard to the President's meeting on Science and Economics Research Relating to Global Change.

- 1) It was agreed that the meeting will be held on Wednesday and Thursday, April 18-19, 1990 in Washington, D.C. Subsequent discussions require that these dates be changed to April 17-18 in order to make available the new Georgetown University Leavey Conference Center and Quest House (where the IPCC meeting was held this week).
- 2) It was agreed that the criteria for the invitations would be those countries that "because of their land masses, large populations or heavy future energy needs, will be compelled to deal with environmental problems having a global magnitude and impact," and those countries that have the scientific and technology capabilities to address the substantive questions of global change. The list of invitee countries was endorsed and is:

The G-7 nations, Australia, Brazil, China, India, Mexico, Nigeria (or another African nation, the Soviet Union, Zaire, Netherlands, Norway, the European Community, and the Organization for Economic Cooperation and Development (OECD). We have, for a whole series of good reasons, added Zaire, Norway and the Netherlands to the earlier list.

- 3) It was decided that the President's invitation to the Heads of State of those nations should be sent out ASAP.
- 4) It was decided that the DPC Working Group would meet in two or three weeks to review progress, including matters such as the agenda for the meeting, schedule of "things-to-do" during the next two and a half months, (PERT chart) and logistics.

To facilitate the next DPC Working Group meeting on the Conference, we will prepare a Concept Paper on the Conference which details:

- 1) Concepts and expectations for the meeting:
 - o The rationale and purposes of hosting the meeting, i.e., why is the President hosting this meeting and what do we expect to accomplish by having the meeting?
 - o What is the proposed agenda and schedule of events for the meeting, and what is the rationale behind the elements included in the agenda?
 - o What are the expected outcomes and products from the meeting?
- 2) An initial outline of arrangements and logistics for the meeting.
- 3) A schedule for the decisions, arrangements, logistics, etc. for the meeting, probably through Gantt and PERT charts.
- 4) An outline of the budget and financial considerations for the meeting.
- 5) Specific action items on which the DPC Working Group agreements and endorsements are requested.

If there are questions, comments, needs for information concerning the conference, please contact Bob Corell at 357-9715, or by FAX at 357-9629, or through the OMNET Telemail System at R. CORELL.

cc: Gov. Sununu

SCIENCE AND TECHNOLOGY ACCOMPLISHMENTS
AND INITIATIVES OF THE BUSH ADMINISTRATION
FACT SHEET

The President announced today the establishment of the President's Council of Advisors on Science and Technology (PCAST). This distinguished panel of scientists, engineers and industry leaders will provide high-level advice directly to the President on a wide range of important issues concerning science and technology.

Advances in science and technology are the key to increased economic competitiveness and improving our quality of life. The President's action today caps a year of vigorous activity by the Administration to advance science and technology issues on a broad front. These actions, in three broad areas, are summarized below:

- I. Strengthening Federal Science and Technology Policy
- II. Enhancing Federal Research and Development Activities
- III. Encouraging Increased Private Sector Involvement in Research and Development

I. Strengthening Federal Science and Technology Policy

- o Upgrading the Status of the Science Advisor and Increasing the Budget for the Office of Science and Technology Policy. -- The President has raised the status of the Science Advisor to Assistant to the President for Science and Technology. The Science Advisor now participates in all deliberations of the Cabinet and of the Domestic and Economic Policy Councils to ensure that Science and Technology issues are fully reflected in Administration policy development. In addition, the 1991 budget proposes \$3.3 million for OSTP, a doubling of the 1989 level.
- o Strengthening the Federal Coordinating Council on Science, Engineering and Technology (FCCSET). -- The Science Advisor initiated action to improve the interagency coordination apparatus for science and technology by consolidating and enhancing the current FCCSET committee structure. Building on the successful experience of the FCCSET Committee on Earth Science, new committees will be formed to coordinate Federal efforts in education and human resource development, materials science and others.
- o Establishing the National Space Council. -- The President issued an Executive Order on April 20, 1989, establishing the National Space Council, chaired by the Vice President. The Space Council provides advice and assistance to the President on space policy and strategy and fosters close coordination, cooperation and information exchange among the space sectors.

- o Establishing the Administration's Council on Competitiveness. -- The President established the Council on Competitiveness, chaired by the Vice President, to oversee regulatory and other competitiveness issues, such as reform of product liability laws.
- o Reinvigorating the Council on Environmental Quality (CEQ). -- The President is committed to strengthening the CEQ and to ensuring that it has the capacity to serve as an effective source of environmental analysis and information in White House. Accordingly, the President's 1991 budget increases CEQ's budget by 90 percent and CEQ's staff by 70 percent.

II. Enhancing Federal Research and Development Activities

A. Increased Investment in Federal R&D

- o The President has proposed a total of \$71 billion for research and development (R&D), including R&D facilities, in his 1991 budget. This is an increase of \$4.5 billion, or 7 percent, over 1990 enacted levels.
- o Within this total, civilian R&D will increase by 12 percent, while defense-related R&D will increase by 4 percent.
- o The President has also proposed to allocate \$12 billion for basic research, an increase of \$1 billion or 8 percent over 1990. Basic research is an essential investment in the nation's scientific and technological future, including its future scientists and engineers.

B. Science and Technology Education

The President has moved aggressively to address the shortcomings in the nation's science and technology education enterprise. He has set goals for the nation's schools and students in science and math, and the 1991 budget will provide over \$1 billion in direct spending in five agencies for science, mathematics and engineering education.

- o National Science Foundation (NSF). -- NSF will allocate \$463 million in 1991, a 30 percent increase over 1990, for a wide variety of education activities to improve the quality of teachers and students, the numbers of students choosing science, math, or engineering careers, and the numbers staying in, particularly those in traditionally underrepresented groups.
- o Department of Education. -- The Department will continue to build on its strong relationships with State educational entities. The 1991 budget proposes

\$230 million, an increase of 69 percent, for the Dwight D. Eisenhower Mathematics and Science program, which provides funds to States to implement improved programs for teaching math and science.

- o National Aeronautics and Space Administration (NASA). -
- NASA will allocate \$51 million in 1991, an increase of 21 percent, for education activities including the "Spacemobile" program, teacher and student workshops and research experiences at NASA laboratories, and special efforts to increase minority participation in science and engineering.
- o Department of Energy (DOE). -- DOE will provide \$25 million in 1991, a 47 percent increase, for educational activities including support for graduate and undergraduate students, high school and university faculty. DOE will implement a new program, in collaboration with the private sector, to train high school faculty in the state-of-the-art science and technology conducted at the DOE laboratories.
- o National Institutes of Health (NIH). -- The research training grant program will be funded at a level of \$292 million which will support almost 12,000 graduate trainees in research laboratories throughout the nation.

C. Doubling the Budget of the National Science Foundation

The President has maintained his strong commitment to the importance of basic research by proposing \$2.4 in budget authority, a more than 14 percent increase, for the National Science Foundation. This will continue progress toward doubling the NSF budget by 1993.

- o World-Class Research Equipment. -- The President has also recognized that world-class science and technology requires world-class research equipment. He has supported the construction of a replacement for the important radiotelescope at Greenbank, West Virginia, and, for 1991, has proposed the initiation or continuation of several high-priority, specialized research facilities including the National High Magnetic Field Laboratory, the Laser Interferometer Gravitational Wave Observatory, and two 8-meter optical/infrared telescopes.
- o Academic Research Facilities Modernization. -- In addition to research support, the Administration will also continue the Academic Research Facilities modernization program begun by NSF in 1990. This will allow experience to be gained in managing the program and time to evaluate the impact on U.S. science and technology.

- o U.S. Antarctic Program. -- NSF manages the U.S. Antarctic Program for the government. This program supports national goals in the Antarctic and is the principal expression of U.S. presence on the Antarctic continent. The 1991 budget will expand an important environmental, safety, and health initiative in the Antarctic to ensure that this world scientific resource is preserved and that the safety and health of scientists working on the continent is assured.

D. Understanding and Exploring Space

The President is firmly committed to a continuing, active and exciting American presence in space -- indeed, to America's leadership in space science and exploration. Overall, the 1991 budget proposes \$15.2 billion for NASA, an increase of \$2.9 billion or 24 percent. NASA's budget has increased by almost 40 percent over 1989.

- o Space Shuttle. -- The current fleet of three Space Shuttles are the world's most versatile launch vehicles. In 1989, the Space Shuttle fleet completed 4 successful flights. The Space Shuttle Columbia recently accomplished the spectacular retrieval of the Long Duration Exposure Facility. The 1991 budget proposes \$4.2 billion, an increase of 22 percent, for Space Shuttle production and operations. This funding will allow for a safe build-up to 10 Shuttle flights, the delivery of the fourth Shuttle, Endeavor, and enhancements such as the Advanced Solid Rocket Motor and the Extended Duration Orbiter capability.
- o Space Station Freedom. -- Space Station Freedom is the largest international R&D project ever undertaken. In 1989, the program underwent a reevaluation that has resulted in a more achievable program and funding profile. The 1991 budget continues the President's commitment to the Space Station by proposing a total of \$2.6 billion, an increase of 36 percent. This will provide for the critical transition from design to actual fabrication.
- o Moon/Mars Exploration. -- On July 20, 1989, the President proposed that America undertake an ambitious mission of manned exploration of the solar system. This journey of a trillion miles will begin with the first step in the 1991 budget -- nearly \$1.3 billion, an increase of 47 percent -- to support robotic science missions and to develop the pacing technologies that will be needed. Of particular interest is the continued commitment of the Administration to the National Aerospace Plane (NASP) program. In 1989 the National Space Council reviewed and revised this program in keeping with a more stable and sustainable pace of technology and funding.

- o Space Science and Applications. -- The U.S. is committed to maintaining its world leadership in space science. An exciting new era of discovery has now begun in unmanned planetary exploration, astronomy, and Earth observations. In 1989, three important scientific missions were launched: Magellan to Venus, Galileo to Jupiter, and the Cosmic Background Explorer. The 1991 budget proposes \$3.3 billion, an increase of 22 percent, for the continued support of missions planned for launch in 1990 including the Hubble Space Telescope, the Gamma Ray Observatory, and the Ulysses to explore the Sun, and development of future missions such as the Comet Rendezvous/Asteroid Flyby and the Cassini mission to Saturn.

E. Global Environmental Change

- o U.S. Global Change Research Program (USGCRP). -- The U.S. is the world leader in global change research. The President has endorsed the USGCRP, a coordinated, multiagency research program of space- and ground-based research and observations designed to provide a sound scientific basis for rational policy decisionmaking on global change issues. The 1991 budget proposes over \$1 billion for this effort, an increase of 57 percent.
- o Mission to Planet Earth (MTPE). -- Also on July 20, the President affirmed the importance of NASA's contribution to the USGCRP, Mission to Planet Earth. The largest part of this initiative consists of a major new program for 1991, the Earth Observing System, a series of space platforms and instruments developed by the U.S., Europe and Japan, which will collect a broad spectrum of environmental data related to global warming, drought, oceans, etc. MTPE will permit, for the first time, Earth to be analyzed as an integrated system.
- o International Activities. -- The President believes that continuing U.S. scientific leadership is needed to address global environmental issues. In the past year, the President announced U.S. support for a worldwide phaseout of chlorofluorocarbon (CFC) production to the extent safe substitutes are available. In 1990, the U.S. will host the Plenary Session of the Intergovernmental Panel on Climate Change (IPCC) in February; a meeting of the world's economic, scientific, and environmental officials to discuss global environmental issues in the Spring; and the first negotiation session on the Framework Convention on Climate Change in late Fall.

F. Environment

- o Clean Air Act. -- The President demonstrated his commitment to clean air by transmitting Clean Air Act

6

Amendments to Congress in July of 1989. The President's plan allows for both environmental protection and economic development and is based on a commitment to using the best science available. In support of his Clean Air proposals, the 1991 air research budget of the Environmental Protection Agency will increase by \$8 million to a total of \$95 million.

G. The Superconducting Super Collider and High Energy Physics

- o The Superconducting Super Collider (SSC). -- The SSC will provide an enormous advance in the capability to explore the secrets of matter and energy. Over the past year, the Department of Energy has established the SSC laboratory at the site near Dallas, Texas. The new laboratory team is conducting a thorough reevaluation of all technical systems with particular attention to magnet design and technical performance of the accelerator. In 1989, research continued on the design and testing of magnets. Approximately 8,000 magnets will be used in the 53-mile SSC tunnel. In addition, during 1989, DOE continued work on the site-specific Environmental Impact Statement (EIS). The EIS is necessary before DOE makes a decision on the "footprint" of the SSC and starts acquiring land for the project.
- o High Energy and Nuclear Physics. -- The Administration is pursuing a robust program of research in the area of high-energy and nuclear physics, which offer the prospects of increasing our knowledge of the basic constituents of matter. Last year, scientists discovered and conducted measurements of the Z-nought particle utilizing the recently upgraded Stanford Linear Collider. The Z-nought particle is important because it transmits one of the basic forces between elementary particles. The 1991 budget provides a funding increase of 8 percent to continue research at Stanford and the three other large accelerator centers: the Brookhaven National Laboratory on Long Island; the Cornell Electron Storage Ring in New York State; and the Fermilab National Laboratory.

H. Life Sciences

- o Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome. -- The Administration remains committed to making continued progress against HIV/AIDS. Five therapies have been approved for use, and since January 1989 over 35 clinical trials have been initiated in a search for additional therapeutic drugs. The Administration has recently taken action to enable State Medicaid programs to cover the costs of the drug AZT for HIV-infected individuals who do not yet exhibit AIDS symptoms. The 1991 budget proposes \$3.5 billion in total for HIV/AIDS research, treatment,

prevention and income support, an increase of 18 percent.

- o Human Genome Project. -- The advent and evolution of genetic engineering techniques over the last decade has enabled the initiation of one of the most exciting science projects ever undertaken -- the development of a map of the full complement of human genetic material (the human genome). Such an undertaking will vastly increase our understanding of the nature and cause of many diseases. The 1991 budget proposes \$108 million for the National Institutes of Health and \$46 million for the Department of Energy to pursue collaboratively this important project.
- o Biotechnology. -- Recent breakthroughs in biotechnology, such as recombinant DNA techniques, cell fusion and gene therapy, offer unprecedented opportunities for improving the nation's productivity, health, and well-being. Increasing Federal investment in basic biotechnology research will spur further advances, as will initiatives that improve payoffs on investments. The 1991 budget proposes \$3.6 billion for biotechnology R&D, an increase of 6 percent over 1990.
- o Agricultural Research Initiative. -- American farmers are among the most productive in the world. New techniques in genetics, molecular and cell biology enable the innovative approaches that will enhance our ability to produce food, while addressing concerns of safety, nutrition and the environment. The 1991 budget will launch a National Research Initiative to more than double the size of USDA's competitive grants program. This will expand funds for plant and animal biotechnology to \$50 million, with a particular emphasis on mapping the genomes of important crop plants. Like the Human Genome Initiative, this effort will enable new opportunities to explore the genetic potential of plants.

I. Energy

- o National Energy Strategy. -- The President has directed Secretary of Energy Watkins to develop a National Energy Strategy to guide the Administration's energy policies and programs. The Department has held two rounds of public hearings and plans to issue a draft document in April. A key element of the strategy will be a blueprint for future energy R&D programs and activities.
- o Clean Coal Technology. -- The Administration is committed to a \$2.5 billion program to demonstrate emerging Clean Coal Technologies. This program will provide additional cost-effective alternatives for reducing acid rain.

- o Solar/Renewables and Energy Conservation R&D. -- The Administration is committed to assisting the development of emerging technologies that offer the potential to provide new sources of energy as well as new ways to use it more efficiently, while protecting the environment. On January 26, 1990, the Department of Energy announced a new 11-point initiative in this area. The 1991 budget provides a increase of 8 percent in funding for conservation, solar and other renewable energy technology R&D.
- o Enhanced Oil and Gas Recovery Research. -- Up to two-thirds of oil and gas reserves are still left in the ground with conventional recovery techniques. In order to stimulate the use of new technologies to increase production from these existing fields, the Administration proposed four new tax initiatives, including a 10 percent credit for new tertiary enhanced recovery projects. In addition, the 1991 budget proposes \$17 million to establish oil and gas geosciences research consortia with industry and universities to advance the science underlying oil and gas recovery.

J. Advanced Technology

- o Manufacturing Technology Centers. -- The Administration proposes to continue funding for these centers, requesting \$5 million in 1991. This Department of Commerce program provides matching grants to universities or non-profit organizations to establish centers for the transfer of innovative, advanced manufacturing technology to small and medium-sized businesses.
- o Advanced Technology Program (ATP). -- The Administration requests \$10 million in 1991, the 1990 funding level, for this new Department of Commerce program. The ATP will provide seed money to industry-led consortia doing generic, pre-competitive research into promising technologies.
- o Magnetic Levitation Transportation. -- The 1991 budget proposes nearly \$10 million for R&D on this emerging technology, an increase of almost 400 percent. These efforts are being carried out by both the Department of Transportation (about \$6 million proposed by 1991) and the Army Corps of Engineers (almost \$4 million). Each agency is pursuing a public-private partnership designed to facilitate private development of an operational maglev system in the U.S.

K. National Security

- o DOD Technology Base. -- The Administration supports a strong technology base to develop options for future weapons systems and to guard against technological surprise by adversaries. The 1991 budget includes \$3.4 billion for the technology base (basic and applied research) funded through the Department of Defense. This will support programs ranging from basic research in the physical sciences to development of high speed semiconductors for use in advanced communications systems and computers.
- o Strategic Defense Initiative (SDI). -- The SDI program remains a high priority of the Administration. The 1991 budget requests \$4.5 billion for SDI, an increase of \$0.9 billion over 1990. The SDI program is developing options for the deployment of strategic defenses based on advanced technologies. Particular emphasis is being placed on promising new concepts such as the "Brilliant Pebbles" small space-based interceptor missiles.

III. Encouraging Increased Private Sector R&D Investment

Private sector investment accounts for about 50 percent of the total national investment in R&D. In addition, the private sector is the principal performer for R&D and is ultimately responsible for transforming R&D results into useful new products and processes. The Administration has taken a number of steps to encourage increased private sector R&D investment and technological innovation.

- o Encouraging Savings and Investment. -- The Administration is proposing the Family Savings Account to stimulate increased savings that provide the resources needed for investments in the future. In addition, the Administration is proposing to lower the tax on capital gains in order to promote increased entrepreneurial activity and investment.
- o Research and Experimentation Tax Credit. -- The Administration again proposes to make permanent the 20 percent tax credit targeted specifically to research and experimentation (R&E) by allowing 100 percent of total research expenses to be used for the computation of the credit for all years after December 31, 1989. In 1989, the Congress enacted a short-term extension in response to the President's proposal of last February.
- o Encouraging R&D by Transnational Companies. -- The Administration proposes to make permanent the rules, as modified by the Omnibus Budget Reconciliation Act of 1989, for the allocation of foreign and domestic R&E

expenditures for companies with foreign operations. The proposal would also allow 100 percent of U.S. expenditures to be covered rather than the current 75 percent. This proposal would apply to all tax years beginning after August 1, 1990, when the current rules expire.

- o Intellectual Property. -- The Administration is committed to pursuing aggressively improved international protection of intellectual property. The current negotiations in the Uruguay Round of the General Agreement on Tariffs and Trade are an important forum for this activity.
- o Tort reform/New Product Liability. -- The Administration has endorsed changes in product liability laws to help restore balance to the tort system, to increase competitiveness, and to reduce uncertainty, particularly for new products, while providing incentives to produce safe products.

Our Changing Planet:

The FY 1991

U.S. Global Change Research Program



A Report by the Committee on Earth Sciences

To Accompany the
U.S. President's Fiscal Year 1991 Budget

This photograph of the Earth was taken from the Apollo 16 Spacecraft. Much of the Earth is heavily cloud covered. A portion of the United States from the Great Lakes to Southern California, including the Rocky Mountain area, is visible. The North American coastline from Southern Mexico to Alaska can be seen.

Our Changing Planet:
The FY 1991
U.S. Global Change Research Program

A Report by the Committee on Earth Sciences

To Accompany the
U.S. President's Fiscal Year 1991 Budget

**Office of Science and Technology Policy
Federal Coordinating Council for Science,
Engineering, and Technology**

Committee on Earth Sciences

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Geological Survey

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Executive Secretary

Paul V. Dresler, Department of the Interior, United States
Geological Survey

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

MEMBERS OF CONGRESS:

I am pleased to forward with this letter "Our Changing Planet: The FY 1991 U.S. Global Change Research Program," a report by the Committee on Earth Sciences of the Federal Coordinating Council for Science, Engineering, and Technology to accompany the President's Fiscal Year 1991 Budget.

The report outlines an accelerated, focused research strategy designed to reduce key scientific uncertainties and to develop more reliable scientific predictions upon which sound policies and responses to global change can be based. Because of the importance of this area, the President is proposing a 57 percent increase in the budget for this effort for FY 1991.

The research program presented here is a key component of the President's overall approach to the global change issue. This approach has, as its central goal, the provision of a sound scientific basis for developing national and international policy on global change. The President has called for an expanded schedule of international collaboration on research, monitoring, data exchange, and a new Framework Convention on climate change. This comprehensive approach recognizes the profound economic and social implications of responding to global environmental changes and maintains U.S. leadership on this issue.

The Committee on Earth Sciences' report outlines a careful blend of ground- and space-based efforts in research, data gathering, and modeling activities with both near- and long-term scientific and public policy benefits. The report has benefited from close interaction with the National Academy of Sciences, the International Council of Scientific Unions' International Geosphere-Biosphere Programme, and the World Meteorological Organization's World Climate Research Programme. As such, I believe the report and the process which produced it provide an exemplary model of a coordinated, integrated research strategy and a sound basis for planning. Chairman Dallas Peck, Vice Chairman Robert Corell, and their interagency committee members, associates, and staff have done an excellent job and are to be commended.

Sincerely,



D. Allan Bromley
Director

To obtain a copy of this document – send request to:

Committee on Earth Sciences
c/o U.S. Geological Survey
104 National Center
Reston, VA 22092
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Executive Summary

- Although the Earth has been changing for millions of years, dramatic recent changes such as antarctic ozone depletion demonstrate that human activities are affecting the Earth system.
- Recognizing the profound economic and social implications of responding to global environmental changes, the President has set in motion a comprehensive process designed to continue U.S. leadership on this issue. This includes an accelerated, focused research effort; active participation in international collaborative efforts intended to culminate in a Framework Convention; and a comprehensive review of potential policies and their implications.
- As the research component of this process, the U.S. Global Change Research Program is designed to reduce key scientific uncertainties and to develop more reliable scientific predictions upon which sound policy strategies and responses can be based.
- An improved predictive model of the integrated Earth system and a better understanding of human interactions with this system will provide direct benefits by anticipating and planning for impacts on commerce, agriculture, energy, resources utilization, and human safety.
- Because of the high priority attached to the U.S. Global Change Research Program, the President is proposing \$1,034 million for this research effort in the FY 1991 budget, a \$374.8 million or 57 percent increase over the FY 1990 level.
- This proposed budget will significantly expand research, data gathering, and modeling activities with both near- and long-term scientific and public policy benefits. It includes a carefully balanced mix of ground- and space-based

research efforts that are essential given the variability of the phenomena being studied and the need to scale local processes to regional and global levels.

- For the ground-based program, the proposed budget will initiate multi-agency research thrusts in several critical areas, including the role of clouds in controlling climate, fluxes of greenhouse gases, resource responses to global change, past changes in the Earth system, and the role of human activities in global change.
- For the space-based program, the proposed budget will initiate the development of the NASA Earth Observing System, a key element in "Mission to Planet Earth," which will provide the centerpiece of an integrated international satellite program for monitoring global change, coupled with a comprehensive data and information system.
- This report summarizes the key features and budget of the proposed U.S. Global Change Research Program for FY 1991. A more detailed FY 1991 research plan will be released in the spring of 1990.
- The research program was developed by the Committee on Earth Sciences of the Federal Coordinating Council for Science, Engineering, and Technology, in close interaction with the National Academy of Sciences, the International Council of Scientific Unions' International Geosphere-Biosphere Programme, and the World Meteorological Organization's World Climate Research Programme.

Introduction

World leaders are taking an increased interest in the economic and social implications of global environmental changes, both natural and human-induced. The 1988 midwestern U.S. drought underscored the potential effects of a warm, dry summer, just as the climate in recent decades in the Sahel starkly reveals the human tragedy that can occur in marginal-subsistence zones of a changing planet. Furthermore, the very recent linking of the antarctic ozone "hole" to man-made chlorofluorocarbons and the current debate over humanity's role in the greenhouse effect have placed the environment high on the national and international agenda.

In virtually all of these issues, the salient feature is the significant scientific uncertainty associated with predicting the behavior of the coupled ocean-atmosphere-land system. The formidable costs associated with addressing environmental change require that policy decisions be based on adequate scientific knowledge. To provide this knowledge, the U.S. Global Change Research Program has been created as a key component of the President's overall approach to global environmental change. Because of the priority attached to this issue, the President is requesting \$1,034 million for the research program in FY 1991, an increase of \$374.8 million or 57 percent over the FY 1990 level.

The present document is the second in a series of overviews that accompany the President's annual budget to the Congress. It highlights the Program's FY 1991 research activities and budget developed by the Committee on Earth Sciences (CES) of the Federal Coordinating Council for Science, Engineering, and Technology.

The CES activities of the past year began with the publication in January 1989 of *Our Changing Planet: A U. S. Strategy for Global Change Research*. Following this strategic plan, the CES prepared *Our Changing Planet: The FY 1990 Research Plan* (July 1989), which reviewed the Earth system changes that have occurred in the past; the forces that are at work today;

and the strengths and weaknesses in current scientific understanding. It also described the highest priority interdisciplinary research needs, agency roles, and new FY 1990 research initiatives.

The FY 1990 Research Plan was reviewed by the National Academy of Sciences, the American Geophysical Union, and others, all of whom strongly endorsed the Program's holistic approach to understanding the Earth system. The *Plan* is also consistent with the concepts outlined by the International Geosphere-Biosphere Programme and the World Climate Research Programme.

While recognizing the need for a comprehensive research and modeling effort, the FY 1991 Program also focuses on the scientific issues underlying current and future policy questions, including: Should the "Montreal Protocol on Substances that Deplete the Ozone Layer" be strengthened? Has a global warming signal been detected, and what are the relative contributions from natural processes and human activities? What will the climate of the coming century be like, and how will it impact agriculture, forestry, habitation, and water and energy supply and use?

Furthermore, the present document shows how this integrated interdisciplinary program has begun to address such crosscutting activities as understanding the carbon cycle, data management, education, and emerging disciplines.

A comprehensive FY 1991 research plan will be published in the spring of 1990.

Planning the FY 1991 Program

In *The FY 1990 Research Plan*, the CES established the following goal and objectives for the U.S. Global Change Research Program:

Goal:

To establish the scientific basis for national and international policymaking relating to natural and human-induced changes in the global Earth system.

Objectives:

To establish an integrated, comprehensive long-term program of documenting the Earth system on a global scale.

To conduct a program of focused studies to improve our understanding of the physical, geological, chemical, biological, and social processes that influence Earth system processes and trends on global and regional scales.

To develop integrated conceptual and predictive Earth system models.

Planning Framework

Each year the CES will review the Program to ensure that it continues to aggressively address its goal and objectives. This process began in mid-July 1989, when CES evaluated individual agency initiatives relative to ongoing programs and the priority and evaluation framework outlined later in this section.

At a series of meetings over the ensuing months, agency representatives developed a final recommendation on the content and resource requirements for the FY 1991 Program. Subsequently, during the fall of 1989, there were extensive program reviews and discussions that led ultimately to the FY 1991 Program and budget summarized herein.

As part of these deliberations, the CES has forged increasingly effective partnerships among the Federal agencies and with the scientific community. These partnerships, the need to integrate science into the policy process, and the focus on interdisciplinary science have become the "Basic Tenets" (see box on page 7) of the CES cooperative planning process.

Priority Framework

In the preparation of *The FY 1990 Research Plan*, the CES created and implemented a multi-level priority-setting framework that was used to focus and integrate the program development and budget proposals. This framework contains three levels of priorities for the U.S. Global Change Research Program, diagrammed in Figure 1. These strategic, integrating, and science priorities focus on those research questions that will produce significant early improvements in understanding and modeling the interactive Earth system. For example, there is little disagreement that a major shortcoming of existing general circulation models is their inability to simulate the role of clouds and convective processes accurately; hence, that research is the highest priority in the Climate and Hydrologic Systems element. However, concurrent progress in high priority activities in all science elements is necessary for the Program to achieve its overall goal, although not all will receive equal emphasis.

Evaluation Criteria

Within each science element, the CES evaluated FY 1991 research initiatives, taking into account the priorities and several evaluation criteria (see box on page 10). These criteria provided a framework for designing the specific project-by-project structure that constitutes the Program (see Appendix for project listing).

The CES Process: Basic Tenets

- ***Integrate Science into the Policy Process.*** The need for effective relationships between the policy processes of governments and the underlying science of environmental issues has always been recognized and central to the U.S. Global Change Research Program. A process for policy development has evolved within the Executive Branch that directly involves the CES, including (i) it being the focal point for the development and coordination of U.S. scientific programs for global change, both domestically and internationally, and (ii) ensuring that the results of these scientific efforts provide the foundation for rational policy debate and effective action.
- ***Maintain a Partnership Among All Participants.*** A partnership has evolved among the CES members and between CES and the non-Federal research community through the relevant Committees and Boards of the National Academy of Sciences (NAS), notably the Committee on Global Change (CGC). Within CES, there has been a conscious effort not to designate "lead" agencies. Leadership is distributed among the agencies, with each contributing its strengths to the planning, documentation, review, and implementation process. This partnership concept is fundamental to the operation of the CES. The same philosophy is operative in the parallel planning relationship with the NAS, including joint meetings, program reviews, and exchange of ideas for developing implementation strategies. In addition, the CES has interacted with (i) the international scientific community and agencies of other governments, (ii) several intergovernmental bodies with global change concerns, (iii) the environmental community, and (iv) the private sector.
- ***Focus on Interdisciplinary Science and Interactions.*** The CES science program is founded on the premise that the essential scientific questions can only be addressed through interdisciplinary research on the interacting components of the Earth system. This is also the scientific strategy of the CGC and its international counterpart, the International Geosphere-Biosphere Programme (IGBP), thereby further strengthening the interactions of the CES and CGC.

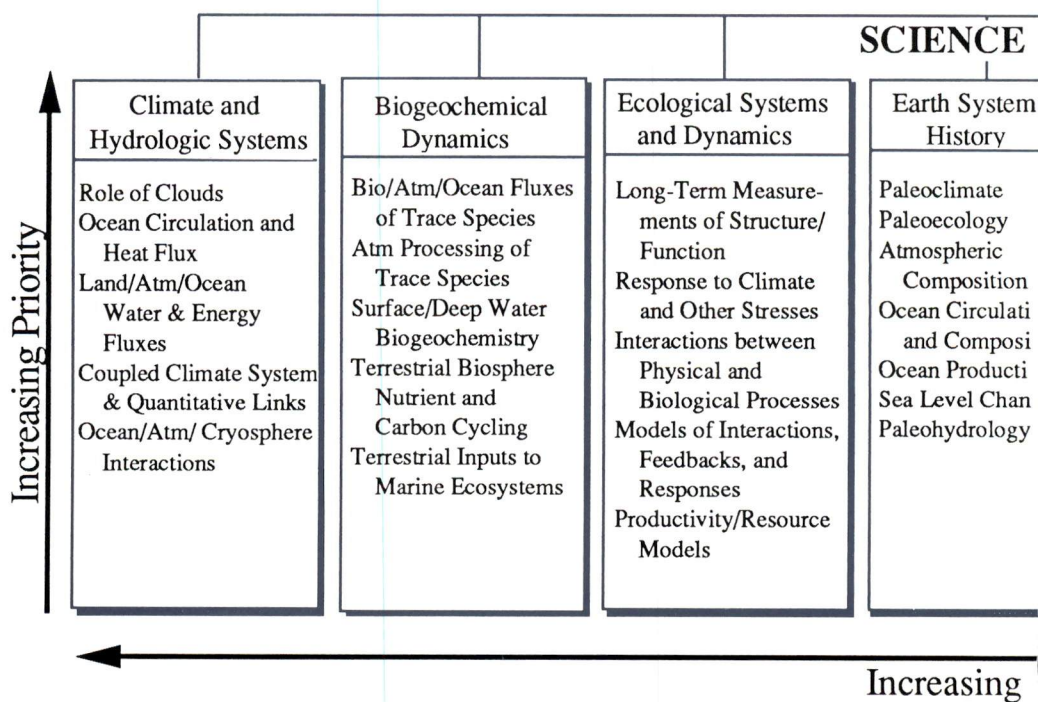
Figure U.S. Global Change Research

STRATEGIC

- Support Broad U.S. and
- Identify Natural and Hu
- Focus on Interactions
- Share Financial Burden, and Encourage Full

INTEGRATING

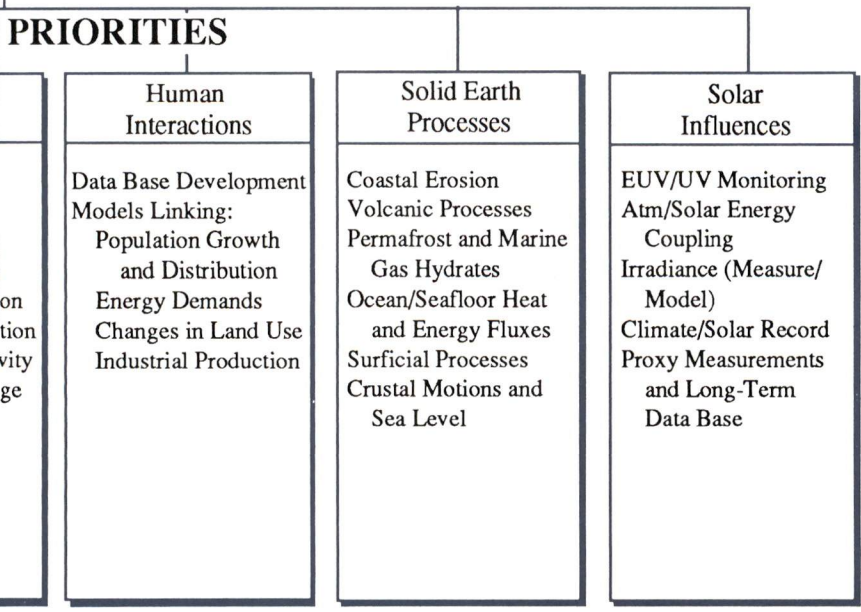
- Documentation of
 - Observational
 - Data Manage
- Focused Studies on and Improved
- Integrated Concep



1 Program Priority Framework

PRIORITIES
International Scientific Effort
man -Induced Changes
and Interdisciplinary Science
Use the Best Resources,
Participation

PRIORITIES
Earth System Change
Programs
ment Systems
Controlling Processes
Understanding
tual and Predictive Models



The CES Evaluation Criteria

- ***Relevance/Contribution.*** The research must address the overall goal and one or more of the three key scientific objectives of the Program.
- ***Scientific Merit.*** The proposed work must be scientifically sound and of high priority, and be the product of a documented scientific planning and review process.
- ***Readiness.*** The level of planning must be mature, of high quality, and the research likely to produce vital and needed advances.
- ***Linkages.*** The CES looks for established inter-agency, other national, and international connections.
- ***Costs.*** The CES considers whether the identified resources are adequate; if they represent an appropriate share of total available resources (e.g., a balance between space- and ground-based program elements); prospects for joint funding; and the degree to which long-term resource implications have been evaluated.
- ***Enhancements to Existing Program Research.*** The highest priority existing programs will receive adequate support before new initiatives are funded.
- ***Agency Approval.*** The proposed program or activity must have policy-level approval by the submitting agency.

Agency and Organizational Roles

At the outset of the Program, the CES developed a set of role statements that specifically define each agency's respective role in the Program (see *The FY 1990 Research Plan*, Appendix A). In developing the FY 1991 Program, that process of role definition has been extended. The current status of participation in the Program by CES agencies and other Federal organizations has three categories:

- (1) Agencies whose budget initiatives are in the "focused" category and hence are detailed in this document.** These are the Department of Commerce, National Oceanic and Atmospheric Administration (DOC/NOAA), Department of Energy (DOE), Department of the Interior (DOI), Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), and the United States Department of Agriculture (USDA).
- (2) Agencies whose programs fall into the "contributing" category.** These agencies' programs support many of the science elements, but were initiated for reasons other than the focused Program goal. They include the agencies with focused programs and the research agencies of the Department of Defense (DOD) (including the Office of Naval Research, the Oceanographer of the Navy, and the U.S. Army Corps of Engineers).
- (3) Agencies and offices of the Executive Branch that contribute to the overall guidance of the Program.** These agencies and offices contribute to the architecture of the Program and are key vehicles for coordinating and linking the Program with overall national and international policy on global change. These include the Council on Environmental Quality (CEQ), Departments of State (DOS) and Transportation (DOT), Office of Management and Budget (OMB), Office of Science and Technology Policy (OSTP), and the White House Office of Policy Development.

Benefits

The U.S. Global Change Research Program is founded on the premise that effective strategies to address environmental issues can be built only on sound scientific information.

Therefore, a hallmark of the Program strategy is linking the U.S. scientific program for global change to the policy process, including:

- Predicting the magnitude and timing of environmental variations, thereby providing the means to plan or avoid their impacts.
- Separating natural changes from human-induced changes, thereby balancing regulatory needs with economic and social development and providing the ability to focus on those parts of the problem that are traceable to human intervention.

Specifically, this is accomplished by supporting a robust, prioritized research effort that can address important policy issues (see box on page 13) and address public needs for predicting and dealing with environmental change through:

- (i) ***Providing Timely Information*** – making available the results of scientific research through special briefings and other information products for the Congress, the Executive Branch, and others immediately after new insights are obtained;
- (ii) ***State of the Science Assessments*** – providing periodic assessments of the "state of the science" in the critical areas of global change (as has been done regarding the stratospheric ozone layer), employing both domestic and international mechanisms, such as the Committees of the NAS and the Intergovernmental Panel on Climate Change (IPCC);

***Benefits of the U. S. Global Change Research Program:
Examples***

- ***Greenhouse Gases.*** A better understanding of the processes, both natural and human-influenced, that govern the sources and fates of greenhouse gases will provide a basis for analyzing integrated control strategies and cost-benefit analyses.
- ***Ozone Depletion.*** Maintaining the "Montreal Protocol on Substances that Deplete the Ozone Layer" will require an improved knowledge of the mechanisms controlling the stability of the stratospheric ozone layer.
- ***Energy.*** Establishing links between carbon dioxide emissions and atmospheric abundances with energy policy scenarios will facilitate the assessment of different energy technologies.
- ***Agriculture/Ecosystems.*** Better knowledge of the linkages of crops, forests and other ecosystems to environmental conditions will enhance the ability to make sound decisions regarding food security, forest management, and conservation of natural resources, including crop selection, reforestation, and deforestation practices.
- ***Water Policy.*** A more complete knowledge of the interaction of the climate and hydrological cycles will help resolve issues involving water supply and demand and will allow better planning for the allocation of water resources during extreme events.
- ***Sea Level.*** Elucidation of the processes that control sea level will provide the predictive capability to guide policies regarding coastal human settlements and wetlands.

(iii) **Regular Prediction/Forecasting Products** - providing a line of information products that address three time scales: seasonal, interannual, and interdecadal.

- **Seasonal Projections** - It is expected that research already under way (including developments from the sciences associated with weather forecasting) will lead to seasonal forecasts (i.e., 30- to 60-day projections) within three to five years. These products will likely be derived from the existing weather forecasting systems operating throughout the countries of the world. Ocean forecasting is in an earlier state of development and will require increased effort to achieve this goal.
- **Interannual Projections** - The advent of a greatly improved understanding of how the tropical ocean induces changes in heating patterns within the atmosphere (El Niño and the Southern Oscillation) is leading toward one of the next realizable lines of predictive products. It is expected that within about 10 years regular assessments and forecasts will be produced quarterly, each providing three- to six-month forecasts, a one-year prognosis, and a two-year outlook of interannual climate variability for selected climatic processes.
- **Interdecadal Projections** - It is expected that prediction of selected climatic processes on interdecadal (ten to twenty years) time scales will emerge during the coming decade. The products will consist of interpretive reports and model predictions. This process is beginning with the science assessment of the IPCC and the Second World Climate Conference in late 1990.

In summary, the overall benefits of the Program are substantial: (i) providing critical data to minimize economic or other adverse impacts by supporting prudent near-term actions where justified, while accelerating the development of more

reliable scientific understanding on which to base long-term policies; (ii) contributing to the Nation's environmental leadership and credibility, both domestically and internationally; and (iii) serving as a catalyst for similar scientific commitments from other nations.

Research Program and Budgets

The following sections summarize the FY 1991 activities and budgets of the U.S. Global Change Research Program in the seven interdisciplinary science elements, by agency, by scientific objective including data management, by Federal budget function, and by the balance between space- and ground-based components. Because of the complex nature of the Program, examples of important research, data collection, and modeling activities will be mentioned along with how they address the research priorities and related policy-relevant questions.

Budget Overview

Table 1 shows the U.S. Global Change Research Program budget proposal by science element, by agency, and by scientific objective. In FY 1990 funding for the U.S. Global Change Research Program is \$659.3 million.* The President's FY 1991 budget proposes a funding level of \$1,034 million, a \$374.8 million (57 percent) increase over the FY 1990 level. Table 2 shows the budgets for programs that contribute to global change research and provide important support to the Program objectives but were initiated for reasons other than the focused Program goal.

* The FY 1990 Program as outlined in the President's FY 1990 Budget to Congress was \$190.5 million (see *Our Changing Planet: A U.S. Strategy for Global Change Research*, January 1989). The FY 1990 Program was adjusted to \$659.3 million over the past year reflecting subsequent FY 1990 Appropriations actions by the Congress and the reevaluation of "focused" and "contributing" programs. The bulk of this increase is due to the transfer of several NASA programs from the "contributing" category.

Budget by Science Element

This section summarizes the FY 1991 activities in the seven interdisciplinary science elements and data management. Figure 2 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by science element. At this time the U.S. Global Change Research Program focuses primarily on the three highest priority science elements: Climate and Hydrologic Systems, Biogeochemical Dynamics, and Ecological Systems and Dynamics. However, the Program maintains an appropriate level of effort in all seven science elements consistent with the policy needs, science priorities, and the current state of scientific program development.

Figure 2
U.S. Global Change Research Program Budget
by Science Element

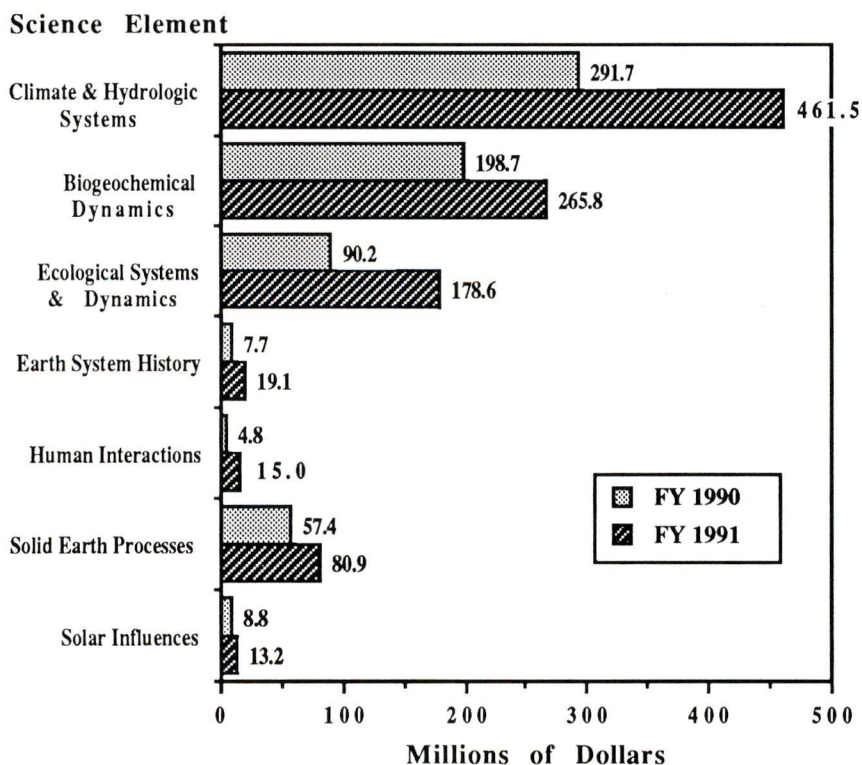


Table
FY 1990-1991 U. S. Global Change
(Dollars)

Focused Program	Total Budget		Climate & Hydro- logic Systems		Biogeochemical Dynamics		Ecological and
	FY90	FY91	FY90	FY91	FY90	FY91	FY90
Agency Totals	659.3	1034.1	291.7	461.5	198.7	265.8	90.2
DOC/NOAA	18.0	87.0	14.2	67.6	3.3	13.5	0.0
DOE	50.0	66.0	32.0	44.0	7.0	9.0	9.0
DOI	13.3	43.7	4.9	12.2	0.8	2.0	0.9
EPA	13.2	26.0	1.0	3.3	2.5	3.1	9.7
NASA	488.6	661.0	221.4	302.5	162.2	198.3	51.0
NSF	55.0	103.0	16.8	29.8	20.2	32.2	3.5
USDA	21.2	47.4	1.4	2.1	2.7	7.7	16.1
Scientific Objective							
Observations	137.2	255.0	89.1	148.9	17.2	38.9	14.1
Data Management	65.2	129.4	32.9	64.0	21.2	34.7	5.5
Understanding	409.7	560.0	143.1	200.3	148.1	176.2	65.5
Prediction	47.2	89.7	26.6	48.3	12.2	16.0	5.1

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Research Program Focused Budget
(in Millions)

Systems Dynamics	Earth System History		Human Interactions		Solid Earth Processes		Solar Influences	
	FY91	FY90 FY91	FY90 FY91	FY90 FY91	FY90 FY91	FY90 FY91	FY90 FY91	FY90 FY91
178.6	7.7	19.1	4.8	15.0	57.4	80.9	8.8	13.2
4.9	0.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0
10.0	0.0	0.0	2.0	3.0	0.0	0.0	0.0	0.0
10.3	2.4	8.0	0.9	5.3	3.4	5.9	0.0	0.0
19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90.0	0.0	0.0	0.0	0.0	47.7	63.0	6.3	7.2
8.5	4.5	9.0	1.2	5.5	6.3	12.0	2.5	6.0
35.3	0.3	1.1	0.7	1.2	0.0	0.0	0.0	0.0
39.6	0.0	0.2	0.0	2.2	13.1	20.8	3.7	4.4
17.7	0.5	2.2	0.4	1.0	3.8	8.8	0.9	1.0
103.2	6.1	13.1	2.9	10.6	40.5	50.1	3.5	6.5
18.1	1.1	3.6	1.5	1.2	0.0	1.2	0.7	1.3

Table
FY 1990-1991 Budget of Contributory Programs
(Dollars)

Contributing Program	Total Budget		Climate & Hydrologic Systems		Biogeochemical Dynamics		Ecological and
	FY90	FY91	FY90	FY91	FY90	FY91	FY90
Agency Totals	853.8	918.2	432.4	443.1	63.6	80.1	209.1
DOC/NOAA	300.6	315.9	254.2	268.0	10.4	10.4	36.0
DOD	31.2	31.0	22.3	22.1	1.1	1.1	6.0
DOE	39.3	39.5	0.0	0.0	21.8	22.4	8.6
DOI	225.1	227.7	97.4	91.0	2.7	2.9	51.4
EPA	83.3	50.6	11.0	8.3	1.6	2.0	70.7
NASA	24.7	25.3	0.0	0.0	0.0	0.0	0.0
NSF	124.2	132.5	45.2	47.2	23.1	26.6	18.9
USDA	25.4	95.7	2.3	6.5	2.9	14.7	17.5

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to the U.S. Global Change Research Program

(in Millions)

Systems Dynamics	Earth System History		Human Interactions		Solid Earth Processes		Solar Influences	
	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91
234.4	24.3	25.7	71.4	77.4	44.9	47.3	8.1	10.2
37.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.0	0.0	0.0	0.0	1.8	1.8	0.0	0.0
8.4	0.0	0.0	0.0	0.0	7.9	7.7	1.0	1.0
54.9	0.4	0.4	65.1	70.4	6.1	6.1	2.0	2.0
40.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	24.7	25.3	0.0	0.0
20.8	23.8	24.3	4.6	4.9	3.5	3.6	5.1	5.1
66.5	0.1	1.0	1.7	2.1	0.9	2.8	0.0	2.1

Climate and Hydrologic Systems

Table 1 shows that the FY 1991 request for this element is \$461.5 million, a \$169.8 million or 58 percent increase over the FY 1990 level.

The increasing abundances of greenhouse gases in the Earth's atmosphere are altering the radiative balance of the planet. However, the impact on the climate is uncertain. The response of the Earth's climate is strongly tied to the natural variability of the climate and hydrologic systems, including the atmospheric, oceanic, cryogenic, and land surface processes that govern the distribution of temperature, moisture, clouds, and rainfall. Effective policy formulation requires quantification of the natural and human-induced variability in the climate and hydrologic systems, and reliable predictions of the magnitude and timing of regional and global changes in response to the increasing abundances of greenhouse gases.

The FY 1991 research efforts listed below reflect the Program's research priorities (see Figure 1) and involve the following policy-relevant questions:

(1) What is the role of clouds in the Earth's radiation and heat budgets?

Clouds and water vapor play a pivotal role in the Earth's radiation and heat budgets. They control the amount of solar energy absorbed by the climate system as well as the infrared radiation emitted to space, and they strongly influence the redistribution of heat throughout the climate system. A change of a few percent in global mean cloud cover or type could either dramatically enhance or counteract the radiative effects of anthropogenic greenhouse gas emissions.

To understand the role of clouds in controlling the Earth's radiative and heat budgets requires knowledge of their distribution, radiative properties, and cloud-radiation feedback

mechanisms. For example, ongoing and new research programs that are focused on this area include: NASA's Earth Radiation Budget Experiment; the NASA, NOAA, and NSF International Satellite Cloud Climatology Project (ISCCP) and associated field campaigns; and a broad range of proposed studies and measurements (NASA's Earth Observing System [EOS] and DOE's Atmospheric Radiation Measurements [ARM] program).

(2) How do the oceans interact with the atmosphere in the storage, transport, and uptake of heat?

The oceans and atmosphere play a vital role in the transport of energy from the equator to the polar regions. The rate at which the oceans exchange heat with the atmosphere controls the magnitude and timing of the predicted global warming due to greenhouse gases.

The prediction of climate change will require ocean observation systems analogous to the existing atmospheric systems used to predict the weather. Understanding the role of the oceans in exchanging energy with the atmosphere requires knowledge of ocean circulation and air-sea energy fluxes.

Numerous ongoing and new research programs contribute to these areas. *In situ* (NOAA, NSF, and DOI) and remote (NASA scatterometer [Earth Probes] and altimeter [TOPEX]) ocean observation systems will contribute to studies of ocean circulation and the coupling of the ocean and the atmosphere. Interannual climate change (Tropical Ocean-Global Atmosphere [TOGA]: NOAA, NSF, and NASA), and the general circulation of the oceans (World Ocean Circulation Experiment [WOCE]: NSF, NOAA, and NASA) are critical investigations. Other key research includes the NOAA Atlantic Climate Change Project, and the proposed new generation of space-based measurements of ocean altimetry, temperature, and wind stress (NASA EOS).

(3) How will changes in climate affect temperature, precipitation, and soil moisture patterns, and the general distribution of water and ice on the land surface?

Changes in seasonal temperatures, precipitation and soil moisture patterns could have significant ramifications for water resources, agricultural productivity, natural ecosystems, and the exchange of water between oceans and glaciers.

Understanding the distribution of precipitation and the impacts of a changing climate on the distribution of water and ice on land surfaces requires knowledge of the fluxes of energy and water within the Earth system, water resources on the land, and changes in the area and volume of glaciers.

Ongoing and new research programs that will contribute to these areas include: the Global Energy and Water Cycle Experiment (GEWEX: NOAA, NSF, DOI, and NASA); the proposed new generation of space-based measurements of precipitation, winds, water vapor, clouds, and ice extent (NASA Earth Probes and EOS); long-term observational networks of water resources (DOI, NOAA, and DOE); field and modeling studies of the climate sensitivity of watersheds (DOI and USDA); continental-scale hydrologic processes (NSF and DOE), water budgets in managed and manipulated ecosystems (USDA) and in temperate and arctic regions (DOE); and compilation of glacier extent worldwide, but especially in the Arctic and Antarctic, using ground-based and satellite data (NSF, DOI, and NASA).

(4) How can the reliability of global- and regional-scale climate predictions be improved?

Accurate predictions of climate change, whether natural and/or human-induced, are vital for evaluating environmental and socioeconomic impacts. The current generation of climate prediction models is inadequate to confidently predict the magnitude and timing of climate change. This is particularly true at the regional scale.

Improving the reliability of model predictions will require the development of climate diagnostics, model assimilation of climatic data, modeling shorter space and time scales, and an improved parameterization of key Earth system processes.

Ongoing and new research programs that will contribute to these areas include: enhanced climate modeling and diagnostics efforts (NOAA, NASA, NSF, and DOE); mechanistic studies of climatic change through analysis of observations (NOAA and NSF); development of climate modeling data assimilation techniques (NOAA and NSF); a critical review of data needs both for detection of climate change and for climate modeling (DOE); development of regional climate and hydrology models linked to global climate models (EPA and USDA); and the development of the capability to forecast seasonal conditions through coupled ocean-atmosphere modeling and extension of conventional weather prediction techniques (NOAA). Results from a number of process-oriented studies will be utilized to parameterize key interactions in models, including cloud-radiation interactions (NASA, NOAA, NSF ISCCP, and DOE ARM), and land-ocean-cryosphere-atmosphere interactions, including land surface hydrology (NSF, NOAA, DOI, and NASA).

Biogeochemical Dynamics

Table 1 shows that the FY 1991 request for this element is \$265.8 million, a \$67.1 million or 34 percent increase over the FY 1990 level.

There is compelling scientific evidence that the atmospheric concentrations of several key radiatively and chemically active gases are increasing, due both to natural processes and human activities. The rates of increase of these gases depend not only on their emissions, but also on the fate of these gases, which involves the cycling of carbon and other key nutrients between the ocean, atmosphere, and terrestrial biosphere. Currently, there are significant uncertainties in understanding

these processes, thus limiting the ability to quantitatively predict future increases in atmospheric trace gas concentrations. This restricts the formulation of effective policies regarding trace gas emissions.

The FY 1991 research efforts listed below reflect the Program's research priorities (see Figure 1) and involve the following policy-relevant questions:

(1) What is the relative importance of the oceans and terrestrial biosphere as sinks for fossil fuel carbon dioxide, and how do they change with time?

Increasing atmospheric concentrations of carbon dioxide are predicted to contribute to global warming. Presently some portion of the emissions from the combustion of fossil fuels and deforestation stay in the atmosphere, with the remainder being taken up by the oceans and the terrestrial biosphere, but the proportions and responsible processes are not well understood. For a given anthropogenic emission scenario, the prediction of atmospheric growth rates of carbon dioxide depend upon an understanding of this sequestering of emitted carbon dioxide.

To understand the relative importance of the oceans and terrestrial biosphere as sinks for fossil fuel carbon dioxide requires knowledge of biogeochemical and physical processes and the fluxes of carbon and nutrients among and between the atmosphere and land and ocean surfaces.

Numerous ongoing and new research programs contribute to these areas. *In situ* studies of the processes responsible for controlling the concentration, distribution, and cycling of oceanic carbon (NSF, NOAA, and DOE), complemented by remote sensing measurements of ocean productivity, sea surface temperatures, and winds (NASA) contribute towards the Joint Global Ocean Flux Study (JGOFS). *In situ* studies of the sequestering of carbon dioxide and the storage and cycling of carbon and other key nutrients within natural and disturbed terrestrial ecosystems (DOI, NSF, EPA, DOE, and USDA)

will be complemented by estimates of standing biomass and the biological productivity of terrestrial ecosystems using satellite imagery (NASA EOS).

(2) What are the major sources responsible for the current increases in atmospheric nitrous oxide and methane?

The well-documented increases in the atmospheric concentrations of methane and nitrous oxide are predicted to contribute to global warming, affect stratospheric ozone, and, in the case of methane, to increase tropospheric ozone. The natural and anthropogenic sources of these gases have been qualitatively explained, but not adequately quantified. Hence, effective emission control strategies cannot be formulated.

Understanding current and future trends in the atmospheric concentrations of methane and nitrous oxide requires knowledge of their emissions from industrial and ecological sources; the processes that control their fluxes between the atmosphere, biosphere, and land and ocean surfaces; the impact of changing environmental conditions upon their fluxes; and their atmospheric distribution and transformations.

Many ongoing and new research programs will contribute to these areas including: studies of the fluxes of methane and nitrous oxide, the processes controlling them, and their response to environmental changes from one or more of the key sources, including natural ecosystems, agricultural systems, managed forests, cattle, biomass burning, and gas hydrates (NASA, NOAA, NSF, EPA, DOI, DOE, and USDA); quantification of the areal extent and environmental and ecological conditions conducive to methane and nitrous oxide emissions from terrestrial ecosystems (NASA EOS); atmospheric distributions and trends of methane and nitrous oxide (NASA and NOAA); and the atmospheric distribution and transformations of species (such as tropospheric ozone, hydroxyl radicals, oxides of nitrogen, carbon monoxide, and non-methane hydrocarbons) that control the distribution and lifetime of methane (NSF, NASA, NOAA, DOE, and EPA).

(3) What are the implications for stratospheric ozone, globally and in polar regions, of increased concentrations of chlorine and bromine?

Current scientific understanding indicates that the antarctic ozone hole will seasonally reoccur until the stratospheric chlorine levels decrease by 30 percent from today's level. However, it is not yet possible to quantify, under conditions of enhanced chlorine and bromine concentrations, the impact of the antarctic ozone hole on ozone levels at mid-latitudes in the southern hemisphere or the probability of significant ozone depletion over the Arctic. An improved quantitative understanding of the processes controlling stratospheric ozone, particularly in the polar regions, would allow improved environmental impact assessments to be conducted and improve policy formulation concerning chlorine and bromine containing chemicals, including proposed substitutes.

To understand the response of stratospheric ozone to changes in chlorine and bromine requires knowledge of their fluxes into the stratosphere; the chemical composition and physical structure of the stratosphere; and the coupling between chemical, dynamical, and radiative processes in the stratosphere.

Ongoing and new research programs that will contribute to these areas include: monitoring the atmospheric distribution of the source gases (NOAA and NASA); monitoring the chemical composition and dynamical structure of the stratosphere using a ground-based network of remote sensing, aircraft and balloons, and satellite observations (NASA, NOAA, and NSF); and studying the atmospheric cycling and transformations of compounds that influence the chemistry of the stratosphere (NASA, NOAA, NSF, and EPA).

Ecological Systems and Dynamics

Table 1 shows that the FY 1991 request for this element is \$178.6 million, a \$88.4 million or 98 percent increase over the FY 1990 level.

Ecological systems are important in global change research for two principal reasons. First, changes in climate, atmospheric composition, and solar radiation can affect the productivity, diversity, and habitat associated with both natural and managed ecosystems. Indeed, much of the policy concern over global change is explicitly linked to such possible ecosystem impacts. Second, photosynthesis, deforestation, and other biospheric processes can affect the chemical composition of the atmosphere, hence contributing to global change. Human influences on ecosystem changes are increasingly a part of current policy debates.

Thus, ecological systems are intrinsically linked to global change through interwoven roles in biogeochemical dynamics, physical climate and the hydrologic cycle, and the actions of humans. However, the scientific uncertainties associated with the composition, distribution, and processes of ecosystems currently slow the formulation of sound, science-based policy options.

The current key questions in these research areas, their relevance to the evolution of public policy of global change, and the associated research of the FY 1991 U.S. Global Change Research Program include the following:

(1) What ecological systems are most sensitive to global change, and how can natural change in ecological systems be distinguished from change caused by other factors?

The diverse climates of the Earth support an equally diverse array of species and ecosystems. Separating the intrinsic natural dynamic changes of ecosystems from those changes

induced by human activities is a challenge that has plagued the ecological sciences and the public policy arena for some time.

The highest priority for determining the sensitivity, types, and causes of possible changes in ecosystems is the documentation of past, current, and future variation in ecosystem properties. Several ongoing monitoring programs and proposed research initiatives will address this need with regard to sensitive ecosystems (e.g., boreal forests, grasslands, and arid and high-elevation areas): DOE's research parks, USDA's forests and experiment stations, DOI's parks, wildernesses and other public lands, and NSF's Long-Term Ecological Research Sites. NASA's EOS satellite-based instruments will extend global observations of ecosystem type, state, and spatial extent. Furthermore, EPA, USDA, NSF, DOI, NOAA, and DOE will examine the ecosystem responses (e.g., alpine treeline change in the western U.S., shrub encroachment into rangeland, ecological succession, small-animal ranges and habitats, and marine ecosystems) to carbon dioxide increases, climatic stresses, and other disturbances.

(2) What are the likely rates of change in ecological systems due to global change, and will natural and managed systems be able to adapt?

Ecosystem change is controlled by the physiological processes of the individual species, as well as by the environments in which they exist. The photosynthetic response of plants to increased carbon dioxide concentrations is relatively fast and often accompanied by higher biological productivity and drought and salinity resistance. However, the full responses of complex ecosystems, such as forests and rangelands, to changes in the climate system and in the chemical composition of the atmosphere may take decades or longer.

Understanding the ecological response to rates of change and how well ecological systems can adapt to change is clearly linked to quantifying impacts for the formulation of policy options. This will require (i) knowledge of ecological responses to specific forcing agents (e.g., temperature stress, soil

moisture, chemical exposure, ocean circulation, and ultraviolet radiation), (ii) research on the interactions between biotic and abiotic processes, and (iii) modeling of interactions, feedbacks, and ecological responses.

The proposed and ongoing research of several agencies will contribute to closing these knowledge gaps. EPA and DOI will develop correlations and models to investigate rates of change in forested and semi-arid ecosystems. USDA, DOE, NSF, and DOI will acquire data on physiological and ecosystem responses in seedling productivity; variation of plant growth due to carbon dioxide, temperature, and ultraviolet exposure; ecosystem changes in high-desert rangeland and coastal regions; successional change of vegetation across climate gradients; and response of managed forests to drought stress. Furthermore, DOE, DOI, USDA, NOAA, and NSF will investigate the responses of particularly sensitive species (e.g., arctic marine mammals, reef corals, commercial fish stock, grasses, grains, and endangered or limited-habitat species) to climatic and other stresses.

(3) How do ecological systems themselves contribute to processes of global change?

The biogeochemical and physical feedbacks from living systems strongly influence the fluxes and amounts of methane, nitrous oxide, carbon dioxide, and the reactive trace gases in the atmosphere, as well as albedo and water fluxes. Decisions regarding land-use policies require that these causative interactions be understood and that their feedbacks be represented correctly in global system models.

DOE, EPA, USDA, NSF, and DOI ongoing and new programs will address these needs through projects that determine the influence of soil biology, total biomass, land-cover type, and transpiration on biogenic gas fluxes and evapotranspiration in different vegetation types, and that characterize the interactions between climate, vegetation, and soils in diverse ecosystems.

Earth System History

Table 1 shows that the FY 1991 request for this element is \$19.1 million, a \$11.4 million or 148 percent increase over the FY 1990 level.

Geological and historical records document the natural variability of the physical environment, climate, and ecosystems from interannual to millennia time scales. These data reveal periods that were significantly colder and warmer than today, as well as past abrupt climate changes and subsequent environmental responses. Understanding this past behavior of the natural system is essential for detecting predicted human-caused perturbations against the background of normal variability and for providing data sets to test climate models. Confidence in model predictions of future change will be increased if the models can reproduce these past climates.

Uncertainties in the predictions of climate models is already a key factor in policy debates, as is whether a greenhouse "signal" can be found in the record of recent decades. In addition, past evidence of the impact of climate changes on ecosystems demonstrates the vulnerability or resilience of these systems to change.

The FY 1991 research efforts listed below reflect the Program's research priorities (see Figure 1) and involve the following policy-relevant questions:

(1) What are the natural ranges and rates of change in the climate and environmental systems?

The paleoclimatic record can provide insight into the cause and effect of global changes. The history of atmospheric carbon dioxide and methane along with records of past climates can be reconstructed from ice core samples. Similarly, the temporal covariations in the terrestrial biosphere, the carbon cycle, and climate need to be reconstructed from fossils, ocean sediments, and the geological record.

To address these opportunities and needs, DOI and NSF will focus on developing new paleoclimate methods, reconstruct past abrupt climate transitions and past warm intervals on Earth, and emphasize studies in the sensitive arid (DOI) and polar (NSF and DOI) regions.

(2) How rapidly have ecosystems adapted to past abrupt transitions in climate?

The long-term geologic record contains evidence for a number of minor- to large-scale, rapid changes that have had profound effects on Earth systems and hence offers the opportunity to observe the environmental effects (e.g., extinction and replacement of biota) of a large sudden perturbation.

While the general characteristics and timing of major abrupt changes throughout the geological record are known, the existing studies are generally incomplete and limited in scale and scope. Better understanding of their effects on Earth systems will require the integrating of records on regional to global scales for selected events.

The programs of USDA, DOI, and NSF will contribute studies that emphasize the effects on the biosphere. The ongoing paleoclimate programs of USDA focus on the impacts of fire severity and frequency on the life histories and distributions of biota. New initiatives will study the effects of climate change on arid regions (DOI), and the impact of abrupt climate changes on ecosystems (NSF).

(3) Do past warm intervals in Earth history provide appropriate scenarios to test model predictions of future global warming?

The assessment of the regional predictions of general circulation models will benefit from a comparison to data showing how representative regions responded during past warm periods. Intervals of past warm climates are known, but

most of the environmental reconstructions of those times are qualitative and the scope of the variables is not comprehensive, which is a limitation in assessing the reliability of the models.

The Program will focus on determining if regional responses to global warming are similar regardless of local conditions or causes of the warming. This goal will be addressed by existing paleoclimatic research projects, such as the Climate of the Holocene Mapping Project (COHMAP) (NSF and DOE) and the Pliocene Project (DOI), as well as by augmenting existing and supporting new interdisciplinary programs. NOAA will augment its study of integrated paleoclimate investigations and global model assessment for these warm-Earth scenarios.

Human Interactions

Table 1 shows that the FY 1991 request for this element is \$15.0 million, a \$10.2 million or 212 percent increase over the FY 1990 level.

A comprehensive picture of global change must include the relationship between biological, atmospheric, hydrologic, and terrestrial changes and the human activities that stimulate or mediate them. These relationships include both the cumulative effects of individual or group actions over long periods of time and the less-concentrated, but equally influential, effects of the actions of social and economic institutions. For example, greenhouse gas emissions are due to several social and economic factors, including growth of human population, energy consumption, agricultural and industrial practices, and regulations.

Without an understanding of human behavior and its consequences for the environment, models will be inadequate to explain, or to develop policies to deal with, global change phenomena. The following research efforts reflect the Program's research priorities (see Figure 1) and involve the following policy-relevant questions:

(1) *What kinds of empirical data are needed to measure and understand human interactions in global change?*

The study of human interactions is dependent on having time-series data on a wide variety of human activities and related phenomena, ranging from energy demands to food consumption patterns. The necessary first step is to establish baseline data on environmentally significant human activities that reflect the differing technological, economic, and cultural forces in various societies.

NSF is supporting the collection of baseline data in environmentally critical areas and will establish Long-Term Regional Research Sites. These will support research on methodological problems in creating data bases which span the range of human activities in various regions and societies and will also encompass historical data. DOI will develop data sets for research that addresses the human factors which influence supply and demand of water and land resources. USDA will organize the data necessary for studying the role of human behavior in natural and managed ecosystems, and in the extent and severity of fires. DOE will continue its data collection on fossil fuel utilization and carbon dioxide emissions.

(2) *How and why do human beings and human systems influence physical and biological systems?*

The development of an accurate predictive understanding of human influences on global change (and hence appropriate public policy responses) is dependent upon the availability of data bases that span time and space, characterizing the fundamental processes of change in human systems, and the interactions of these systems with the physical and biological processes. Therefore, a critical early step in understanding human interactions in global change is the support of process studies.

NSF will expand its Human Dimensions of Global Environmental Change Program to put additional emphasis on social processes such as the economic influences in deforestation and the effectiveness of legal and regulatory controls over water resources. NSF's Long-Term Regional Research Sites will be the focus of research on long-term patterns and processes of social, economic, and ecological change. DOI will support the development of methods to estimate: (i) tradeoffs among competing social, environmental, and economic goals, and (ii) the role of human choices on water supplies and in coastal erosion and inundation. USDA's research program will include the effect of fires on rural population distributions.

Solid Earth Processes

Table 1 shows that the FY 1991 request for this element is \$80.9 million, a \$23.5 million or 41 percent increase over the FY 1990 level.

Many solid Earth processes are directly involved in the life-sustaining elements of the regional and global environment. Melting of glaciers, especially polar ice sheets, would cause sea level to rise; large volcanic eruptions can cause climatic cooling for short periods of time; and methane released from permafrost and gas hydrates in response to climatic warming can change atmospheric composition. An improved understanding of solid Earth processes will allow for more effective long-term planning in those coastal regions most vulnerable to rising sea level and for the protection of human populations most apt to be endangered by volcanic eruptions and other catastrophic solid earth processes.

The FY 1991 research efforts listed below reflect the Program's research priorities (see Figure 1) and involve the following policy-relevant questions:

(1) *How do different coastal regions respond geologically and ecologically to higher sea level, and how can the contributions from changes in climate (e.g., glacier melting and ocean warming) be differentiated from those due to tectonic processes?*

Sea level is predicted to rise as a consequence of global warming, but the absolute magnitude, rate, and timing of the sea level rise are uncertain. Elevated sea level could have serious consequences for coastal environments and human populations, and an improved predictive capability for sea level rise is required for the effective formulation of adaptation or mitigation strategies.

Understanding sea level changes and their consequences requires measurements of the absolute magnitude and rate of sea level rise; differentiation between the contributions of climatic change from those due to movements of the Earth's crust; and prediction of the geological and ecological response of different coastal environments.

Ongoing and new research programs that contribute to these areas include: studies of glaciation and deglaciation during periods of climatic change (NSF and DOI); *in situ* global sea level network (NOAA); satellite ocean altimetry (TOPEX: NASA); the NOAA, NSF, and NASA programs to use the space-based Global Positioning System (GPS), Satellite Laser Ranging (SLR), and Very Long Baseline Interferometry (VLBI) to measure sea level changes; studies of coastal erosion and inundation on the East Coast of the United States (DOI and NASA); Coastal Wetlands Change and Dynamics Program (DOI); and the application of new isotopic methods for dating of landforms, soils, and sediments (NSF).

(2) What are the magnitude, geographic location, and frequency of volcanic eruptions and their effect on climate?

Large volcanic eruptions emit gases, ash, and aerosols into the atmosphere that can cause significant short-term perturbations to the Earth's climate by changing the radiative budget. It is essential to quantify climate change induced both by volcanic eruptions and by increased abundances of greenhouse gases.

Understanding the impact of volcanic eruptions on the Earth's climate requires an improved understanding of the magnitude, frequency, and geographic location of subaerial and submarine volcanic events and the nature and amount of emitted material. Hydrothermal venting from the ocean floor is a major source of heat from the Earth's interior, and it influences the global carbon cycle.

Several ongoing and new programs contribute to this research effort including: studies of gas and ash emissions and degassing processes from U.S. volcanoes (DOI); satellite measurements of atmospheric volcanic aerosols and sulfur gases (Total Ozone Mapping Spectrometer, Earth Probes, and EOS: NASA); and studies of the fluxes of energy, gases, fluids, and particulates from submarine eruptions on the mid-ocean ridges (Ridge Interdisciplinary Global Experiment [RIDGE]: NSF, NOAA and DOI).

(3) How do permafrost regions of the Northern Hemisphere respond to climate warming?

An accelerated release of methane trapped in arctic permafrost and gas hydrates due to a climatic warming would alter the chemical composition of the atmosphere and further enhance the greenhouse effect. Ongoing and new research will contribute to this area through projects that study the dynamics of permafrost change (NSF) and by assessing whether there is a current climatic warming on a local, regional, or hemispheric scale by monitoring subsurface temperatures in arctic permafrost (DOI).

Solar Influences

Table 1 shows that the FY 1991 request for this element is \$13.2 million, a \$4.4 million or 50 percent increase over the FY 1990 level.

The sun influences two of the most important current policy-related phenomena: the depletion of ozone by chlorofluorocarbons and climate warming due to greenhouse gases. In both areas, the main scientific problem is one of separating the effects that are due to human influences from changes induced by natural forcing agents, such as the sun.

The FY 1991 research efforts listed below reflect the Program's research priorities (see Figure 1) and involve the following policy-relevant questions:

(1) What aspects of solar variability are influencing the stratospheric ozone layer?

Since ozone is generated by the breakup of oxygen by solar UV radiation, observed ozone changes will depend, in part, on solar activity. Thus, the detection of human-caused ozone depletions requires that the solar component of ozone change be properly accounted for. This understanding requires long-term UV observations of adequate precision ($\pm 1\%$) over the solar cycle. The required observations will be provided by instruments on NASA's Upper Atmosphere Research Satellite (UARS) and EOS.

(2) What impact do other inputs, e.g., particles, have on the upper atmosphere and how are they coupled to other atmospheric regions?

The physical properties of the upper atmosphere (e.g., temperature, composition, and density) are sensitive to human-influenced gases, such as carbon dioxide and methane, and to solar particles. Changes induced by these agents could be quite substantial and hence could affect satellite orbits and provide

insight into potential sun-atmosphere couplings. NSF's Coupled Energetics and Dynamics of Atmospheric Regions (CEDAR) and Geospace Environment Modeling (GEM) programs will begin the establishment of data bases on solar inputs relevant to the global circulation and couplings.

(3) How does the sun's output vary and what is the impact on terrestrial climate?

A key factor in establishing the Earth's radiation budget is the total solar radiation reaching the planet. This requires continuous measurements of the total solar radiation with very high long-term stability (0.1%). These observations will be provided by Active Cavity Radiometer Irradiance Monitors (ACRIM) on NASA's UARS and EOS.

Data Management

Table 1 shows that the FY 1991 request for data management is a \$129.4 million, a \$64.2 million or 98 percent increase over the FY 1990 level.

Data and information management will provide a bridge between global change observations and scientific understanding, and will be a key factor in the success of programs carried out within all seven interdisciplinary science elements. The traditional concepts and present practices of data management are inadequate for global change studies. The interdisciplinary, interagency, and international aspects of these studies, coupled with a long-term view, pose unprecedented challenges to the data management and research communities alike. Consequently, cooperation in seeking new approaches to archiving and management of data is essential.

Data management includes the means and mechanisms to describe, gather, transmit, validate, process, archive, and disseminate data. The initial thrust will be on data base development in the highest priority science elements and

strengthening the infrastructure required to process, manage, and improve access to the great variety of ground- and space-based observations.

The key data management questions with policy implications include:

(1) How can the data handling and access capabilities be best organized and strengthened?

Data management systems for global change must be able to accept and archive dissimilar types of data collected from different data collection systems, i.e., both ground- and space-based data by different organizations in different formats and on different media.

Interactions among CES agencies through the Interagency Working Group on Data Management for Global Change and with the science community have begun to facilitate improved access to data and data handling capabilities. A major problem facing scientists attempting to use global change data sets is that it is extremely difficult to find out who has what data and how good the data are. Using existing facilities, NASA, NOAA, NSF, DOE, and DOI will continue to develop and expand a Master Directory for Global Change Data by linking with a common architecture, directories, catalogs, and inventories of data in all global change science elements. Hundreds of global change data sets already have been documented and entered.

Studies have been initiated to develop archives with improved quality control, documentation, and ease of access to satellite data, including formation of the EOS Data and Information System (NASA, NOAA and DOI), and procedures are being developed for better distribution of digital data bases. Access to and assimilation of the DOD environmental data bases are being addressed. Bilateral agreements have been signed between NASA and NOAA and between NASA and

USGS for the development of data systems to manage satellite data. The exchange of satellite information between NASA, NOAA, European Space Agency (ESA), Canada, and Japan has been instituted. NASA and NOAA are gathering relevant foreign data to combine with U.S. data.

(2) How can the agencies build the data sets needed to facilitate early results from the Program?

Long-term global measurements must routinely be supported by documentation regarding instrument calibrations, coverage, sampling, data editing, data reduction algorithms, including ancillary data, algorithm validation, assimilation or analysis procedures, and correlative measurements.

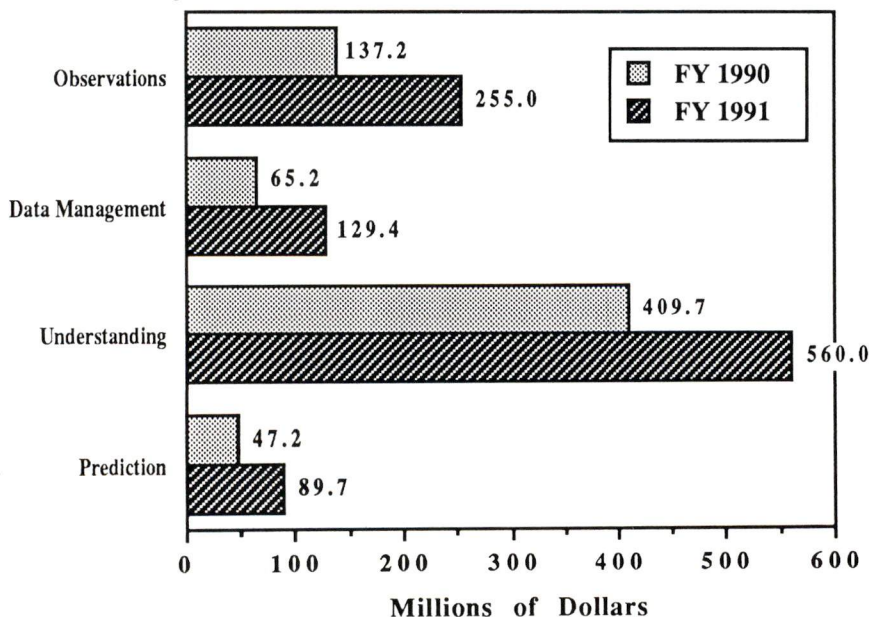
Many ongoing and new research programs contribute to the task of developing integrated global-scale satellite and *in situ* data sets that will support model development including the development of data bases in support of: biological responses to climate, abrupt climate change, anthropogenic forces in global change, long-term ecological research, studies of ecosystem stress, land-surface data, fire severity and occurrence, sea surface temperature fields, and regional ecosystem variables that are sensitive to global change. (All CES agencies are involved in one or more of these activities.) DOE will support a critical review of data for climate modeling, and NSF will support a geosystems data base activity that includes the development and quality control of model-generated data sets. On a priority basis, data sets are being extended into the past, both to document global change and to test and validate diagnostic and predictive models. NOAA and NSF data management elements provide resources for the development of historical and paleo data bases. DOE and DOI have similarly focused programs.

Budget by Scientific Objective

Figure 3 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by scientific objective: observations, data management, understanding, and prediction. These budgets reflect a balance between each of the scientific objectives, with a strong commitment to data management.

Figure 3
U.S. Global Change Research Program Budget
by Scientific Objective

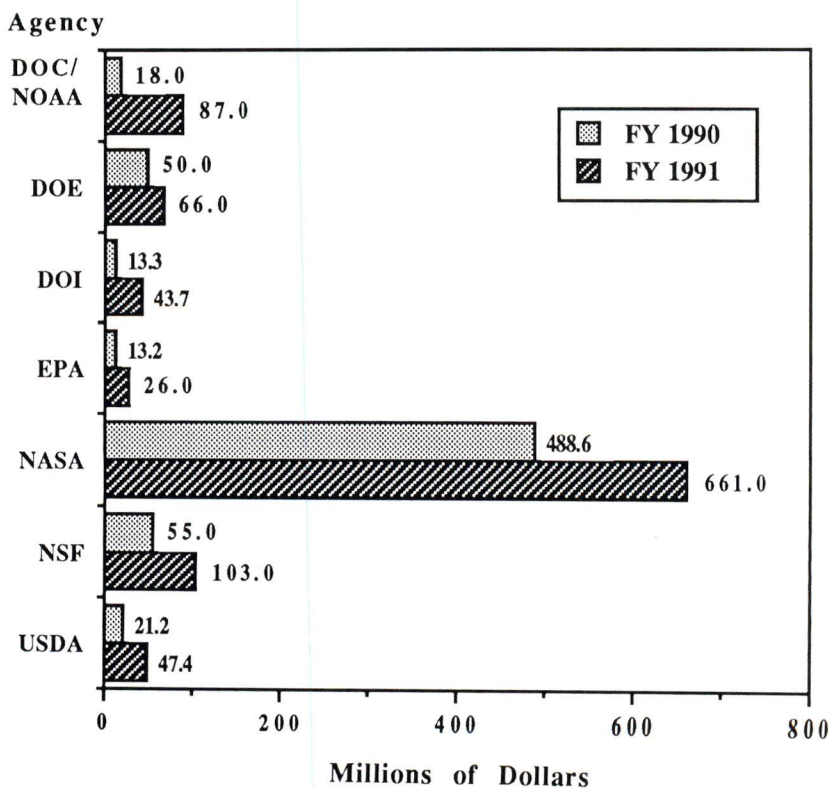
Scientific Objective



Budget by Agency

Figure 4 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by agency. The individual agency efforts build upon their respective scientific and technical strengths.

Figure 4
U.S. Global Change Research Program Budget
by Agency



National Oceanic and Atmospheric Administration (NOAA).

In FY 1991, NOAA has proposed an \$87 million Climate and Global Change Program in support of the U.S. Global Change Research Program. This represents a \$69 million or 383 percent increase above the FY 1990 level. The FY 1991 NOAA contribution involves enhancements to ongoing efforts in: operational *in situ* and satellite observation programs with an emphasis on oceanic and atmospheric dynamics (including sea level), circulation, and chemistry; focused research on ocean-atmosphere interactions, the global hydrological cycle, the role of oceanic circulation and biogeochemical dynamics in climate change, atmospheric trace gas/climate interactions, and the response of marine resources to climate change and related stresses; and programs to improve climate modeling, prediction, and information management capabilities.

Department of Energy (DOE). In FY 1991, DOE has proposed a \$66 million budget for global change research, a \$16 million or 32 percent increase above the FY 1990 level. The DOE maintains a research program directed at the impact of energy production and use on the global Earth system by focusing primarily on climate, atmosphere, ocean, and ecosystem responses. DOE will augment research on climate modeling; studies of carbon dioxide sources in the atmosphere, oceans, and land; impacts on vegetation and ecosystems; and research efforts to quantitatively describe the radiative balance and the cloud-climate feedback in the atmosphere. New initiatives focus on critical data needs for global change research and the climatic variables that may serve as indicators of global change; and on funding to provide education and training to the next generation of scientists.

Department of the Interior (DOI). In FY 1991, DOI has proposed a \$43.7 million budget for global change research, a \$30.4 million or 229 percent increase above the FY 1990 level. DOI efforts include studies of: paleoclimates; interaction and sensitivity of hydrologic, ecological, and landscape systems with climate; arid, polar, and coastal regions and systems; volcano-atmosphere interactions; methane hydrates; changing

land surface characteristics; ocean heat fluxes; social, environmental, and economic consequences of global change including human activities, water resources, biological species variation, and land management; and carbon cycle variation studies; as well as archiving and distributing space- and land-based Earth science data.

Environmental Protection Agency (EPA). In FY 1991, EPA has proposed \$26 million for global change research, an increase of \$12.8 million or 97 percent above the FY 1990 level. EPA's research efforts are focused on evaluating the processes and quantifying the relative contributions of anthropogenic and biological sources of trace gases, quantifying and modeling the consequences of climate change on ecosystems and their subsequent feedback to the atmosphere, and the interaction of trace gases in the atmosphere. Special emphasis will be given to climate sensitive regions, e.g., tundra, wetlands and forests. EPA's research will help provide the process-level understanding and modeling capabilities to predict global change.

National Aeronautics and Space Administration (NASA). In FY 1991, NASA has proposed \$661 million for global change research, an increase of \$172.4 million or 35 percent above the FY 1990 level. NASA research efforts are primarily focused on space-based studies of the Earth as an integrated system. These activities include ongoing research and satellite programs (e.g., the Upper Atmosphere Research Satellite, Ocean Topography Experiment, etc.) that are important precursors to the FY 1991 initiatives: Earth Probes (a series of satellite measurements prior to EOS to monitor atmospheric ozone, ocean color, precipitation in the tropics, and ocean surface winds) and the Earth Observing System (EOS). EOS will provide an integrated, comprehensive monitoring and data management program of simultaneous measurements of key global change variables.

National Science Foundation (NSF). In FY 1991, NSF has proposed \$103 million for global change research, an increase of \$48 million or 87 percent above the FY 1990 level. NSF proposes to augment and initiate programs coordinated internationally to observe, understand, and model atmospheric, oceanic, terrestrial, and social processes and their coupled interactions. Studies include ocean circulation, ocean-atmosphere interactions, cloud-radiation interactions, global atmospheric chemistry, biogeochemical processes, land-sea interactions, past climate change, crustal and related processes impacting global change, ecosystems, solar processes, human dimensions of global change, data base research and development, and a multi-agency education initiative for global change.

United States Department of Agriculture (USDA). In FY 1991, USDA has proposed \$47.4 million for global change research, an increase of \$26.2 million or 124 percent above the FY 1990 level. USDA research efforts are focused on ground-based research programs studying agricultural, forest and range ecosystems as influenced by factors such as water balance, atmospheric deposition, plant responses to changes in atmospheric constituents, UV-B radiation and other global change variables. Some representative studies that will focus on agricultural effects on environmental variables will include mechanisms of methane generation and nitrous oxide release; soil properties including moisture, erosion, organic matter dynamics, nutrient fluxes, and microbes; relationship of global change to forest and range fires, insects, and plant pathogens; and agricultural management systems.

Budget by Federal Budget Function

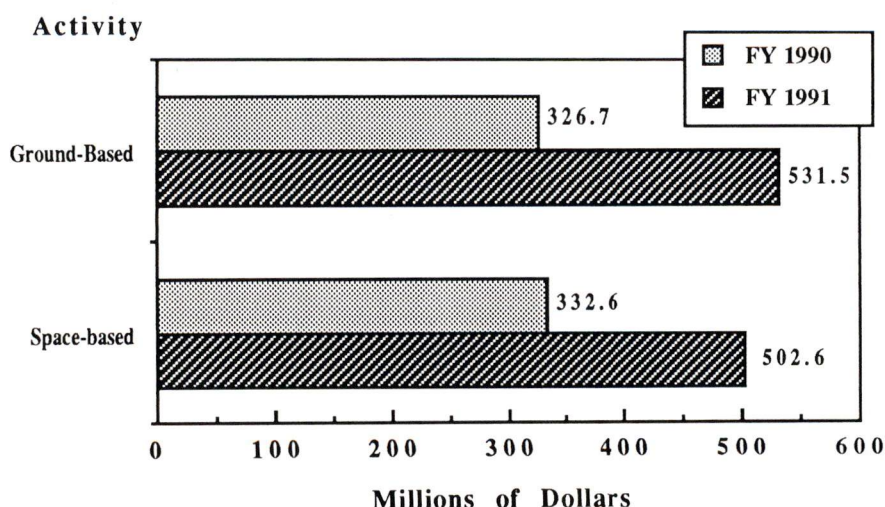
Scientific, environmental, energy, and agricultural resources are vital to the health of our Nation. Table 3 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by Federal Budget Function. In FY 1991, significant increases above FY 1990 levels are proposed for each budget function. The U.S. Global Change Research Program must be viewed as a single integrated research effort with its success dependent upon cooperation and contributions from each of the individual agency programs.

Table 3 FY 1990 - 1991 U.S. Global Change Research Program by Budget Function (Dollars in Millions)				
Budget Function	Budget Function Number	1990	1991	
TOTAL		659.3	1034.1	
General Science, Space and Technology	250	543.6	764.0	
NASA		488.6	661.0	
NSF		55.0	103.0	
Energy (DOE)	270	50.0	66.0	
Natural Resources and Environment	300	44.5	156.7	
DOI		13.3	43.7	
EPA		13.2	26.0	
DOC / NOAA		18.0	87.0	
Agriculture (USDA)	350	21.2	47.4	

Budget by Ground- and Space-Based Research

Figure 5 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by space- and ground-based research activities. Maintaining an appropriate balance between ground- and space-based research programs is essential for a successful U.S. Global Change Research Program. *In situ* and theoretical studies of physical, chemical, biological, and geological processes must be complemented by a comprehensive space-based program to provide the global observations of key environmental variables. The combination of ground- and space-based measurements is required given the temporal and spatial variability of the systems being studied, and the need to scale the processes occurring at the local level to the regional and global levels. The ground-based program is essential to interpret some of the global satellite observations (e.g., long-term trends), as well as to obtain scientific information not attainable from space (e.g., trace gas fluxes). Both types of program need to be strongly supported, and the FY 1991 budget reflects a reasonable balance.

Figure 5
U.S. Global Change Research Program Budget
by Ground- and Space-Based Programs



Ground-based: The FY 1991 request for the ground-based program is \$531.5 million, a \$204.8 million or 63 percent increase over the FY 1990 level. The budgets of NOAA, DOE, DOI, EPA, NASA, NSF, and USDA include support for a broad range of ground-based and modeling research activities. The activities range from small individual investigator research programs to participation in complex international scientific projects. The budgets would initiate multi-agency research thrusts in several critical areas including: the role of the oceans and terrestrial biosphere in trace gas fluxes; the exchange of energy between the oceans and atmosphere; the cycling of water throughout the Earth system; and expanded monitoring of responses to global change, such as sea level.

Space-based: The FY 1991 request for space-based programs is \$502.6 million, a \$170.0 million or 51 percent increase over the FY 1990 level. The NASA budget includes continued support for TOPEX and UARS, as well as the Earth Probes and EOS initiatives. The TOPEX, UARS, and Earth Probes missions will provide key global measurements, prior to the EOS era that starts in late 1997, including stratospheric composition; surface topography of the global oceans and sea surface wind velocity in order to advance the understanding of ocean circulation; rainfall in the tropics in order to determine the role of tropical precipitation in climate; and ocean color to improve the understanding of ocean productivity. EOS will provide an integrated, comprehensive monitoring program of simultaneous measurements of key global change variables, coupled with a comprehensive data and information system.

U.S. scientific agencies are playing a key role in a number of interdisciplinary international scientific programs involving the land, oceans, and atmosphere, and interactions between them, that require a combination of ground- and space-based measurements for successful implementation. These programs include: World Ocean Circulation Experiment; Tropical Ocean - Global Atmosphere; Global Ocean Flux Studies; Global Ocean Ecosystems Dynamics; Global Energy and Water Cycle Experiment; Global Tropospheric Chemistry Program; International Satellite Cloud Climatology Program; and International Satellite Land Surface Climatology Program.

The Carbon Cycle: An Example of Interdisciplinary Research

Modification of the global carbon cycle by human activities spans both science and policy concerns. This section of the report presents a case study of how the U.S. Global Change Research Program approaches a complex multidisciplinary research area like the carbon cycle.

Policy Needs

Emission of carbon dioxide from the combustion of fossil fuels and changes in land-use practices, and of methane from cattle, rice paddies, permafrost, natural wetlands, gas hydrates, and natural gas production are partly responsible for perturbation of the carbon cycle. Changes in the carbon cycle may affect regional and global climate, the chemistry of the atmosphere, the hydrologic cycle, and the productivity and functioning of ecosystems. Consequently, prudent environmental policy formulation will require a solid scientific understanding of how the carbon cycle varies naturally, how human activities change it, and how it might respond to future changes in environmental conditions.

Scientific Background

Atmospheric carbon dioxide is a radiatively active trace gas with concentrations 25 percent greater now than in the pre-industrial era (prior to 1850) and increasing at about 0.4 percent annually because of human activities. Annual anthropogenic emissions of carbon dioxide are currently about 5.5 billion metric tons from fossil fuel combustion, plus an additional 0.8 to 3.0 billion metric tons from tropical deforestation. Over the past century, fossil fuel use and cement manufacturing released about 200 billion metric tons of carbon into the atmosphere. In the same time period, land-use changes (primarily deforestation) may have released as much as an additional 115 billion metric tons of carbon. However, only 130

billion metric tons of these combined releases remain in the atmosphere. A critical question concerning the global carbon balance is, "What has happened to the remaining carbon dioxide and what will happen to it in the future?"

The natural fluxes of carbon dioxide into and out of the atmosphere from the oceans and terrestrial biosphere are an order of magnitude greater than the anthropogenic fluxes. The oceans, which contain about 50 times more carbon than does the atmosphere, are known to be an important long-term sink for carbon from the atmosphere. In addition, while terrestrial vegetation has always assimilated atmospheric carbon dioxide by photosynthesis, it recently has been suggested that vegetation and soils at northern mid-latitudes may be becoming more effective in sequestering carbon from the atmosphere because of either changes in land management (e.g., reforestation) or because the increasing atmospheric carbon dioxide concentrations may be stimulating plant productivity. These oceanic, terrestrial, biogeochemical, and ecological processes ultimately determine the fate of carbon dioxide from human activities. However, uncertainties in the knowledge of the magnitude of the oceanic and terrestrial sinks limit the accuracy of forecasts of the future fraction of "anthropogenic" carbon dioxide that will remain in the atmosphere.

Atmospheric methane is a radiatively and chemically active trace gas whose concentration is now a factor of two greater than it was in the pre-industrial era and is increasing at about 1 percent annually, presumably because of human activities. The atmospheric abundance of methane is controlled by emissions from oxygen-deficient sources such as natural wetlands, permafrost and gas hydrates, rice cultivation, biomass burning, cattle, natural gas venting, and removal by atmospheric chemical reactions.

Uncertainties in the knowledge of the magnitude of the individual sources and sinks of carbon dioxide and methane severely limit the accuracy of forecasts of their future atmospheric concentrations.

Required Understanding

Biological and physical processes control the uptake and release of carbon by the oceans, and ecosystem dynamics are equally important on land. Economic and human factors dictate the magnitude of fossil fuel emission and the intensity of land disturbance. The task of predicting future abundances of atmospheric carbon dioxide, methane, and other carbon-containing gases requires scientific information, spanning numerous scientific disciplines, including: the exchange of carbon dioxide between the oceans and the atmosphere; the exchange of carbon dioxide and total carbon between the shelves and open oceans, and between the surface waters, deep ocean and sediments; the exchange of gases between terrestrial ecosystems and the atmosphere; the storage and cycling of carbon within terrestrial ecosystems; the extent and ecological state of terrestrial and aquatic ecosystems; atmospheric distributions and transformations of gases; paleocarbon budgets; and the influence of human choices on the carbon cycle.

U. S. Global Change Research Program Approach

After evaluating the policy needs, scientific background, and required understanding, a responsive, multidisciplinary research effort was developed. The box on page 54 gives examples of specific U.S. Global Change Research Program activities related to the carbon cycle. Synthesis and integration of results obtained by investigators working within their numerous disciplines is a critical challenge guiding the U.S. Global Change Research Program. This diversity of research, data collection, and modeling activities is typical of global change research.

Examples of Carbon Cycle Research Activities in the FY 1991 U.S. Global Change Research Program

Climate and Hydrologic Systems

- *General Circulation Models (GCM)*. Conduct carbon dioxide scenario experiments in GCMs using coupled atmosphere-ocean models. (DOE, NASA, NSF, and NOAA)

Biogeochemical Dynamics

- *Earth Probes: Satellite Ocean Color Imager and Scatterometer*. Determine ocean productivity and the wind stress at the ocean surface, which will help characterize the carbon dioxide flux across the air/sea interface. (NASA)
- *Ocean Carbon Studies*. Initiate a program of high-precision measurements of carbon dioxide and total carbon, investigate the cycling of carbon in the world's oceans, and determine the air-sea flux of carbon dioxide. (NSF, NOAA, and DOE)
- *Global Carbon Dioxide and Methane Trends*. Monitor the changing abundance of the radiatively active trace species at globally distributed sites. (NOAA, NSF, NASA, and DOE)
- *Terrestrial/Atmospheric Carbon Cycling*. Determine the fluxes of methane and non-methane hydrocarbons from terrestrial ecosystems and the atmospheric processes that establish their lifetime. (NASA, NSF, NOAA, DOE, EPA, and DOI)

Ecological Systems and Dynamics

- *Carbon Cycling in Ecosystems.* Study carbon cycling in terrestrial ecosystems and the processes controlling carbon dioxide fluxes from photosynthesis, respiration, and land-use changes. (DOE, EPA, DOI, USDA, and NSF)
- *Land-Surface Characterization.* Develop data bases for improved vegetation characterization, such as vegetation/land-cover maps, and vegetation greenness indices. (DOI, NOAA, and NASA)

Earth System History

- *Paleo-Atmospheric Carbon Dioxide Abundances.* Carry out ice core studies of carbon dioxide concentrations and other associated variables. (DOE and NSF)
- *Geological History of the Carbon Cycle.* Reconstruct changes in the distribution of carbon isotopes in the Earth's systems. (NSF and DOI)
- *Modeling the Past Carbon Cycle.* Develop models of the long-term partitioning of carbon between the atmosphere, ocean, and terrestrial reservoirs. (DOI)

Human Interactions

- *Carbon Dioxide Emissions.* Develop second-generation carbon dioxide emission models. (DOE)
- *Carbon Dioxide and Standard of Living.* Examine the national differences in fossil fuel consumption and its relation to the standard of living. (NSF)

Solid Earth Processes

- *Volcanic Carbon Dioxide.* Assess long-term volcanic contributions of carbon dioxide to the oceans and atmosphere. (DOI, NSF, and NOAA)
- *Methane Emissions from Permafrost and Methane Hydrates.* Assess the volume and potential release of methane from permafrost and methane hydrates. (DOI and NSF)

Special Issues

The CES has addressed several issues that are important to the success of the U.S. Global Change Research Program. The sections below describe those issues and the approach that CES has taken.

Education

The science of global change is complex and inherently multidisciplinary. While unraveling answers to scientific questions undoubtedly will require new approaches and technology, another important concern is the development of the human resources and scientific talent to conduct multidisciplinary global change research.

To address this need NSF and DOE will initiate human resources programs in FY 1991 that will annually support several hundred postdoctoral appointments, graduate students, and undergraduate students as research participants, as well as several summer institutes on interdisciplinary global change research problems. The NSF program will be managed by representatives from each of the CES agencies. Training opportunities, both in the U.S. and abroad, will include: (i) support at the individual project level, (ii) training centered at major research centers or technology centers, and (iii) opportunities for students to pursue training at institutions of their choice. The DOE program will encourage basic training at universities offering interdisciplinary programs and operational experience in team research at national laboratories and other science and technology centers. In addition, one component of the NASA EOS program is for educational scholarships.

Emerging Disciplines

The U.S. Global Change Research Program presented here should not be viewed as a full exposition of the details of the program in the outyears. The program will evolve as new projects are developed in response to scientific developments

and policy needs. Each of the U.S. scientific agencies has programs at various stages of planning, and furthermore, there are major scientific planning activities related to global change within U.S. (Committee on Global Change of the National Academy of Sciences) and international (e.g., the International Geosphere-Biosphere Programme [IGBP] of the International Council of Scientific Unions [ICSU], and the World Climate Research Programme [WCRP] of the World Meteorological Organization [WMO]) scientific communities that have not reached the point of submission to agencies for any formal consideration. Examples include work on paleontology, hydrology, experimental ecology, and human interactions.

International Dimension

The U.S. Global Change Research Program is founded on the premise that international cooperation and coordination are fundamental to the scientific planning and the implementation of the entire Program. Research programs like the IGBP and the WCRP are truly international in scope and in design. The complex scientific agenda and the infrastructure needed to address the programs outlined here require a careful assessment and integration of the Program's components with programs of other governments; intergovernmental bodies (e.g., U.N. bodies such as the IPCC); and international non-governmental science coordinating and facilitating mechanisms (e.g., ICSU).

There is no "international" budget item included in the U.S. Global Change Research Program because it is integral to each project element. A major CES coordinating effort has been initiated with ICSU and the international scientific community, the intergovernmental organizations, and CES-like bodies in other countries. During 1990, it is expected that an integrating infrastructure will begin to evolve; will be endorsed by the various participating agencies, organizations, and institutions; and will involve to some extent the private and industrial sector. Bilateral and multilateral research agreements and programs between the U.S. and other countries are an essential part of this international framework.

Appendix

FY1990-1991 Global Change Research Program by Project

Agency		Project	Program Status
DOC	NOAA	TOGA-Tropical Ocean-Global Atmosphere,, incl. COARE-Coupled Ocean Atmos. Response Expt.	Enhanced
DOC	NOAA	Ocean Dynamics&Circulation: Atlantic Variability	
DOC	NOAA	WOCE-World Ocean Circulation Experiment	
DCO	NOAA	Chemical Tracers & WOCE Hydrography	
DOC	NOAA	Global Hydrological Cycle/GEWEX	
DOC	NOAA	Upper Ocean/Marine Surface Observations	
DOC	NOAA	Stratospheric Monitoring	
DOC	NOAA	Global Sea Level	
DOC	NOAA	Ocean Carbon	
DOC	NOAA	Climate Data Assimilation System	
DOC	NOAA	Long-Term Data Mgmt Planning & Infrastructure	
DOC	NOAA	Climate Modeling & Analytical Centers	
DOC	NOAA	Climate Diagnostics & Database Development	
DOC	NOAA	Paleoclimate Diagnostic Studies	
DOC	NOAA	Marine Sulfur Emissions/Cloud Feedbacks	
DOC	NOAA	Trace Gases/Radiatively Important Trace Species	
DOC	NOAA	Operational Ocean Modeling	New
DOC	NOAA	Long-Term Observing System Planning	
DOC	NOAA	Measurement Technique Development & Testing	
DOC	NOAA	GESDM-Global Environ. Sciences Data Mgmt	
DOC	NOAA	Near-Term Forecasting Improvement	
DOC	NOAA	Marine Ecosystem Response	
DOC	NOAA	Model-Based Fluxes	
DOE	OHER	Core CO ₂ Research	Existing
DOE	OHER	Effects	
DOE	OHER	Information/Coordination	
DOE	OHER	Human Interactions	
DOE	OHER	Oceans	
DOE	OHER	Quantitative Links	Enhanced
DOE	OHER	ARM-Atmospheric Radiation Measurements	
DOE	OHER	Data for Climate Modeling/Detection	New
DOE	OHER	Education	
DOI	USGS	Coastal Erosion & Inundation	Existing
DOI	USGS	Permafrost	Enhanced
DOI	USGS	Interaction of Climate & Hydrologic Systems	
DOI	USGS	Land Surface Data System	
DOI	USGS	Paleoclimates Research	
DOI	USGS	Climate Arid Regions	
DOI	USGS	Biogeochemistry of Greenhouse Gases	New
DOI	FWS	Coastal Wetland Change & Dynamics	
DOI	FWS	Monitoring Fish & Wildlife Impacts	
DOI	MMS	Ecosystem Stress	
DOI	MMS	Physical Oceanography	
DOI	NPS	Integrated Studies NPS Ecosystems	

DOI	NPS	Dynamics of Coastal Systems	New
DOI	PBA	MESEEC- Methodologies to Estimate Social, Economic, and Environmental Consequences	
DOI	PBA	TOCSEEG-Tradeoffs between Competing Social, Environmental & Economic Goals	
DOI	BLM	Ecological Change in Environmentally Stressed Ecosystems of the Western & Northern U.S.	
DOI	USGS	Biogeochemical Research	
DOI	USGS	Sensitivity Hydrologic Systems	
DOI	USGS	Land Characterization	
DOI	USGS	Volcano Emissions	
DOI	WBR	Regional Studies	
DOI	WBR	Sensitivity Hydrologic Systems	
EPA	ORD	Emissions Research	Existing
EPA	ORD	Stratospheric Ozone	Enhanced
EPA	ORD	Ecological effects	
EPA	ORD	Regional Climate	
EPA	ORD	Biofeedbacks	
EPA	ORD	Tropospheric Chemistry	
NASA	OSSA	Space- Based	Existing
NASA	OSSA	UARS-Upper Atmosphere Research Satellite	
NASA	OSSA	TOPEX-Ocean Topography Experiment	
NASA	OSSA	Payload & Instrument Development	
NASA	OSSA	Scatterometer	Enhanced
NASA	OSSA	Operations & Data Analysis	
NASA	OSSA	Earth Observing System (EOS) Platform	
NASA	OSSA	EOS-Earth Observing System	New
NASA	OSSA	Earth Probes	Enhanced
NASA	OSSA	Ground-based	
NASA	OSSA	Solid Earth Science	
NASA	OSSA	Interdisciplinary Research & Analysis	
NASA	OSSA	Suborbital Research Observations	
NASA	OSSA	Model & Data Hydrology/Circ./Physical Climate	
NASA	OSSA	Model & Data Solid Earth/Ecological Systems/ Biogeochemical Dynamics	
NASA	OSSA	Hydrologic/Circulation/Physical Climate Processes	
NASA	OSSA	Upper Atmosphere Research Program	
NASA	OSSA	Laser Network	
NASA	OSSA	Ecosystem Dynamics & Biogeochemical Processes	
NSF	GEO	Stratospheric Ozone	Existing
NSF	GEO	Antarctic Ecosystems	Enhanced
NSF	GEO	TOGA-Tropical Oceans-Global Atmosphere	
NSF	GEO	GTCP-Global Tropospheric Chemistry Program	
NSF	BBS	HDGEC-Human Dimensions of Global Environmental Change	
NSF	GEO/BBS	LMER-Land-Margin Ecosystems Research	
NSF	GEO	RIDGE-Ridge Interdisciplinary Global Experiment	
NSF	GEO	Geodynamics	
NSF	GEO	ARCSS-Arctic Systems Science	
NSF	GEO	Geologic Record	
NSF	GEO	CEDAR-Coupling, Energetics, & Dynamics of Atmospheric Regions	

NSF	GEO	GOFs-Global Ocean Flux Study	Enhanced
NSF	GEO	WOCE-World Ocean Circulation Experiment	
NSF	BBS	Bioresponse to Climate	
NSF	GEO	GEWEX-Global Energy&Water Cycle Experiment	
NSF	GEO	GEM-Geospace Environment Modeling	New
NSF	CES/NSF	Education & Training Program	
NSF	GEO	Abrupt Climate Change	
NSF	GEO	GLOBEC-Global Ocean Ecosystems Dynamics	
NSF	GEO/BBS	Geosystems Databases	
NSF	GEO	CHP-Continental Hydrologic Processes	
USDA	ARS	Biological Response to UV-B	Existing
USDA	CSRS	Atmospheric Deposition	
USDA	CSRS	Stratospheric Ozone Depletion	Enhanced
USDA	FS	Water Yield, Erosion & Sedimentation	
USDA	FS	Wildlife/Domestic Species Interactions	
USDA	FS	Aquatic Ecosystems & Fisheries Habitat	
USDA	FS	Fire Severity	
USDA	FS	Energy, Water, Carbon & Nutrient Cycles	
USDA	FS	Microbes, Plant Pathogens & Insects	
USDA	FS	Species Life History	
USDA	ARS	Ecosystem Modeling	New
USDA	ARS	Biogeochemical Fluxes	
USDA	ARS	Ozone Effects	
USDA	CSRS	Methane & Trace Gases	
USDA	SCS	Pedosphere-Paleoecology	
USDA	SCS	Pedosphere-Processes	

Key to Program Status

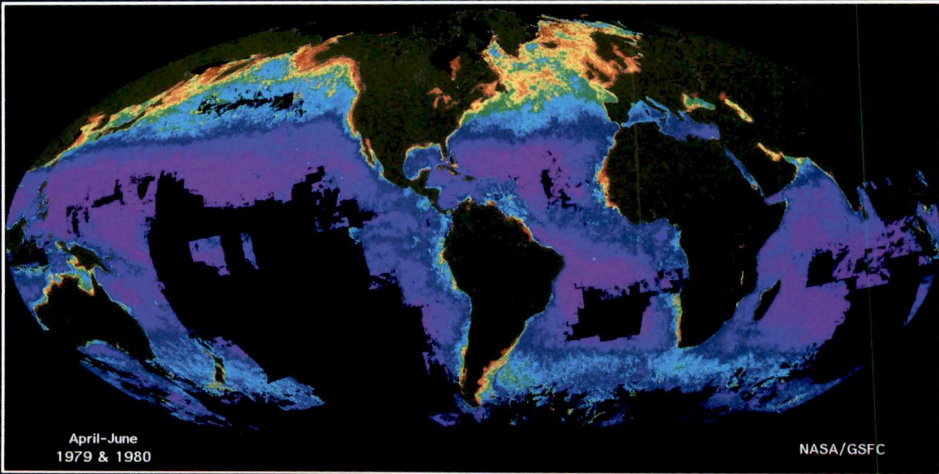


Existing Program
Enhancement of Existing Program
New Initiative

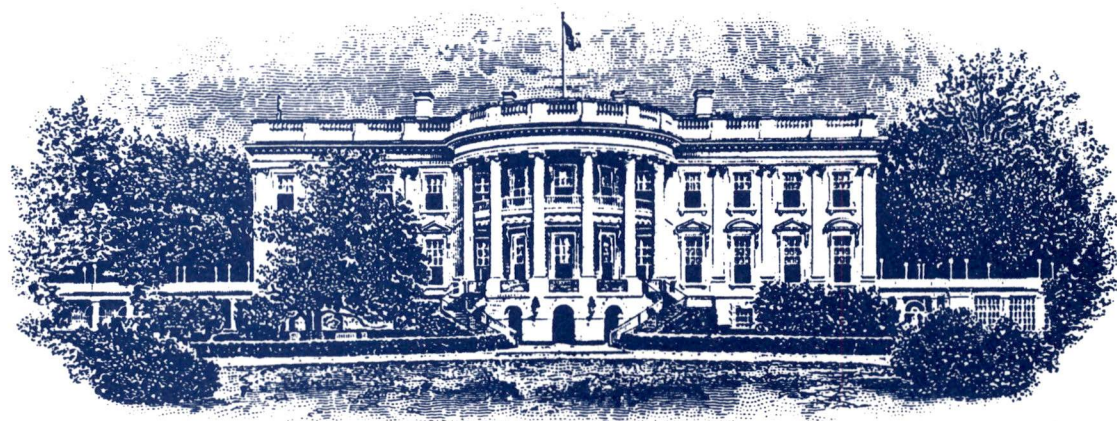
Agency Acronyms

DOE	OHER	Office of Health & Environmental Research
DOI	FWS	Fish & Wildlife Service
	MMS	Minerals Management Service
	NPS	National Park Service
	PBA	Policy & Budget Administration
	WBR	Bureau of Reclamation
	USGS	U.S. Geological Survey
EPA	ORD	Office of Research & Development
NASA	OSSA	Office of Space Science & Applications
NSF	GEO	Geosciences Directorate
	BBS	Biological, Behavioral & Social Sciences Directorate
USDA	ARS	Agriculture Research Service
	CSRS	Cooperative State Research Service
	FS	Forest Service
	SCS	Soil Conservation Service

Global phytoplankton concentrations change seasonally. This three-month composite of phytoplankton concentrations for April—June in 1979 and 1980 shows the “blooming” of phytoplankton over the entire North Atlantic with the advent of northern hemisphere spring. Phytoplankton pigment concentrations range from red (most concentrated) to purple (least concentrated). These measurements were made by the Coastal Zone Color Scanner (CZCS), a radiometer that operated on NASA’s Nimbus 7 satellite from 1978 to 1986.



**PRESIDENT'S COUNCIL OF ADVISORS
ON
SCIENCE AND TECHNOLOGY**



**Camp David, Maryland
February 3, 1990**

THE WHITE HOUSE

WASHINGTON

February 2, 1990

Governor John Sununu:

Dear John:

Here with some information relevant to tomorrow's meeting at Camp David. I very much appreciate your help and support in making this possible.

Sayon tomorrow

Sincerely,
Adam.

CAMP DAVID

TOM LOVEJOY

EARTH SCIENCE
GLOBAL CHANGE
EDUCATION.

RALPH GOMLEY

COMPUTERS
10X/DECADE
→ OPTICAL FIBRES →
LEADING ROLE

COMPETITIVENESS
NEW KIND OF COMPETITION
JAPANESE TALENT FOR S IMPROV.

BERNADINE HEALY

PHYSICIAN/BIO MEDICAL
MEDICINE
FED. INVESTMENT IN BASIC SCIENCE / BASIC BIOLOGY.
↑ IMPORTANCE IN FUTURE
MOTHER OF SCIENCE / BIO = BRAINS
EDUCATION / SEEK ↑ GRADUATE

CHUCK DRAKE

EDUCATION
* SCIENCE/TECHNOLOGY NO FUN ANYMORE *
* OPP. TO BE WRONG IS DISAPPEARING.
TOO MUCH FOCUS ON SAFE SCIENCE.
GLOBAL CHANGE -
UNDERSTAND SOME
NEED RESEARCH.
TRY SOME THINGS

WALTER MASSEY

SCIENCE EDUCATION
LEADERSHIP CAN MAKE A DIFFERENCE
1 PH.D. IN SCIENCE/ENG. MINORITY IN NEXT 5 YRS.
INDIVIDUAL INSTITUTIONS CAN MAKE A DIFF.
USE UNIVERSITIES / NATL. LABS BETTER

HAROLD SHAPIRO

EDUCATION

DAVID PACKARD

COMPETITIVENESS
OCEAN SCIENCE / REMOTE VEHICLES

SOL BUCHSBAUM

COMPETITIVENESS - COMPETITORS
ROOM FOR COOPERATION
INDUSTRIES SHARE UP FRONT COST
BEGINNING TO TAKE PLACE
BALANCE BETWEEN COMPETITION / COOPERATION
LABS → PRIVATE SECTOR
* ETHNIC ROLE OF LABS *

CAMP DAVID

PETER LIKENS

INDUSTRIAL COMPETITION
EDUCATION MATH / SCIENCE
FACULTY IN SCIENCE / ENGR.
GRADUATE STUDENT -

JOHN METAGUE

MATHEMATICS EDUCATION
FOR MASSES
WORKFORCE IN COUNTRY -
72% US / 94% JAPAN H.S. DEGREES
SCIENCE ENGINEERING INDICATORS
" MULTISTEP PROBLEM SOLVING
6% US 50% JAPAN
* MFQ. TOOLS GONE ABROAD *

NORMAN BORLAUG

FOOD PRODUCTION EXPERIENCE
ECONOMIC PLANNING.
COMPLACENCY OF GENERAL PUBLIC
SENSE OF TECH. & QUALITY OF LIFE
EDUCATIONAL PROBLEM
HISTORY OF WHAT MADE OUR COUNTRY GREAT
EX: EBOL RISK IN FOOD
NATURAL PROBLEMS
FOOD NEEDS
6 (WORLD POP) 1 BILL. / 11 YRS
≈ 20% / DECADE

DANIEL NATHANS

LIFE SCIENCES
AIDS GOOD EXAMPLE: SHORT CYCLE ANALYSIS
HOW NURTURE PRODUCTS FROM THIS INVESTMENT.

11
REFER TO 1997

CAMP DAVID

$C_{OCEAN} \sim C_{ATM} = 50 \text{ to } 1$

$\rho = .07$, $\frac{GZ}{.07} \approx 1000$
vs. GZ " "

IF $1/4$ IN THICKNESS

$\approx 200 \text{ to } 250 \text{ TIMES MASS}$

TOP 30 FT. OF OCEAN = MASS ATM.

$\equiv$ BIOLOGICAL IMPACTS.

GLOBAL CHANGE VS. GLOBAL WARMING.

"IT IS A CAPITAL OFFENSE TO THEORIZE
IN THE ABSENCE OF FACT"

IN CASE OF G.H. EFFECT / RUDIMENTARY —

SAT. DATA

NASA/NOAA " S./T PROFILES "

DIRECT INFO OF CLOUD COVER.

H₂O VAPOR " " "

WITHIN A DECADE —

ELECTRIC POWER USE —

THE WHITE HOUSE

WASHINGTON

February 1, 1990

MEMORANDUM FOR THE PRESIDENT

FROM: D. ALLAN BROMLEY

Anan

SUBJECT: Meeting with the President's Council of Advisors
on Science and Technology (PCAST) at Camp David,
February 3, 1990

I. SUMMARY

You have invited the President's Council of Advisors on Science and Technology (PCAST) to meet with you at Camp David on Saturday, February 3, from 10:30 a.m. to 1:30 p.m. The Council reports to you -- no science and technology advisory group has enjoyed comparable status in over 15 years -- and this will be its inaugural meeting. The members will be sworn in by the Vice President on Friday, February 2, at 1:15 p.m. in his office in the Old Executive Office Building.

II. DISCUSSION

The Council brings together a cross-section of the nation's most distinguished scientists and engineers from industry, academia and non-profit organizations. The names and affiliations of these individuals, many of whom you know personally, are attached. You have named Bernadine Healy, M.D. as Vice Chairman and have directed that I serve as Chairman.

At your suggestion, I have asked the members to prepare themselves to discuss with you the three following topics:

- O Science, technology and economic growth;
- O Mathematics and science education; and
- O Environmental science and global change.

I know the members share our conviction that these topics are of the utmost importance, and I expect our Camp David discussions to be both substantive and lively. I should add, however, that while I have learned never to underestimate people of this quality, it is unlikely that the Council will offer us carefully crafted recommendations before we leave Camp David. This is really their first time at bat, as a group. (They will be assembling Friday for the swearing-in and for a reception and dinner, when they will get acquainted with my senior staff.)

In preparation for the meeting, my staff sent the members some examples of the policy questions that arise in debates on the three topics for discussion. We deliberately included among them some that are controversial, simply because we in your Administration are wrestling with them now and because we are counting on the Council to bring to us the views of the private sector on these issues. I attach a list of potential questions that the Council members might raise for discussion at Camp David.

The members thus will have devoted considerable thought to the discussion topics. A critical order of business for me, as Chairman, will be to channel the energy of the Council to best meet your needs. Your meeting with the group for these wide-ranging discussions will build the bridges that I believe will ensure that you receive the independent counsel that you want.

Let me finally, both personally and on behalf of the entire U.S. scientific and technological communities, thank you once again for your hospitality and for the very visible measure of support that your invitation to hold this meeting at Camp David conveys.

Attachments

- | | |
|-------|-------------------------------------|
| Tab A | Listing of the Members of the PCAST |
| Tab B | Potential Discussion Questions |

**THE PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
(PCAST)**

NORMAN BORLAUG, Distinguished Professor, Department of Soils and Crop Sciences, Texas A&M University

D. ALLAN BROMLEY, Assistant to the President for Science and Technology, Executive Office of the President (**Chairman**)

SOLOMON J. BUCHSBAUM, Senior Vice President, Technology Systems, AT&T Bell Laboratories

CHARLES L. DRAKE, Albert Bradley Professor of Earth Sciences and Professor of Geology, Dartmouth College

RALPH E. GOMORY, President, The Alfred P. Sloan Foundation

BERNADINE P. HEALY, Chairman of the Research Institute, The Cleveland Clinic Foundation (**Vice-Chairman**)

PETER LIKINS, President, Lehigh University

THOMAS E. LOVEJOY, Assistant Secretary for External Affairs, Smithsonian Institution

WALTER T. MASSEY, Vice President for Research and for Argonne National Laboratory, University of Chicago

JOHN P. McTAGUE, Vice President-Research, Ford Motor Company

DANIEL NATHANS, Professor of Molecular Biology and Genetics, Johns Hopkins University School of Medicine

DAVID PACKARD, Chairman of the Board, Hewlett-Packard Company

HAROLD T. SHAPIRO, President, Princeton University

PCAST BACKGROUND PAPER

Science, Technology and Economic Growth

Few today dispute the tight coupling of the economic growth and competitiveness of the U.S. with the vigor and diversity of its sciences and technology. While the U.S. remains dominant in most areas of science and in many areas of technology, our positions are being vigorously challenged. In industry, a number of countries have overtaken us in the conversion of technical advances into advanced, cost effective, reliable products. In responding to these challenges, we have many assets at our disposal, not the least of which are the underlying strengths of our science and technology, a superb university system, and the entrepreneurial spirit of our people.

Through the President's Council of Advisors on Science and Technology, the President is soliciting your advice and input on how the Federal Government can best assist the nation's response to these challenges.

Each of you will have your own ideas on how best to undertake this process. We have, however, assembled a number of questions and concerns, some of which you may choose to address.

- o Rapid translation of the results of science and technology into high-performance, cost-competitive commercial products is a problem in many of our industries. What are the cultural, macroeconomic, regulatory and educational factors that have led us to this situation and what should we be doing to rectify them?

- o The U.S. is a highly creative nation with an unrivaled basic science and technology infrastructure in our research universities and in our industrial and government laboratories. Is there need to be concerned that the U.S. is a net exporter of science and technology, frequently with little of lasting significance gained in return? And if so, what should we do, if anything, to protect the interests of U.S. taxpayers and industry that have funded development of the key technologies?

- o We are training far too few scientists, engineers and technologists for the manufacturing base that we envisage for our future and, by and large, our work force is educationally ill prepared for modern manufacturing practices. What measures need be considered to rectify this situation?

- o Science and technology is a component and a concern of virtually every department and agency of the U.S. Government. How best can the S&T responsibilities of various agencies of government be served individually and yet be coordinated so that

the needs of the public and of the economy are most effectively and economically served?

- o Over 150 major federal laboratories are in existence today. What are the future roles of these laboratories in national security? In the economy? Can they serve a useful and economically justifiable role in the transfer of technology to the civilian economy as has been directed by Congress? What measures should be taken to facilitate such a role? The latter might include, for example, expanded mission statements, agency responsibility, selective funding.

- o At the direction of Congress, OSTP has been asked to identify critical technologies that are essential to the competitiveness, long-term national security, the environment and the economic well-being of the nation. Semiconductors, high-performance computing, and high-temperature superconductors have been identified as three such technologies during the Bush and Reagan Administrations. Are there others of comparable significance? How do we identify them?

- o Once critical technologies have been identified, is there a Federal role in promoting their advancement to commercialization? If so, should this role be confined to support of basic research through NSF, NIH, DOD, DOE and other agencies or is Federal involvement through pre-competitive development stages justified in particular cases? If the latter, what should be the criteria and conditions for such involvement?

- o The U.S. has long pressed for more open financial markets and has deregulated banking over the past several years. But, when Japanese and other banks gained major positions in the U.S. market because lower capital cost requirements abroad resulted in lower costs, the Federal Government reacted by persuading foreign banks to increase capital reserves. In effect the Treasury moved to give limited protection to U.S. banks by creating an equitable framework for competition. Should we more frequently consider comparable action when critical industries such as the semiconductor industry are threatened, i.e., should we more frequently enter into negotiation to create a "level playing field" for industries considered critical to the U. S.?

- o In the 30's, the Federal Government became deeply involved in development of hydroelectric power and in the 60's in development of the interstate highway system. Should the Federal Government now begin exploring with U.S. companies the measures necessary to begin rewiring America with fiber optic cable? Such a network could stimulate a new generation of products for the information age such as high-resolution facsimile machines, digital photography and high-definition television. Such a network could be a boon to individualized instruction in our schools.

PCAST BACKGROUND PAPER MATHEMATICS AND SCIENCE EDUCATION

There is widespread agreement that mathematics and science education at the precollege level needs to be revitalized. At the same time, there is a growing awareness that our system of higher education, long the envy of our competitors abroad, faces challenges that threaten its preeminence.

The President has requested your advice on how the Federal government can assist in strengthening American mathematics and science education at all levels. A few issues that PCAST might choose to address in this context are indicated below. Recognizing that you have devoted considerable thought to the overall problem, we have kept our discussion brief and our listing incomplete. We have, however, included an appendix that provides more detailed information on the crisis in precollege education and on the Administration's response to date.

Graduate and Undergraduate Math and Science Education

By all accounts, the overall quality of math and science education at the graduate and undergraduate levels is excellent. Maintaining this excellence, and making it more uniform among our colleges and universities, will require a concerted effort in the face of the changes taking place in the environment in which these institutions are embedded.

o Institutions of higher education have a critical interest, and can play a number of important roles, in rectifying the failures of our precollege education system. Are there ways in which the Federal government can assist colleges and universities in this effort?

o The increasingly strong coupling between basic research, technical development, and product commercialization is changing the way many university scientists -- and universities -- conduct their activities. How will this affect math and science education? How should the Federal government, as the primary supporter of basic research at universities, respond?

o A major strength of our best research colleges and universities has been their ability to supplement classroom lectures with hands-on participation -- for both graduate and undergraduate students -- in research projects. In most cases, these research projects are funded by the Federal government. Should research projects be funded at other, geographically diverse, colleges and universities as a means of improving math, science and engineering education? If so, under what conditions?

o Many colleges and universities have deferred repair and renovation of existing, and construction of new, academic research

facilities to the point that the long-term financial viability of the institutions may be threatened. Should the Federal government play a role in addressing this problem? Should a portion of the indirect costs recovered from research grants be channeled specifically toward solving this problem?

o There is a trend, encouraged by the Federal government, toward increased international cost-sharing and collaboration in research projects in many areas of academic research. Are there consequences or higher education in mathematics, the sciences and engineering?

Precollege Education

American precollege education in mathematics and science is, on average, poor in quality and poorly suited to the demands of the late twentieth century. This appears to be particularly true for math, science, and technical preschool education. (Please see appendix for a more detailed statement of the extent of the crises and an indication of the government's response to date.) For example:

o Our economy has shifted dramatically toward a high technology and services-oriented base, but our schools have not changed to meet these new needs. How can the Federal government help ensure that our children are taught the specific skills they will need when they graduate? How can we stimulate programs to supplement the education of undertrained graduates?

o The increasing need for scientists, engineers and technicians in our economy can be met only if an increasing fraction of students from currently under represented groups -- women and minority group members -- opt for careers in these areas. How can we make these career choices more attractive to youth at the critical K-9th grade stage?

o The average achievement levels in math and science of our high school graduates fall well below those of students in many other nations. Some of our teachers and schools produce outstanding students, year in and year out. Should we be doing more to stimulate wider adoption of their techniques?

o The mathematics community has devoted considerable effort to national curriculum reform, and the AAAS is sponsoring a reform effort in the sciences. Should the Federal government sponsor, or encourage other groups to sponsor, efforts to develop curricula leading to technician careers in various areas?

**PCAST BRIEFING PAPER
GLOBAL CHANGE**

Background: Although there are many uncertainties regarding the magnitude, timing, and regional distribution of possible future climate changes, there is no question that atmospheric concentrations of greenhouse gases are increasing. There is also no question regarding the underlying physics of greenhouse gases. However, both the current models that predict climate changes and our knowledge of the earth system are sufficiently unclear that there is considerable disagreement over the predictions for the future.

There are a number of activities underway in the Federal Government to address both the scientific and the policy/economic issues associated with global change. An interagency group, the Committee on Earth Sciences (CES), chaired by Dallas Peck, under the Federal Coordinating Council for Science, Engineering, and Technology, has developed a Federal Global Change Research Program. This Program is described in some detail in the enclosed document. In addition to direct contacts between the CES and the academic community, the CES interacts with the U.S. academic community and the international science community through the National Academy of Sciences' Committee on Global Change (CGC), chaired by Hal Mooney.

Possible Policy Issues for Consideration by PCAST:

- o What actions might be taken to slow growth of atmospheric concentrations of greenhouse gases (both sources and sinks)?
- o What actions/responses to adjust to changes in regional climate ought to be investigated and evaluated?
- o What are the potential economic and social costs of either taking or not taking such actions?
- o What are the best criteria for setting policy for limiting greenhouse gas emissions that will also ensure that actions do not unnecessarily hinder economic growth?
- o How can the coordination of international efforts be improved to take advantage of the best available expertise in the world community of scientists, economists, industrialists, and environmentalists? Are new international committee structures needed? Should additional forums be developed for the exchange of both policy and science concerns of participating nations?
- o Are there ways to improve the coordination or communication between research efforts in the private sector and those funded by the Federal government that are relevant to global warming?

o Are there ways to improve the development and sharing of data resulting from the monitoring of Earth systems by the international scientific community?

o Are the current control strategies for the development of an international agreement concerning greenhouse gases, such as grouping all gasses together and encouraging solutions that allow emissions trading as much as possible, the optimum ones?

o Is there some level of uncertainty below which the U. S. and other nations should not implement control strategies that are associated with significant economic penalties? How would this level be determined?

o Are current economic modeling efforts properly directed towards supporting the policy decisions that will need to be made in the near future?

Possible Scientific Issues for Consideration by PCAST:

o Do the priorities addressed in the CES documents properly reflect the important scientific questions?

o Is the scientific agenda expressed by the CES suited to providing answers both in the short term, for immediate policy concerns, as well as in the long term?

o Is the mix of ground-based and space-based research properly balanced?

o Should the interactions between the CES and the national and international academic and business communities be broader or more intensive? How might these interactions be enhanced?

THE WHITE HOUSE
WASHINGTON

February 1, 1990

INAUGURAL MEETING OF THE
PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY (PCAST)

DATE: Saturday, February 3, 1990
LOCATION: Camp David, Maryland
TIME: 10:30 a.m. to 1:30 p.m.
FROM: D. ALLAN BROMLEY

D. Allan Bromley

I. PURPOSE

To hold the inaugural meeting of the President's Council of Advisors on Science and Technology (PCAST).

II. BACKGROUND

You established the Council by Executive Order No. 12700 to advise you on all matters of science and technology. Members are drawn from the private sector and are appointed by you. The Assistant to the President for Science and Technology Policy, Dr. D. Allan Bromley, serves as the Chairman. You have selected Bernadine Healy, M.D. from among the members of the Council to serve as Vice Chairman.

III. PARTICIPANTS

The President
The Vice President
The Chief of Staff to the President
The Director of the Office of Management and Budget
The Chairman of the Council of Economic Advisers
The Assistant to the President for Science and Technology
The Chairman of the Council on Environmental Quality

Members of the PCAST (names and affiliations attached)

IV. PRESS PLAN

White House Photographer only.

V. SEQUENCE OF EVENTS

(Meeting agenda attached)

10:30 a.m. Meeting begins

12:00 noon Break

12:15 p.m. Working Lunch

1:30 p.m. Meeting ends

Attachments

Tab A Listing of the Members of the PCAST

Tab B Meeting Agenda

Tab C Talking Points

**THE PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
(PCAST)**

NORMAN BORLAUG, Distinguished Professor, Department of Soils and Crop Sciences, Texas A&M University

D. ALLAN BROMLEY, Assistant to the President for Science and Technology, Executive Office of the President (**Chairman**)

SOLOMON J. BUCHSBAUM, Senior Vice President, Technology Systems, AT&T Bell Laboratories

CHARLES L. DRAKE, Albert Bradley Professor of Earth Sciences and Professor of Geology, Dartmouth College

RALPH E. GOMORY, President, The Alfred P. Sloan Foundation

BERNADINE P. HEALY, Chairman of the Research Institute, The Cleveland Clinic Foundation (**Vice-Chairman**)

PETER LIKINS, President, Lehigh University

THOMAS E. LOVEJOY, Assistant Secretary for External Affairs, Smithsonian Institution

WALTER T. MASSEY, Vice President for Research and for Argonne National Laboratory, University of Chicago

JOHN P. McTAGUE, Vice President-Research, Ford Motor Company

DANIEL NATHANS, Professor of Molecular Biology and Genetics, Johns Hopkins University School of Medicine

DAVID PACKARD, Chairman of the Board, Hewlett-Packard Company

HAROLD T. SHAPIRO, President, Princeton University

**Nominees for Membership on the
President's Council of Advisors
on Science and Technology
(PCAST)**

NORMAN E. BORLAUG

Nobel Laureate Borlaug is currently leader of the Sasakawa-Global-2000 agricultural program in sub-Saharan Africa, Distinguished Professor of International Agriculture at Texas A&M University, and a Senior Consultant to CIMMYT.

He was Director of the Wheat Research and Production Program of the International Maize and Wheat Improvement Center, Mexico, from 1964 until his retirement in 1979.

Dr. Borlaug's career began in 1935 in the U.S. Forest Service, and he subsequently worked as an instructor in plant pathology at the University of Minnesota in 1941, where he received his Ph.D. in plant pathology in 1942. From 1942 through 1944 he was a microbiologist with the E. I. DuPont de Nemours & Co.. He also served as research scientist in charge of wheat improvement with the Cooperative Mexican Agricultural Program, Mexican Ministry of Agriculture and the Rockefeller Foundation, 1944-60, and later, as Associate Director of the Foundation assigned to the Inter-American Food Crop Program, 1960-63.

SOLOMON J. BUCHSBAUM

Solomon J. Buchsbaum has been Senior Vice President, Technology Systems, at AT&T Bell Laboratories since 1979.

Dr. Buchsbaum's early career included work at the MIT Research Laboratory of Electronics. After receiving his Ph.D. in physics from the Massachusetts Institute of Technology in 1957, he joined Bell Laboratories in 1958 as a member of the technical staff and later became department head and director of the Electronics Research Laboratory. In 1968, Dr. Buchsbaum was named Vice President for Research at the Sandia Laboratories and served there in a number of different capacities. He returned to Bell Laboratories in 1971 as an Executive Director. In 1976 he became Vice President, Network Planning and Customer Systems.

Dr. Buchsbaum is a member of the National Academy of Sciences and of the National Academy of Engineering. He was the recipient of the President's National Medal of Science in 1986.

CHARLES L. DRAKE

Charles L. Drake has been the Albert Bradley Professor of Earth Sciences at Dartmouth since 1984 and Professor of Geology since 1969. Dr. Drake's professional career began at Columbia University in 1953. He joined the staff at Dartmouth College in 1958 after receiving his Ph.D. in geology from Columbia University where he has continued his career, including service as Professor and Chairman of the Department, 1967-69; as Dean of Graduate Studies and as Associate Dean of the Science Department, 1978-81.

Dr. Drake is a recipient of the G. P. Woollard Award, Geophysical Division of the Geological Society of America.

RALPH E. GOMORY

Ralph E. Gomory is President of the Sloan Foundation and, until his recent retirement, was Senior Vice President for Science and Technology, IBM Corporation. He received his Ph.D. in mathematics from Princeton University in 1954.

Dr. Gomory's professional experience includes teaching and research at Princeton University, 1957-59. In 1959, he joined the Research Division of IBM and was named Director of the Mathematical Sciences Department in 1965. In 1970 he became IBM Director of Research and held that position until 1985, becoming IBM Vice President in 1973, Senior Vice President in 1985, and IBM Senior Vice President for Science and Technology in 1986. He has been awarded a number of honorary degrees and prizes including the John von Neumann Theory Prize in 1984 and the President's National Medal of Science in 1988.

BERNADINE HEALY, VICE CHAIRMAN

Bernadine Healy is Chairman of the Research Institute of The Cleveland Clinic Foundation, a position she assumed in 1985, and is a staff member of the Clinic's Department of Cardiology. Prior to that time, she was Deputy Director of the Office of Science and Technology Policy at the White House, and until that appointment had been a Professor at The Johns Hopkins University School of Medicine and Hospital. Dr. Healy received her medical degree from Harvard Medical School in 1970. Her medical career continued at Johns Hopkins from 1976 to 1984, where she was Professor of Cardiology and Medicine, Director of the Coronary Care Unit, and Assistant Dean for Postdoctoral Programs and Faculty Development.

Dr. Healy is a member of the Institute of Medicine of the National Academy of Sciences. She is the immediate Past President of the American Heart Association and a former President of the American Federation for Clinical Research.

PETER W. LIKINS

Peter W. Likins is President of Lehigh University. His professional career began as a development engineer with the Jet Propulsion Laboratory, California Institute of Technology in 1958. In 1964 he joined the faculty at the University of California, Los Angeles, where in time he became Professor of Engineering and later, Associate Dean. Dr. Likins received his Ph.D. in engineering mechanics from Stanford in 1965. In 1976 he became Professor and Dean of Columbia University, serving until 1980, when he became Provost of the University. In 1982 he was named President of Lehigh.

THOMAS E. LOVEJOY

Thomas E. Lovejoy is the Assistant Secretary for External Affairs, The Smithsonian Institution. His previous experience includes service as a research assistant at the University of Pennsylvania, 1971-74, after receiving his Ph.D. in biology from Yale University in 1971; as Executive Assistant to the Science Director and as Assistant to the Vice President for Resources and Planning of the Academy of Natural Sciences, 1972-73; as the Vice President for Science of the World Wildlife Fund-U.S., 1973-87; and as Executive Vice President, 1985-89.

Dr. Lovejoy is President of the Society for Conservation Biology.

WALTER E. MASSEY

Walter E. Massey has been the Vice President of the University of Chicago for Research and for Argonne National Laboratory since 1984. He has also been Professor of Physics at the University since 1979.

Dr. Massey previously served as a physics instructor at Morehouse College, 1958-59; and after receiving his Ph.D. in physics from Washington University in 1966, as a staff physicist with the Argonne National Laboratory until 1968; as Assistant Professor of Physics, University of Illinois, Urbana, 1968-70; Associate Professor of Physics and Dean of the College, Brown University, 1975-79.

He is Vice President, and President-elect of the American Physical Society and is the Past President and Chairman of the American Association for the Advancement of Science.

JOHN P. MCTAGUE

John P. McTague is Vice President - Research, Ford Motor Company, and has served in that position since 1986.

In 1983 Dr. McTague was appointed Deputy Director of the Office of Science and Technology Policy, becoming Acting Science Advisor to the President and Acting Director of OSTP in 1986. Prior to that, he was Chairman of the National Synchrotron Light Source Department, Brookhaven National Laboratory, 1982-83. He was Professor of Chemistry and a member of the Institute of Geophysics and Planetary Physics, University of California, Los Angeles, 1970-82. Dr. McTague began his professional career as a member of the Technical Staff, North American Aviation Science Center, on receiving his Ph.D. in physical chemistry from Boston University, and remained there until 1970. He is U.S. Chairman of the U.S. Japan Joint High Level Advisory Panel on Cooperation in Research and Development in Science and Technology.

DANIEL NATHANS

Nobel Laureate Nathans is Professor of Molecular Biology and Genetics at The Johns Hopkins University Medical School and Senior Investigator of the Howard Hughes Medical Institute. He has been on the faculty of The Johns Hopkins University Medical School since 1962.

After receiving his Medical Degree from Washington University in 1954, he served as Medical Resident at the Columbia-Presbyterian Medical Center in New York, 1955, 1957-59; as Clinical Associate at the National Cancer Institute, 1955-57, and Guest Investigator in biochemistry at the Rockefeller University, 1959-62.

Dr. Nathans received the Nobel Prize in Physiology or Medicine in 1978 for his research with enzymes that cut DNA into specific pieces, one of the basic tools of genetic engineering.

DAVID PACKARD

David Packard has been Chairman of the Board of the Hewlett-Packard Co. since 1972. Mr. Packard received his B.A. and B.S.E.E. degrees from Stanford University in 1934 and 1939, respectively.

His professional experience includes service as an engineer with the Vacuum Tube Engineering Department, GE Co., 1936-38; co-founder and partner, the Hewlett-Packard Co., 1939-47; President, 1947-64; and Chairman and Chief Executive Officer, 1964-69. Prior to his present position, Mr. Packard served as U.S. Deputy Secretary of Defense from 1969-71.

Mr. Packard received the Vannevar Bush Award of the National Science Board in 1987 and the President's National Medal of Technology and the Presidential Medal of Freedom in 1988.

HAROLD T. SHAPIRO

Harold T. Shapiro has been President of Princeton University since 1988.

Dr. Shapiro's previous academic experience has been with the University of Michigan, first after receiving his Ph.D. in economics from Princeton University in 1964, as an Assistant Professor of Economics in 1964. His career progressed from Associate Professor, 1967-70; Professor, 1970-76; Chairman of the Department of Economics, 1974-77; Professor of Economics and Public Policy, 1977; Vice President for Academic Affairs, 1977-79.

Dr. Shapiro was President of the University of Michigan from 1980 until 1987. He has served as a member of many industrial, governmental and academic boards and commissions.

MEETING AGENDA

Inaugural Meeting of the President's Council of Advisers on Science and Technology (PCAST)

**Saturday, February 3, 1990
10:30 a.m. - 1:00 p.m.
Camp David, Maryland**

Opening Remarks	The President The Chief of Staff
Introduction of Members	The Chairman
Brief Tabling of Member Issues	PCAST Members
Discussion of PCAST Functions and Operations	The Chairman
Discussion of Selected S&T Issues of National Importance	Open
Discussion of Future Agenda	Open
Discussion of Initial Panel Activities	Open
Concluding Remarks	The President
Adjournment	

SUGGESTED TALKING POINTS

**FOR YOUR INAUGURAL MEETING WITH THE MEMBERS OF THE
PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY (PCAST)**

FEBRUARY 3, 1990 - CAMP DAVID, MARYLAND

- O PCAST is a little different from most of the groups that advise me: you bring the perspective of the private sector to bear on issues involving science and technology (and it won't surprise you to hear me say that most public policy issues involve S&T at some point).

- O I am assuming you will all feel comfortable in speaking freely in our meetings -- and that you will not be uncomfortable when we also speak freely. You are an important resource for us. We want to know what you think on the issues; but we also would like to be able to use you to help us think through possible solutions that occur to us -- to use you as a sounding board. I hope very much that this morning's meeting will be a step toward developing the mutual trust that we will need if our work together is to succeed.

O My Administration will be resolving many issues over the coming years where your counsel will be important. From the brief menu that you and Allan generated, I have selected three for discussion here at our first meeting:

- Science, Technology and Economic Growth;
- Math and Science Education; and
- The Environment and Global Change.

I have a few remarks I want to make on each of these, as we take them up in turn. But first, I know, Dan, that you had a chance to meet the members yesterday, and have sworn them in -- do you have any comments that you would like to make? I'm sure, too, that John and Allan will have remarks.

**SUGGESTED TALKING POINTS
FOR THE THREE SELECTED ISSUES FOR DISCUSSION**

-- Science, Technology and Economic Growth

Continuing strength and R&D support for Science and Technology are essential for national security and economic growth; support for Science and Technology is a critical part of this Administration's investment in our future.

Defining an appropriate role for the Federal Government in assisting to maintain our national economic growth has a very high priority right now.

I do not intend to adopt any sort of 'Industrial Policy' where the Government essentially picks the winners and losers within the private sector.

There are, however, many areas where the Federal Government can be effective, far short of interfering in production processes and commercialization of products.

Today, let's focus on ideas for new activities that could result in a significant strengthening of our nation's economic growth.

-- Science and Mathematics Education

I know that we have a very paradoxical situation in our nation's educational enterprise. We set the world's standards for graduate training, but our pre-college education is a national disgrace.

The situation is so serious that last fall -- for only the third time in this century -- I convened a Governors' Summit to discuss possible approaches and solutions.

My Administration and I are actively working to follow up on activities planned at the Summit, but I want help on new activities that will help our school systems, especially in areas related to mathematics and science education.

I have emphasized that I want to be the 'Education President' because during my term I intend to lay the foundations to ensure excellence across the board in education, starting with pre-school and kindergarten. It is critical to start this now because of the length of time it will take to see the results.

What are your thoughts?

-- **The Environment and Global Change**

Global change has become a top political issue throughout the world.

The United States will undertake those activities necessary to ensure that we are not causing irreparable harm to the environment. But, all of our policies are going to be based on sound scientific evidence and sound economic understanding.

If there is an untapped reservoir of data or expertise available in the private sector, I want to know about it and make sure that such information is incorporated in our planning process.

Through our participation in the United Nations Intergovernmental Panel on Climate Change -- and I will be hosting a plenary meeting of this international group here in Washington next week -- and the activities of the Domestic Policy Council Working Group on Global Climate Change that Allan chairs, I believe that we have made a substantial start in putting together a coherent national policy, but I would like to know how you view what we have done and whether you believe we are handling the issue adequately.

TENTATIVE AGENDA

Inaugural Meeting of the President's Council of Advisers on Science and Technology (PCAST)

**Saturday, February 3, 1990
10:30 a.m. - 1:00 p.m.
Camp David, Maryland**

Opening Remarks	The President The Chief of Staff
Introduction of Members	The Chairman
Brief Tabling of Member Issues	PCAST Members
Discussion of PCAST Functions and Operations	The Chairman
Discussion of Selected S&T Issues of National Importance	Open
Discussion of Future Agenda	Open
Discussion of Initial Panel Activities	Open
Concluding Remarks	The President
Adjournment	

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY

NOTICE OF MEETING

The President's Council of Advisors on Science and Technology (PCAST) will meet on February 3, 1990 at Camp David, Maryland, from 10:30 a.m. until 1:30 p.m.

The purpose of the Council is to advise the President on matters involving science and technology.

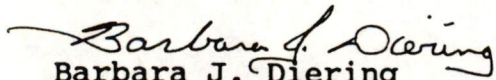
Proposed Agenda:

1. Opening Remarks by the President.
2. Orientation of Members Concerning PCAST Functions and Operations.
3. Discussion of Selected Science and Technology Issues of National Importance.
4. Discussion of Panel Activities and Composition.
5. Discussion of Future Agenda.

The meeting will be closed to the public.

The meeting will include discussion of information that is classified in the interest of national defense or for foreign policy reasons. In addition, agenda items 2, 3, and 4 will involve discussions of internal personnel procedures of the Executive Office of the President and information which, if prematurely disclosed, would significantly frustrate the implementation of recommendations made concerning agency action. A portion of the discussion of panel composition will involve the disclosure of information of a personal nature the public disclosure of which would constitute a clearly unwarranted invasion of personal privacy. Accordingly, the meeting will be closed to the public pursuant to 5 U. S. C.

§552b.(c)(1), (2), (6), and (9)(B).


Barbara J. Diering
Committee Management Officer

January 22, 1990

BILLING CODE FY 1990
3170-01 OSTP

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

CHARTER

PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY

1. Committee's Official Designation:

President's Council of Advisors on Science and Technology (PCAST). The Council was established by Executive Order Number 12700, dated January 19, 1990.

2. Objective and Scope of Activities and Duties:

- The purpose of the PCAST is to advise the President on all matters involving science and technology.
- In furtherance of this mission the PCAST shall conduct a continuing review and assessment of developments in science and technology and the chairman may invite panels of experts to investigate and report to the Council on specific issues of national importance.

3. Duration

The Council will have continuing responsibility for advising the President. The Council will terminate on June 30, 1991, unless sooner extended.

4. Official to Whom the Council Reports:

The PCAST will report to the President, through the Chairman of the Council.

5. Agency Responsible for Providing Necessary Support for this Council:

Office of Science and Technology Policy (OSTP).

6. Description of Duties:

The Duties of the Council are solely advisory and are stated in paragraph 2 above.

7. Costs:

The estimated annual operating cost of the Council is \$375,000, including 2 man years of support staff activity.

8. Estimated Number and Frequency of Meetings:

The President's Council of Advisors on Science and Technology shall normally meet twelve times each year at regular intervals, and at such other times as may be called by the President or the Director, OSTP. In addition, 10-15 meetings each year by Panels are anticipated.

9. Panels:

Panels may be formed to conduct studies on specific issues assigned by the President or the Director, OSTP.

10. Members:

PCAST members shall be appointed by the President from the private sector. The PCAST shall consist of no more than 14 members and the Chairman. The Director, OSTP shall serve as Chairman of the Council, and the Vice Chairman shall be appointed by the President from the members of the Council.

The Council may utilize additional technical experts as needed to constitute its panels and study groups. These technical experts shall be appointed by the Chairman and shall serve at the pleasure of the Chairman.

This Charter for the Advisory Committee named above is hereby approved:

Signed:


D. Allan Bromley

Assistant to the President for Science and Technology, and
Director, Office of Science and Technology Policy, and
Chairman, President's Council of Advisors on Science and
Technology.

Date signed: January 23, 1990

Date filed: January 24, 1990

THE WHITE HOUSE
Office of the Press Secretary
(Miami, Florida)

For Immediate Release

January 19, 1990

EXECUTIVE ORDER

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PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY

By the authority vested in me as President by the Constitution and laws of the United States of America, and in order to establish, in accordance with the provisions of the Federal Advisory Committee Act, as amended (5 U.S.C. App. 2), an advisory committee on science and technology, it is hereby ordered as follows:

Section 1. Establishment. There is established the President's Council of Advisors on Science and Technology ("Council"). The Council shall be composed of not more than 15 members, one of whom shall be the Director of the Office of Science and Technology Policy, and 14 of whom shall be distinguished individuals from the private sector to be appointed by the President. The Director of the Office of Science and Technology Policy shall serve as Chairman of the Council. The Vice Chairman shall be appointed by the President from among the 14 private sector members. The Chairman shall report directly to the President.

Sec. 2. Functions. (a) The Council shall advise the President on matters involving all areas of science and technology.

(b) In the performance of its advisory duties the Council shall conduct a continuing review and assessment of developments in science and technology, and shall, through the Chairman, report thereon to the President whenever requested.

(c) The Chairman may, from time to time, invite experts to investigate and report to the Council on specific issues of national consequence.

Sec. 3. Administration. (a) The heads of Executive agencies shall, to the extent permitted by law, provide the Council and its panels such information with respect to scientific and technological matters as required for the purpose of carrying out its functions.

(b) Members of the Council shall serve without any compensation for their work on the Council. However, members appointed from among private citizens of the United States may be allowed travel expenses, including per diem in lieu of subsistence, as authorized by law for persons serving intermittently in the Government service (5 U.S.C. 5701-5707).

(c) Any expenses of the Council shall be paid from the funds available for the expenses of the Office of Science and Technology Policy.

(d) The Office of Administration shall, on a reimbursable basis, provide such administrative services as may be required.

Sec. 4. General. (a) Notwithstanding any other Executive order, the functions of the President under the Federal Advisory Committee Act, as amended, except that of reporting to the Congress, which are applicable to the Council, shall be performed by the Office of Administration in accord with the guidelines and procedures established by the Administrator of General Services.

(b) The Council shall terminate on June 30, 1991, unless sooner extended.

GEORGE BUSH

THE WHITE HOUSE,
January 19, 1990.

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**THE PRESIDENT'S COUNCIL OF ADVISERS ON SCIENCE AND TECHNOLOGY
(PCAST)**

(Pending Announcement by the President)

**NORMAN BORLAUG, Distinguished Professor, Department of Soils and Crop Sciences,
Texas A&M University**

**ALLAN BROMLEY, Assistant to the President for Science and Technology, Executive Office
of the President (Chairman)**

**SOLOMON BUCHSBAUM, Senior Vice President, Technology Systems, AT&T Bell
Laboratories**

**CHARLES DRAKE, Albert Bradley Professor of Earth Sciences and Professor of Geology,
Dartmouth College**

RALPH GOMORY, President, The Alfred P. Sloan Foundation

**BERNADINE HEALY, Chairman of the Research Institute, The Cleveland Clinic Foundation
(Vice-Chairman)**

PETER LIKINS, President, Lehigh University

THOMAS LOVEJOY, Assistant Secretary for External Affairs, Smithsonian Institution

**WALTER MASSEY, Vice President for Research and for Argonne National Laboratory,
University of Chicago**

JOHN McTAGUE, Vice President-Research, Ford Motor Company

**DANIEL NATHANS, Professor of Molecular Biology and Genetics, Johns Hopkins University
School of Medicine**

DAVID PACKARD, Chairman of the Board, Hewlett-Packard Company

HAROLD SHAPIRO, President, Princeton University

NORMAN E. BORLAUG

Norman E. Borlaug was Director of the Wheat Research and Production Program of the International Maize and Wheat Improvement Center, Mexico, from 1964 until his retirement in 1979.

Dr. Borlaug's career began in 1935 with his service in the U.S. Forest Service, and he subsequently worked as an instructor in plant pathology at the University of Minnesota in 1941, and as a microbiologist with the E. I. DuPont de Nemours & Co., 1942-44. He also served as research scientist in charge of wheat improvement with the Cooperative Mexican Agricultural Program, Mexican Ministry of Agriculture and the Rockefeller Foundation, 1944-60, and later, as Associate Director of the Foundation assigned to the Inter-American Food Crop Program, 1960-63.

He currently is leader of the Sasakawa-Global-2000 agricultural program in sub-Saharan Africa, Distinguished Professor of International Agriculture at Texas A&M University, and a Senior Consultant to CIMMYT and many other public and private agricultural research and development organizations.

Dr. Borlaug is recognized as the Father of the Green Revolution, and received the Nobel Prize for Peace in 1970.

Dr. Borlaug received his B.S. and M.S. degrees from the University of Minnesota in 1937 and 1941, respectively, and his Ph.D. in plant pathology there in 1942.

Dr. Borlaug's research interests include agricultural development, wheat breeding, agronomy, fertilizers, fungicides, weed killers, plant pathology and forestry.

SOLOMON J. BUCHSBAUM

Solomon J. Buchsbaum has been Senior Vice President, Technology Systems, at AT&T Bell Laboratories since 1979.

Dr. Buchsbaum's early career included work at the MIT Research Laboratory of Electronics. He joined Bell Laboratories in 1958 as a member of the technical staff and later became department head and director of the Electronics Research Laboratory. In 1968, Dr. Buchsbaum was named Vice President for Research at the Sandia Laboratories and served there in a number of capacities. He returned to Bell Laboratories in 1971 as an Executive Director. In 1976 he became Vice President, Network Planning and Customer Systems.

Dr. Buchsbaum has provided advice to both the private and governmental sectors, including service as a member of the President's Science Advisory Council from 1970-73; as a consultant to the Office of Science and Technology Policy, 1976-82; and as a member and Chairman, The White House Science Council, 1982-89. He is a member of the National Academy of Sciences and of the National Academy of Engineering. He was the recipient of the President's National Medal of Science in 1986.

Dr. Buchsbaum received his B.S. and M.Sc. degrees from McGill University, Canada, in 1952 and 1953, respectively, and his Ph.D. in physics from MIT in 1957.

His professional interests include plasma physics, gaseous electronics, plasmas in solids, controlled thermonuclear fusion, optical communications, and communications systems and technologies.

CHARLES L. DRAKE

Charles L. Drake has been the Albert Bradley Professor of Earth Sciences at Dartmouth since 1984 and Professor of Geology since 1969.

Dr. Drake's professional career began at Columbia University in 1953. He joined the staff at Dartmouth College in 1958 where he has continued his career, including service as Professor and Chairman of the Department, 1967-69; as Dean of Graduate Studies and as Associate Dean of the Science Department, 1978-81.

He has participated in the work of a number of national and international committees, including serving as President of the Geological Society of America, 1975-76; and of the American Geophysical Union from 1984-86.

Dr. Drake is recognized as one of the Nation's most highly respected earth scientists.

He is a recipient of the G. P. Woollard Award, Geophysical Division of the Geological Society of America.

Dr. Drake received his B.S.E. from Princeton University in 1948 and his Ph.D. in geology from Columbia University in 1958.

His research interests include marine geology and geophysics, tectonics, structural geology, and seismology.

RALPH E. GOMORY

Ralph E. Gomory, until his recent retirement, was Senior Vice President for Science and Technology, IBM Corporation. He now holds the position of President, The Sloan Foundation.

Dr. Gomory's experience includes teaching and research at Princeton University, 1957-59. He joined the Research Division of IBM in 1959 and became Director of the Mathematical Sciences Department in 1965. He was made IBM Director of Research in 1970 and held that position until 1985, becoming IBM Vice President in 1973, Senior Vice President in 1985, and IBM Senior Vice President for Science and Technology in 1986. He has served in many capacities in academic, industrial and governmental organizations, and he is a member of the National Academy of Sciences and the National Academy of Engineering. He has been awarded a number of honorary degrees and prizes including the John von Neumann Theory Prize in 1984 and the President's National Medal of Science in 1988. He is a member of the National Commission on Superconductivity.

Dr. Gomory received his B.A. degree from Williams College in 1950, studied at Cambridge University and received his Ph.D. in mathematics from Princeton University in 1954.

Dr. Gomory's scientific research interests have included linear and integer programming, network flow theory, nonlinear differential equations and computers. In recent years he has written on the nature of technology and product development, on research in industry and on industrial competitiveness.

BERNADINE HEALY

Bernadine Healy is Chairman of the Research Institute of The Cleveland Clinic Foundation, a position she assumed in 1985, and is a staff member of the Clinic's Department of Cardiology. Prior to that time, she was Deputy Director of the Office of Science and Technology Policy at the White House, and until that appointment had been a Professor at The Johns Hopkins University School of Medicine and Hospital.

A graduate of Vassar College in 1965, Dr. Healy received her medical degree from Harvard Medical School in 1970. Her medical career continued at Johns Hopkins from 1976 to 1984, where she was Professor of Cardiology and Medicine, Director of the Coronary Care Unit, and Assistant Dean for Postdoctoral Programs and Faculty Development.

Dr. Healy has served in many capacities on both private and governmental boards and commissions. She was Executive Secretary of the White House Panel on the Health of Universities and chaired the White House Cabinet Working Group on Biotechnology. Subsequently she became a member of the White House Science Council and also served as Chairman of the Advisory Panel for New Developments in Biotechnology of the Office of Technology Assessment of the U.S. Congress. Dr. Healy serves on several councils and committees within the National Institutes of Health, including the Advisory Committee to the Director of the NIH, and is a member of the Institute of Medicine of the National Academy of Sciences. She was recently appointed to the Special Medical Advisory Committee of the Department of Veterans Affairs.

Dr. Healy is a member of the Board of Overseers of Harvard College and a member of several of Harvard's Visiting Committees. She chairs the Ohio Council on Research and Economic Development of the Ohio Board of Regents and is a Trustee of the Edison Biotechnology Center. She is the immediate Past President of the American Heart Association and a former President of the American Federation for Clinical Research. She also serves on the Board of Directors of Medtronic, Inc., and the National City Corporation.

PETER W. LIKINS

Peter W. Likins is President of Lehigh University. His professional career began as a development engineer with the Jet Propulsion Laboratory, California Institute of Technology in 1958. In 1964 he joined the faculty at the University of California, Los Angeles, where in time he became Professor of Engineering and later, Associate Dean. He moved to Columbia University in 1976 as Professor and Dean, serving until 1980, when he became Provost of the University. In 1982 he was named President of Lehigh.

Dr. Likins received his B.S. in civil engineering from Stanford University in 1957, his S.M. in civil engineering from MIT in 1958, and his Ph.D. in engineering mechanics from Stanford in 1965.

Dr. Likins' research interests include problems of space vehicle dynamics, stability and control.

Dr. Likins has served as a consultant to various industrial and governmental research agencies, and as a member of the Packard-Bromley White House Science Council Panel on the Health of U.S. Colleges and Universities.

THOMAS E. LOVEJOY

Thomas E. Lovejoy is the Assistant Secretary for External Affairs, The Smithsonian Institution.

His previous experience includes service as a research assistant at the University of Pennsylvania, 1971-74; as Executive Assistant to the Science Director and as Assistant to the Vice President for Resources and Planning of the Academy of Natural Sciences, 1972-73; as the Vice President for Science of the World Wildlife Fund-U.S., 1973-87; and as Executive Vice President, 1985-89.

He is Chairman of the U.S. Man and Biosphere Program and serves on the Executive Committee of SCOPE (Scientific Committee on Problems of the Environment) of the International Council of Scientific Unions. He is President of the Society for Conservation Biology.

Dr. Lovejoy, on the international level, has focused his attention on continuing efforts to retain substantial sections of the Brazilian tropical rain forests.

Dr. Lovejoy received his B.S. degree from Yale College in 1964 and his Ph.D. in biology from Yale University in 1971.

Dr. Lovejoy's research interests include tropical ecology, ornithology, problems of ecology theory relating to conservation, and natural resource management.

WALTER E. MASSEY

Walter E. Massey is Vice President of the University of Chicago for Research and for Argonne National Laboratory. He has held this position since 1984. He has also been a Professor of Physics at the University since 1979.

Dr. Massey previously served as a physics instructor at Morehouse College, 1958-59; as a staff physicist with the Argonne National Laboratory, 1966-68; as Assistant Professor of Physics, University of Illinois, Urbana, 1968-70; Associate Professor of Physics and Dean of the College, Brown University, 1975-79.

Dr. Massey has served in a number of leadership positions in academic, industrial and governmental institutions, including six years as a member of the National Science Board. He is Vice President of the American Physical Society and is the Past President and Chairman of the American Association for the Advancement of Science.

Dr. Massey received his B.S. degree from Morehouse College in 1958 and his M.A. and Ph.D. degrees in physics from Washington University in 1966.

His research interests include many-body theories of quantum liquids and solids, theory of classical liquids, and solid state theory; the teaching of science and mathematics, and the role of science and technology in a democratic society.

JOHN P. MCTAGUE

John P. McTague is Vice President - Research, Ford Motor Company, and has served in that position since 1986.

In 1983 Dr. McTague was appointed Deputy Director of the Office of Science and Technology Policy, becoming Acting Science Advisor to the President and Acting Director of OSTP in 1986. Prior to that, he was Chairman of the National Synchrotron Light Source Department, Brookhaven National Laboratory, 1982-83. He was Professor of Chemistry and a member of the Institute of Geophysics and Planetary Physics, University of California, Los Angeles, 1970-82. He began his professional career as a member of the Technical Staff, North American Aviation Science Center, 1964-70.

Dr. McTague is a physical chemist with a B.S. degree from Georgetown University, 1960, and a Ph.D. from Brown University, 1965. He is U.S. Chairman of the U.S. Japan Joint High Level Advisory Panel on Cooperation in Research and Development in Science and Technology, and serves on the Naval Research Advisory Committee and the Board of Visitors of the National Institute of Standards and Technology. His board memberships include Ford Aerospace Corporation, Argonne National Laboratory, and the Metropolitan Center for High Technology.

DANIEL NATHANS

Daniel Nathans is Professor of Molecular Biology and Genetics at The Johns Hopkins University Medical School and Senior Investigator of the Howard Hughes Medical Institute.

Dr. Nathans received his B.S. degree from the University of Delaware in 1950 and his M.D. from Washington University in 1954.

He served as Medical Resident at the Columbia-Presbyterian Medical Center in New York, 1955, 1957-59; as Clinical Associate at the National Cancer Institute, 1955-57, and Guest Investigator in biochemistry at the Rockefeller University, 1959-62.

Since 1962 he has been on the faculty of The Johns Hopkins University Medical School.

Dr. Nathans received the Nobel Prize in Physiology or Medicine in 1978 for his research with enzymes that cut DNA into specific pieces, one of the basic tools of genetic engineering. He is a member of the National Academy of Sciences.

His major research interest is the molecular biology of cell growth and cancer.

DAVID PACKARD

David Packard has been Chairman of the Board of the Hewlett-Packard Co. since 1972.

His experience includes service as an engineer with the Vacuum Tube Engineering Department, GE Co., 1936-38; co-founder and partner, the Hewlett-Packard Co., 1939-47; President, 1947-64; and Chairman and Chief Executive Officer, 1964-69. Prior to his present position, Mr. Packard served as U.S. Deputy Secretary of Defense from 1969-71.

Mr. Packard has been a member, as well as chairman, of a number of boards and commissions, including the U.S.-Japan Advisory Commission, 1983-85; the U.S.-U.S.S.R. Trade and Economic Council's Committee on Science and Technology, 1975-82; the President's Blue Ribbon Commission on Defense Management, 1985-86; and the White House Science Council, 1982-89. He has been a member of the Business Council since 1963, and a founding member of the Business Roundtable.

Mr. Packard, who is a member of the National Academy of Engineering, received the Vannevar Bush Award of the National Science Board in 1987, the President's National Medal of Technology and the Presidential Medal of Freedom in 1988.

Mr. Packard received his B.A. and B.S.E.E. degrees from Stanford University in 1934 and 1939, respectively.

His research interests include electronics, communication and data processing technologies, and ocean science.

HAROLD T. SHAPIRO

Harold T. Shapiro has been President of Princeton University since 1988.

Dr. Shapiro's previous academic experience has been with the University of Michigan, first as an Assistant Professor of Economics in 1964. His career progressed from Associate Professor, 1967-70; Professor, 1970-76; Chairman of the Department of Economics, 1974-77; Professor of Economics and Public Policy, 1977; Vice President for Academic Affairs, 1977-79; and he was named President in 1980, the position he held until 1987.

Dr. Shapiro has served as a member of several industrial, governmental and academic boards and commissions, and has participated actively in many science- and technology-related studies.

Dr. Shapiro received his B.Comm. degree from McGill University, Canada, in 1956 and his Ph.D. in economics from Princeton University in 1964.

Dr. Shapiro, who is an economist, has research interests that encompass the relationship of science to innovation, and economic forecasting and policy analysis.

D. ALLAN BROMLEY

D. Allan Bromley is Assistant to the President for Science and Technology and Director of the Office of Science and Technology Policy (OSTP) in the Executive Office of the President.

Dr. Bromley carried out pioneering studies on both the structure and dynamics of nuclei and is considered the father of modern heavy ion science. He has played major roles in the development of accelerators, of detection systems, and in computer based data acquisition and analysis systems. He is currently on leave from his position as Henry Ford II Professor of Physics at Yale University, where he was founder and Director of the A.W. Wright Nuclear Structure Laboratory.

Dr. Bromley has been a leader in the national and international science and science policy communities for more than 20 years, serving as a member of the White House Science Council throughout the Reagan Administration and as a member of the National Science Board in 1988-89. He was the recipient of the President's National Medal of Science in 1988 and the Presidential Medal of the New York Academy of Sciences in 1989.

He has served as President of the American Association for the Advancement of Science and of the International Union of Pure and Applied Physics.

Dr. Bromley received the B.Sc. degree in 1948 at Queen's University, Canada, the M.Sc. degree from Queen's University in 1950, and the Ph.D. degree in nuclear physics from the University of Rochester in 1952. He has since been awarded 10 honorary doctorates.

JUDITH L. BOSTOCK

Judith Louise Bostock was appointed as the Special Assistant to the Director of the Office of Science and Technology Policy in September of 1989. Prior to her appointment, Dr. Bostock spent seven years as an Operation's Research Analyst in the area of Science Policy for the Office of Management and Budget.

From 1972 through 1982, Dr. Bostock was a faculty member in the Physics Department of the Massachusetts Institute of Technology (M.I.T.). She and her research group carried out both theoretical and experimental studies of low transition temperature superconductors, focussing mainly on Niobium and Nb-based A15 and C15 compounds. She remained a Visiting Professor of Physics while at the Office of Management and Budget until 1986. Before joining the M.I.T. faculty Dr. Bostock was the Special Assistant to the Head of the Institute for Theoretical Condensed Matter Physics at the University of Saarlandes in Saarbrücken, West Germany.

Dr. Bostock was awarded a number of teaching commendations including a Lilly Teaching Fellowship and was appointed a Danforth Foundation Associate. She also was a technical consultant for Faculty Development Organizations throughout the country, the Naval Research Laboratory, the BDM Corporation, and Addison Wesley Publishing Company/Science Textbook Division.

Dr. Bostock received an A.B. degree from Trinity College, a B.S. degree from Dickinson College and both a M.S. and Ph.D. from Georgetown University with a major in Solid State Physics (Experimental and

KARL A. ERB

Karl A. Erb is the Assistant Director for Physical Sciences and Engineering of the White House Office of Science and Technology Policy.

Dr. Erb is a 1965 graduate of New York University. He received his Ph.D. in Physics from the University of Michigan in 1970 and joined the University of Pittsburgh in that year as an Instructor. In 1972 he joined the Yale Physics Department faculty where he also was an active member of the Wright Laboratory until 1980 when he moved to the Oak Ridge National Laboratory as Staff Scientist. He subsequently was named Technical Assistant to the Associate Laboratory Director.

Dr. Erb joined the National Science Foundation in 1986 as Program Director for Nuclear Physics, where he remained until he was detailed to the White House Office of Science and Technology Policy in 1989.

Dr. Erb served during 1987-89 as Director of the Joint DOE/NSF Nuclear Science Advisory Committee, while the committee prepared the U.S. Long Range Plan for Nuclear Science.

Dr. Erb's research interests include experimental nuclear physics--with emphasis on heavy-ion science and nuclear molecular phenomena--as well as instrumentation and accelerator physics.

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

NANCY G. MAYNARD
Assistant Director for the Environment

Dr. Maynard is Assistant Director for the Environment in the Office of Science and Technology Policy (OSTP). She joined OSTP from the Laboratory for Oceans at NASA Goddard Space Flight Center where she was Associate Chief for Research. She is a biological oceanographer with a number of years of experience in both hands-on research as well as the administrative/management aspects of science. While at NASA she was involved in both active research on remote sensing of biological processes in polar oceans as well as the scientific administration of a large division of scientists and engineers in NASA. Her recent research has focused on the annual and interannual variations in biological productivity along the ice edge and open water areas of polar seas and the physical factors controlling the production. The work involved the use of satellite imagery, aircraft data, and shipboard studies and includes recent flight missions to the Greenland Sea and Iceland as part of several large interdisciplinary earth science programs.

Her work in remote sensing of biological processes in polar oceans began in 1985 when she decided to return to hand-on scientific research after a number of years in scientific and environmental administration and management. She won a NASA-funded NRC Associateship through the Jet Propulsion Laboratory and Scripps Institution of Oceanography in California where she then had the opportunity to learn the use of satellite and aircraft observations for studying the biology of the oceans.

Before Dr. Maynard returned to research, she had served as Staff Director to the Ocean Studies Board of the National Academy of Sciences for 2 years where she was responsible for maintaining broad oversight of national and international ocean sciences and policy affairs in addition to other staff activities. Dr. Maynard spent a year in OSTP prior to this assignment as a Department of Commerce S&T Fellow -- from 1982 to 1983, during which time she worked primarily on international science and technology policy issues. She had the major staff responsibility for the new U.S.-India S&T Initiative, established by President Reagan and Prime Minister Gandhi.

Dr. Maynard joined OSTP from the National Oceanic and Atmospheric Administration, Department of Commerce, where she spent 5 years as a member of a team of scientists who responded to spills of oil and hazardous materials in the marine environment in Alaska and, later, in the Southeast United States. In between spills, and during spills on the scene, she served as scientific advisor to the U.S. Coast Guard to help mitigate and measure spill impacts on both the environment and human health. She also provided technical assistance on oil and hazardous spill response to a number of other countries including the U.S. Virgin Island, Bermuda and Canada. She was awarded the Public Service Commendation by the U.S. Coast Guard in 1979 for her work on oil spill response in Alaska.

From 1976 until 1978, Dr. Maynard served as Environmental Studies Field Coordinator for the U.S. Bureau of Land Management in Alaska where she served as lead scientist in a multidisciplinary study to assess the potential effects on oil and gas development on the marine environment.

Before joining the government in 1976, Dr. Maynard conducted research on the ecology of the Florida Everglades, phytoplankton ecology and paleoecology, oil pollution biology, and intertidal ecology. Dr. Maynard received a B.S. in Biology and Chemistry from Mary Washington College of the University of Virginia in 1963. She received a M.S. in Zoology from the University of Miami in 1967 and a Ph.D. in biological oceanography from the Rosenstiel School of Marine and Atmospheric Sciences of the University of Miami in 1974. She was appointed a post-doctoral fellow in the Division of Engineering and Applied Physics at Harvard University in 1975. Dr. Maynard was born in Middleboro, Massachusetts on April 18, 1941. She lives in Annapolis, Maryland and has one daughter.

WILLIAM D. PHILLIPS

William D. Phillips has been nominated by the President to be Associate Director of the Office of Science and Technology Policy (OSTP) for Industrial Technology. Pending his confirmation by the U.S. Senate, he is continuing in his multiple capacities as President, Missouri Advanced Technology Institute, in which he has served since 1989; Science Advisor to the Governor of Missouri, in which he has served since 1987; and Professor of Chemistry, Washington University, St. Louis, Missouri, in which he has served since 1987.

Dr. Phillips began his career in 1951 as a research chemist with E.I. du Pont de Nemours and Co., where he held increasingly responsible technical and managerial positions leading to a tenure from 1976 to 1978 as Assistant Director of Research and Development. From 1978 to 1984, he served concurrently as Charles Allen Thomas Professor of Chemistry, Chairman of the Department of Chemistry and Professor of Biological Chemistry in the School of Medicine at Washington University. Dr. Phillips served as Director of the Center for Biotechnology at Washington University from 1982 until 1984 when he became the Senior Vice President for Science and Technology at Mallinckrodt, Inc., in St. Louis.

Dr. Phillips has been a member of the National Academy of Sciences since 1971 and of the American Academy of Arts and Sciences since 1970. In addition he has served on numerous boards of directors, editorial boards and advisory committees.

Dr. Phillips received his B.A. degree in chemistry from the University of Kansas in 1948 and his Ph.D. in physical chemistry from the Massachusetts Institute of Technology in 1951.

ROBERT L. POST, JR.

In May 1988, Dr. Post joined the Office of Science and Technology Policy (OSTP), initially on special detail from the Office of Management and Budget (OMB). He is currently Assistant to the Director and supports the Director on a variety of issues. Examples include preparing and internally coordinating OSTP public statements and coordinating them with OMB. He is responsible for OSTP activities and initiatives in materials science and engineering. He is the Chairman of the interagency Committee on Materials (COMAT), and is the OSTP assistant to the Director for the National Advisory Committee on Semiconductors.

From May 1988 to April 1989, Dr Post was the Special Assistant to the Science Advisor for Budget Policy and was the principal point of contact with OMB. He was responsible for the activities of the OSTP on high performance computing. He had the primary responsibility within OSTP for the coordination and review of the OSTP interagency report The Federal High Performance Computing Program. During the transition period between March 1989 and September 1989, he served as Executive Director of OSTP. During much of this period, he served as an acting head of the International Affairs Directorate in OSTP, and as the OSTP point of contact for the global change initiative.

From 1978 through May 1988, Dr. Post was a budget examiner at the Office of Management and Budget. He had primary responsibility for the preparation and coordination of the Administration's budget request to Congress for the Atomic Energy Defense Activities of the Department of Energy.

From 1976 through 1978, Dr. Post was a consultant at R&D Associates. He worked in areas including special nuclear materials, civil defense and strategic targeting algorithms.

From 1971 through 1974, Dr. Post served on active duty (Captain USAF) at the Air Force Weapons Laboratory. He developed prediction techniques for nuclear weapons effects that were incorporated into the official set of prediction techniques then used by the Air Force for the design of hardened structures.

Dr. Post received his education at MIT (B.S. in Geology in 1967), UCLA (PHD in Geology in 1973) and at Harvard (MBA in 1976). He was a postdoctoral research geophysicist at UCLA in 1974 and published research articles in Science and Tectonophysics.

February 1990

J. THOMAS RATCHFORD

Dr. J. Thomas Ratchford is Associate Director for Policy and International Affairs of the Office of Science and Technology Policy (OSTP) in the Executive Office of the President. Prior to his appointment to this post by President Bush in November 1989, Dr. Ratchford was the Associate Executive Officer of the American Association for the Advancement of Science (AAAS). At AAAS he served as deputy to the chief executive officer and headed the Association's program directorates: Education and Human Resources, International Programs and Science and Policy Programs.

Educated and trained as a solid state physicist, Dr. Ratchford has taught at Washington and Lee University and served on research staffs of various private and governmental laboratories. From 1964 to 1970, he was responsible for formulating and administering a basic research program in the solid state sciences for the Office of Scientific Research of the Department of the Air Force. Dr. Ratchford was a member of the professional staff of the Committee on Science and Technology of the United States House of Representatives from 1970 to 1977, and was one of the first scientists to serve the Congress on a full-time basis. His responsibilities there dealt mainly with policy and funding for science and technology, and for energy research and development.

As a Congressional Fellow of the American Political Science Association in the late 1960's, Dr. Ratchford served in the offices of members of the House and Senate with particular interests in scientific and technological issues. In 1976, he was a Research Scholar at the International Institute for Applied Systems Analysis in Laxenburg, Austria, doing research on the economics and technologies of global energy systems.

Over the years he has chaired outside advisory panels for organizations such as the Gas Research Institute, the Congressional Office of Technology Assessment, and the National Science Foundation, and has served as a consultant and advisor to various governmental, university and industrial organizations.

Dr. Ratchford received his B.S. in mathematics and physics from Davidson College in 1957. The University of Virginia awarded him an M.A. in 1959 and a Ph.D. in 1961, both in physics. A member of Phi Beta Kappa and Sigma Xi, he is a fellow of the AAAS and a member of the American Physical Society and the Virginia Academy of Science. He is married to the former Joanne Walton Causey, and they have four children: Joseph Thomas Jr., Laura Leigh, James Raymond and David Andrew.

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MICHELLE K. VAN CLEAVE

Michelle Kim Van Cleave was reappointed Assistant Director for National Security Affairs and Counsel, White House Office of Science and Technology Policy, on October 1, 1989--positions she had held from August 1987 through February 1989. Prior to rejoining OSTP, Ms. Van Cleave served as Republican Counsel to the Committee on Science, Space, and Technology, U.S. House of Representatives.

From 1981 through July 1987, Ms. Van Cleave was Assistant for Defense and Foreign Policy to Congressman Jack Kemp (R-NY), serving concurrently as National Security Assistant to the House Republican Conference and Associate Staff Member, House Appropriations Subcommittee on Foreign Operations, U.S. House of Representatives.

From 1979 through 1981, Ms. Van Cleave was an associate with the Los Angeles law firm of Horvitz and Greines, specializing in appellate advocacy.

Ms. Van Cleave was Coordinator and Staff Attorney in the Office of the General Counsel, 1981 Presidential Inaugural Committee, and assisted in the work of the Department of Defense Transition Team Office of President-elect Reagan 1980. At the Republican Convention in 1984, Ms. Van Cleave was a member of the Platform Committee staff, with responsibility for foreign policy.

Ms. Van Cleave has served as a member of the Board of Advisors, Center for Security Policy, and as consultant to the Heritage Foundation, the Fund for an American Renaissance, and the American Security Council. She has spoken before a variety of conferences and organizations including the Aspen Institute Berlin, the New York Institute of Technology, the National Defense University, Tufts University, Johns Hopkins School for Advanced International Studies, Republican National Committee regional meetings, the Military Operations Research Society and the American Chamber of Commerce (Manila). She also served as a Congressional Staff Advisor to the U.S. delegation to the United Nations Second Special Session on Disarmament.

Ms. Van Cleave holds M.A. and B.A. degrees in international relations from the University of Southern California and a J.D. from the U.S.C. School of Law. She is a member of the State Bar of California.

December 1989

EUGENE WONG

Eugene Wong has been nominated by the President to be Associate Director of the Office of Science and Technology Policy (OSTP) for Physical and Engineering Sciences. Pending his confirmation by the U.S. Senate, he is continuing in his joint capacity as Professor and Chairman in the Department of Electrical Engineering and Computer Sciences at the University of California, Berkeley.

Dr. Wong began his research career in 1955 with IBM where he served until 1956 and again from 1960 until 1962. He served as Assistant Professor from 1962 to 1965, an Associate Professor from 1965 to 1969, a Professor from 1969, and Chairman from 1985 to 1989, all in the Electrical Engineering and Computer Sciences Department of the University of California at Berkeley. In addition, he has been a consultant to many leading U.S. corporations and was a founder of INGRES Corporation, a major software company.

Dr. Wong became a member of the National Academy of Engineering in 1987. He also has received numerous academic honors and awards, and has served on many editorial boards and advisory committees.

Dr. Wong recieved his B.S., A.M. and Ph.D. degrees in Electrical Engineering from Princeton University in 1955, 1958 and 1959 respectively. His areas of research include stochastic processes and database management systems.

JAMES WYNGAARDEN

James Wyngaarden is Associate Director for Life Sciences in the Office of Science and Technology Policy.

Dr. Wyngaarden received his M.D. degree from the University of Michigan in 1948.

He served as Medical Resident at Massachusetts General Hospital, 1950-52; Visiting Investigator, Public Health Research Institute in New York, 1952-53; and Investigator at the National Institutes of Health, 1953-56.

He held various positions on the faculty of Duke University School of Medicine, 1956-65, and was Visiting Scientist at the Institute de Biologie-Physiochimique in Paris, 1963-1964; Chairman of the Department of Medicine and Physician-In-Chief of the University of Pennsylvania School of Medicine and Hospital, 1965-67; Chairman, Department of Medicine and Physician-In-Chief of the Duke University Medical Center, 1967-82; Director of the National Institutes of Health, 1982-1989.

Dr. Wyngaarden is a member of the National Academy of Sciences, the Institute of Medicine, the American Academy of Arts and Sciences, the Sociedad Medica de Santiago de Chile, the Royal College of Physicians of London, and the Royal Academy of Sciences of Sweden. He has served on many committees including the President's Science Advisory Committee, the President's Committee for the National Medal of Science, the U.S.-Israel Binational Science Foundation Board of Directors, the French and American AIDS Foundation Board of Trustees, and the World AIDS Foundation Board of Directors and has received numerous honorary degrees from U.S. and foreign universities.

His research interests include biochemical regulatory mechanisms, and human genetic disease.

THE WHITE HOUSE
WASHINGTON

January 11, 1990

MEMORANDUM FOR THE MEMBERS OF THE PCAST

FROM: D. ALLAN BROMLEY *D. Allan*
SUBJECT: Our Meeting with President Bush

I have discussed a menu of possible topics for in-depth discussion at Camp David with the President, and he has selected:

1. Science and Technology and Economic Growth
2. Mathematics and Science Education
3. Environmental Science and Global Change

as the three areas on which he would like to hear discussion at this first meeting -- noting that he is very much interested in the Information Revolution, one of the other items on my menu but that he feels that we would need more time than will be available at Camp David to do it justice and that we should therefore defer it until perhaps our next meeting.

Might I suggest that, although all of you will clearly wish to contribute to all these discussions, that Buchsbaum, Gomory, McTague and Packard might focus in particular on the first topic; Healy, Likins, Massey, Nathans and Shapiro on the second; and Borlaug, Drake and Lovejoy on the third.

Enclosed herewith is a draft agenda for the meeting, together with a listing of the PCAST membership. All but two members have now completed their FBI clearances, and I anticipate that all will be completed prior to the meeting. Please keep in mind that the membership of the PCAST is privileged information until such time as the President announces his appointments, so I trust that you will keep it -- together with plans for our first meeting -- strictly confidential.

As indicated on the agenda, I would propose to introduce each of you briefly and then ask each of you to tell the President -- and the group -- something of your present major interests, but it is important that these comments be kept brief -- one or two minutes at most. I would also propose to ask each of you to follow this with a very

brief statement of what you consider to be the most important issue facing the President that has significant science and technology components where PCAST might provide helpful input. There will probably be considerable overlap here, and it would be well for each of us to have a few alternatives in mind. Together, they will form a very sketchy outline for the President of the kinds of issues where PCAST could be helpful to him. I will, of course, ask him to suggest to us areas where he particularly wants input.

John Sununu, as Chief of Staff and as an M.I.T. mechanical engineer and Tufts professor on leave, is very much interested in our activities and will have comments for us as well.

We can discuss many of these issues when we get together on Friday, February 2. I would like to take this opportunity to thank you for your input to date and am very much looking forward to working with you.

Sincerely yours,



D. Allan Bromley
Assistant to the President
for
Science and Technology

Enclosures

Tentative Agenda
List of Nominees

**PCAST BRIEFING PAPER
GLOBAL CHANGE**

Background: Although there are many uncertainties regarding the magnitude, timing, and regional distribution of possible future climate changes, there is no question that atmospheric concentrations of greenhouse gases are increasing. There is also no question regarding the underlying physics of greenhouse gases. However, both the current models that predict climate changes and our knowledge of the earth system are sufficiently unclear that there is considerable disagreement over the predictions for the future.

There are a number of activities underway in the Federal Government to address both the scientific and the policy/economic issues associated with global change. An interagency group, the Committee on Earth Sciences (CES), chaired by Dallas Peck, under the Federal Coordinating Council for Science, Engineering, and Technology, has developed a Federal Global Change Research Program. This Program is described in some detail in the enclosed document. In addition to direct contacts between the CES and the academic community, the CES interacts with the U.S. academic community and the international science community through the National Academy of Sciences' Committee on Global Change (CGC), chaired by Hal Mooney.

Possible Policy Issues for Consideration by PCAST:

- o What actions might be taken to slow growth of atmospheric concentrations of greenhouse gases (both sources and sinks)?
- o What actions/responses to adjust to changes in regional climate ought to be investigated and evaluated?
- o What are the potential economic and social costs of either taking or not taking such actions?
- o What are the best criteria for setting policy for limiting greenhouse gas emissions that will also ensure that actions do not unnecessarily hinder economic growth?
- o How can the coordination of international efforts be improved to take advantage of the best available expertise in the world community of scientists, economists, industrialists, and environmentalists? Are new international committee structures needed? Should additional forums be developed for the exchange of both policy and science concerns of participating nations?
- o Are there ways to improve the coordination or communication between research efforts in the private sector and those funded by the Federal government that are relevant to global warming?

o Are there ways to improve the development and sharing of data resulting from the monitoring of Earth systems by the international scientific community?

o Are the current control strategies for the development of an international agreement concerning greenhouse gases, such as grouping all gasses together and encouraging solutions that allow emissions trading as much as possible, the optimum ones?

o Is there some level of uncertainty below which the U. S. and other nations should not implement control strategies that are associated with significant economic penalties? How would this level be determined?

o Are current economic modeling efforts properly directed towards supporting the policy decisions that will need to be made in the near future?

Possible Scientific Issues for Consideration by PCAST:

o Do the priorities addressed in the CES documents properly reflect the important scientific questions?

o Is the scientific agenda expressed by the CES suited to providing answers both in the short term, for immediate policy concerns, as well as in the long term?

o Is the mix of ground-based and space-based research properly balanced?

o Should the interactions between the CES and the national and international academic and business communities be broader or more intensive? How might these interactions be enhanced?

SEE ATTACHED PAMPHLET.

PCAST BACKGROUND PAPER

Science, Technology and Economic Growth

Few today dispute the tight coupling of the economic growth and competitiveness of the U.S. with the vigor and diversity of its sciences and technology. While the U.S. remains dominant in most areas of science and in many areas of technology, our positions are being vigorously challenged. In industry, a number of countries have overtaken us in the conversion of technical advances into advanced, cost effective, reliable products. In responding to these challenges, we have many assets at our disposal, not the least of which are the underlying strengths of our science and technology, a superb university system, and the entrepreneurial spirit of our people.

Through the President's Council of Advisors on Science and Technology, the President is soliciting your advice and input on how the Federal Government can best assist the nation's response to these challenges.

Each of you will have your own ideas on how best to undertake this process. We have, however, assembled a number of questions and concerns, some of which you may choose to address.

- o Rapid translation of the results of science and technology into high-performance, cost-competitive commercial products is a problem in many of our industries. What are the cultural, macroeconomic, regulatory and educational factors that have led us to this situation and what should we be doing to rectify them?

- o The U.S. is a highly creative nation with an unrivaled basic science and technology infrastructure in our research universities and in our industrial and government laboratories. Is there need to be concerned that the U.S. is a net exporter of science and technology, frequently with little of lasting significance gained in return? And if so, what should we do, if anything, to protect the interests of U.S. taxpayers and industry that have funded development of the key technologies?

- o We are training far too few scientists, engineers and technologists for the manufacturing base that we envisage for our future and, by and large, our work force is educationally ill prepared for modern manufacturing practices. What measures need be considered to rectify this situation?

- o Science and technology is a component and a concern of virtually every department and agency of the U.S. Government. How best can the S&T responsibilities of various agencies of government be served individually and yet be coordinated so that

the needs of the public and of the economy are most effectively and economically served?

o Over 150 major federal laboratories are in existence today. What are the future roles of these laboratories in national security? In the economy? Can they serve a useful and economically justifiable role in the transfer of technology to the civilian economy as has been directed by Congress? What measures should be taken to facilitate such a role? The latter might include, for example, expanded mission statements, agency responsibility, selective funding.

o At the direction of Congress, OSTP has been asked to identify critical technologies that are essential to the competitiveness, long-term national security, the environment and the economic well-being of the nation. Semiconductors, high-performance computing, and high-temperature superconductors have been identified as three such technologies during the Bush and Reagan Administrations. Are there others of comparable significance? How do we identify them?

o Once critical technologies have been identified, is there a Federal role in promoting their advancement to commercialization? If so, should this role be confined to support of basic research through NSF, NIH, DOD, DOE and other agencies or is Federal involvement through pre-competitive development stages justified in particular cases? If the latter, what should be the criteria and conditions for such involvement?

o The U.S. has long pressed for more open financial markets and has deregulated banking over the past several years. But, when Japanese and other banks gained major positions in the U.S. market because lower capital cost requirements abroad resulted in lower costs, the Federal Government reacted by persuading foreign banks to increase capital reserves. In effect the Treasury moved to give limited protection to U.S. banks by creating an equitable framework for competition. Should we more frequently consider comparable action when critical industries such as the semiconductor industry are threatened, i.e., should we more frequently enter into negotiation to create a "level playing field" for industries considered critical to the U. S.?

o In the 30's, the Federal Government became deeply involved in development of hydroelectric power and in the 60's in development of the interstate highway system. Should the Federal Government now begin exploring with U.S. companies the measures necessary to begin rewiring America with fiber optic cable? Such a network could stimulate a new generation of products for the information age such as high-resolution facsimile machines, digital photography and high-definition television. Such a network could be a boon to individualized instruction in our schools.

APPENDIX: MATHEMATICS AND SCIENCE PRECOLLEGE EDUCATION

An essential component of the current crisis in pre-college education is that the social and economic needs of the nation have changed, and our schools have not changed to meet those needs.

A major Presidential initiative to address this issue recently culminated in the Education Summit held with the Governors of the fifty states. The Jeffersonian Compact, the agreement the President and the Governors made at that summit (Copy attached), acknowledged that:

- o constitutionally and traditionally the responsibility for education is at the state and local level and should remain that way.
- o there should be national goals for education jointly set by the President and the Governors. (These are currently being developed by high level White House staff and a task force of Governors and will be announced at the February meeting of the National Governors' Association.)
- o the state and local governments should continue to bear the lion's share of responsibility for funding education (approximately 90 percent).
- o the continuing budget deficit imposes limits on new spending by the Federal Government on education.

Following the setting of national goals, the Administration will consider appropriate policies to support the states and localities in reaching those goals. The President will consider the advice and input of many groups inside and outside government. The President's Council of Advisors on Science and Technology (PCAST) is one of the groups on which the President will depend for advice and guidance. The advice of PCAST on the Federal role in precollege mathematics and science education; post-high school education for scientists, engineers, and technicians; and other issues will be extremely valuable.

COMPONENTS OF THE PROBLEM

Mismatch of Workforce Skills and Industry Needs

The convergence of several social and economic trends portend difficulties for the economy in general and for the high-technology enterprises in particular. The difficulty is essentially a mismatch between the educational and skill qualifications of the workforce and the labor demands of the economy. The analysis which follows is focused primarily on skill development at the precollege level.

Skill Levels for Future Jobs

As the economy shifts to a high-technology manufacturing base and strong service economy, the jobs available to new entrants into the workforce require higher levels of skill and education than ever before. The median years of education required of the current workforce is 12.8; for jobs available by the year 2000, the median years of education required will be 13.5. High school graduation rates of approximately 75 percent and low achievement test scores combined, indicate that there will be fewer qualified applicants for the available jobs unless the trends of dropouts and low achievement are reversed.

Between 1988 and 2000, the occupational composition of jobs in industry is expected to change from production and assembly-line work toward professional, managerial, and technical occupations. Projections are that the number of jobs for scientists and engineers in private industry will increase by 600,000 persons, with three-fifths of these new jobs located in the services-producing sector. The Bureau of Labor Statistics forecasts a need for approximately 6 million technicians by the year 2000, approximately 2 million more than currently in the workforce.

Trends Affecting Quality and Quantity of Workforce

The pipeline of students studying science and engineering (see chart 1) indicates a pattern of limited supply of scientists and engineers at the bachelors, masters, and doctoral levels in the future. The limited supply of new science and engineering (S/E) graduates has required increasing reliance on foreign-origin personnel to meet the demand for S/E workers. Exacerbating the trend of small proportions of S/E graduates among American youth, are the trend of population declines among the 18-to-24-year-olds and the trend of declining interest among this age group to seek degrees in S/E.

While the overall U.S. population will increase by 18 percent between 1980 and 2000, the 18-to-24-year-old population will decrease by 19 percent. Data on college freshmen show interest in S/E majors has declined substantially (see chart 2); interest in science is down by one-third over two decades and interest in engineering decreased by one-quarter in seven years. If the decline in interest in S/E majors continues with the decreasing 18-to-24-year-old population, there may be serious shortages of scientists and engineers for the 21st century.

Changing Demographics

The composition of the nation's young population is changing in ways that may greatly influence the nation's future supply of scientists, engineers, and technicians. Currently, Black and Hispanic youngsters are 25 percent of the school population; by

the year 2000, they are projected to be 47 percent. Traditionally, the largest source of scientists and engineers has been the pool of white males. This pool will be shrinking at the same time that the demand for engineers and scientists will be increasing. The paucity of these minority groups in science and engineering workforce is no longer only an equity issue; it is also an economic issue. The shrinking of the proportion of white males in the population will necessitate efforts to reverse trends of under representation of women and minorities in the S/E workforce. Currently, 13 percent of the S/E workforce is female, 2.2 percent is Black, and 2.1 Hispanic.

Science Report Card

The trend of low achievement in mathematics and science at the precollege level will impact the quality and quantity of S/E workforce of the next century. Achievement trends for 9-, 13-, and 17-year olds in science from 1970 to 1986 show a pattern of initial declines followed by subsequent upturns; however, the recent improvements did not offset earlier decreases in test scores. Student scores in 1986 remained below 1970 levels for all three age groups.

International comparisons show that American students perform poorly compared to students in other industrialized nations. At age 13, U.S. students ranked ninth out of 12 in overall science achievement; at the 12th grade level, U.S. students were compared to students in 13 industrialized nations and ranked thirteenth in biology, eleventh in chemistry, and ninth in physics.

Mathematics Report Card

In mathematics, the pattern of achievement on national achievement tests from 1973 to 1986 shows that 9- and 13-year olds scored slightly higher in 1986 than in 1973 and 17-year olds scored slightly lower.

International comparisons in mathematics show patterns similar to those in science. At age 13, U.S. students were last compared to students in 12 other countries in mathematics achievement. At grade 12, compared to students in 13 other countries, U. S. students ranked eleventh in geometry, twelfth in algebra, and thirteenth in calculus.

CURRENT REFORM EFFORTS IN MATHEMATICS AND SCIENCE EDUCATION

The States

The states have been active in general education reform efforts since 1983, particularly in increasing graduation requirements. In mathematics and science, there has been a significant increase in the number of courses taken by high school graduates. Students took an average of one semester more of mathematics in 1987 than in 1982. Enrollments in advanced mathematics classes were up by nearly a third. Students also took more courses in basic science and computer science in 1987 than in 1983.

With respect to teaching, the states are initiating programs to attract and license professional mathematicians and scientists as teachers even though they have not met formal requirements in pedagogical training. The states are also supporting the work of the National Board for Professional Teaching Standards, a recently-formed body which plans to professionalize teaching by certifying teachers in the same stringent ways medical boards certify physicians.

The Mathematics Community

At the national level, the mathematics and scientific communities have advocated change in precollege education. The National Academy of Sciences created the Mathematical Sciences Education Board to coordinate the efforts of all of the mathematical societies in forging a consensus for a national strategy for change in mathematics education. These Societies, as well as the Board, respect the local and state autonomy in implementation of all national recommendations. To date, national standards for curriculum have been developed by the National Council of Teachers of Mathematics and have been widely accepted across the states. National standards for teaching are near completion; these standards will be used by the newly-established National Board for Professional Teaching Standards.

The Science Community

In science, the reform movement lags that of mathematics. However, the American Association for the Advancement of Science sponsors Project 2061, a promising reform effort in the sciences. Phase I of Project 2061 was completed with the publication of Science For All Americans (see attached executive summary). In Phase Two of Project 2061, selected schools, school districts, and states are in the process of developing curricula which will achieve the goals set forth in the Phase I documents.

The Business/Industry Community

Investment and participation of the private sector in education is

no longer for philanthropic and public relations purposes only. American businesses and industries recognize that the economic health of their organizations and of the nation's economy is dependent upon the strength of America's schools. The private sector is responding to the crisis at the local level with a variety of individual programs with local schools and school districts, and is becoming increasingly active at state and national levels where there is greater possibility for systemic change and restructuring. Although ready to help with monetary and human resources, the private sector recognizes that putting more funds into the same system will not produce better results.

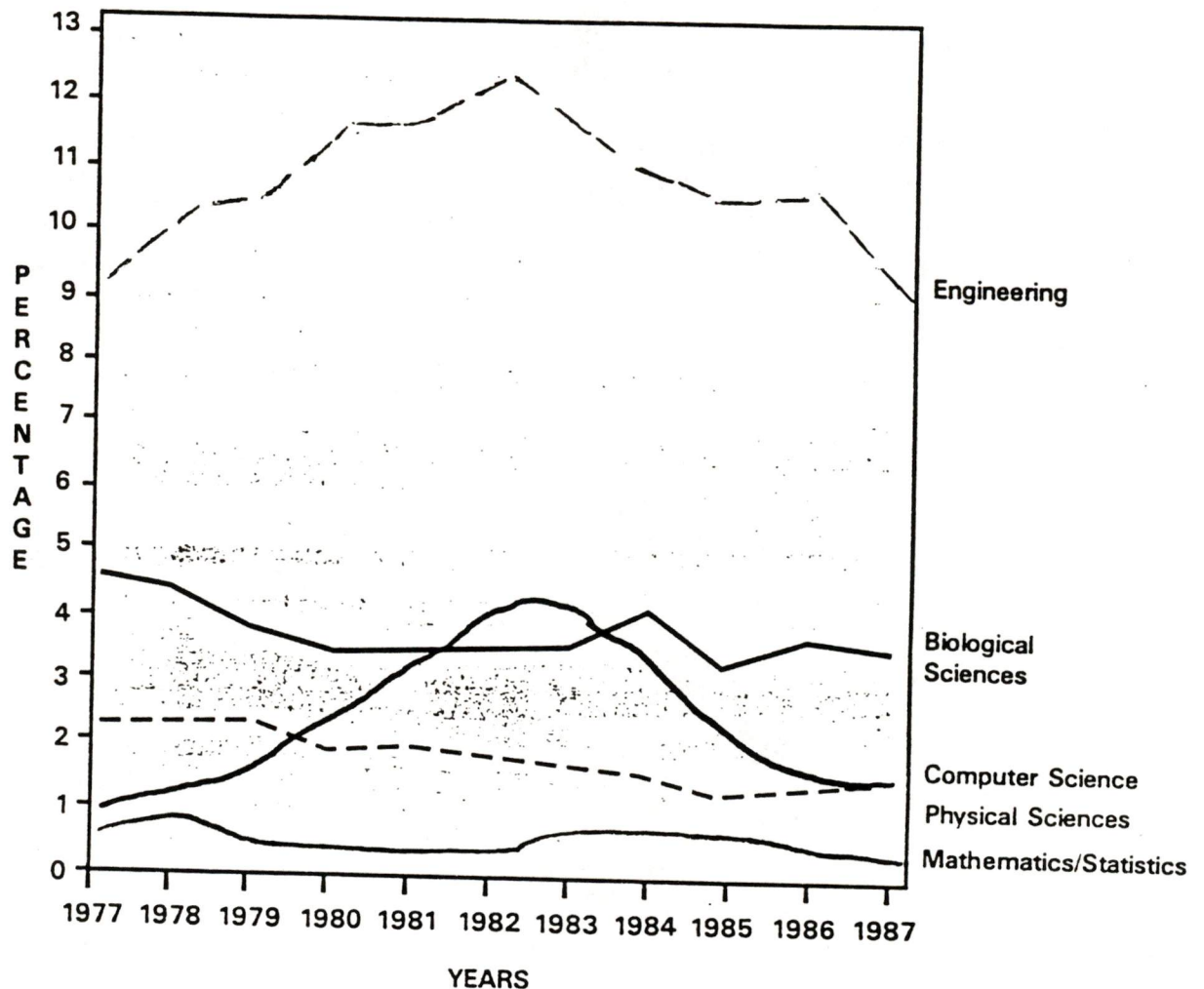
The National Science Foundation (NSF) and the Department of Education (DoED)

These national (as opposed to Federal) efforts are beginning to receive support from the major Federal agencies with responsibilities for mathematics and science education -- namely, the National Science Foundation (NSF) and the Department of Education (DoED). Both agencies have supported national efforts within their existing programs: NSF mainly through the Directorate of Science, Engineering, and Education; DoED through the Dwight David Eisenhower Mathematics and Science Program. The former program has in FY 1990 discretionary funds of \$ 204 million; the latter has FY 1990 funds of \$136 million, mostly formula-driven. The President's proposed budget for FY 1991 shows increases of 23 percent for the NSF program and 70 percent for the DoED program.

Other Federal Agencies

Federal participation in mathematics, science, engineering, and technology education is not limited to NSF and DOED. The Departments of Energy and Defense support undergraduate and graduate education activities through their research grant programs, as do the National Institutes of Health and the National Aeronautical and Space Agency(NASA). Federal laboratories associated with these and other agencies also sponsor a variety of activities in science and mathematics education targeted at the precollege level.

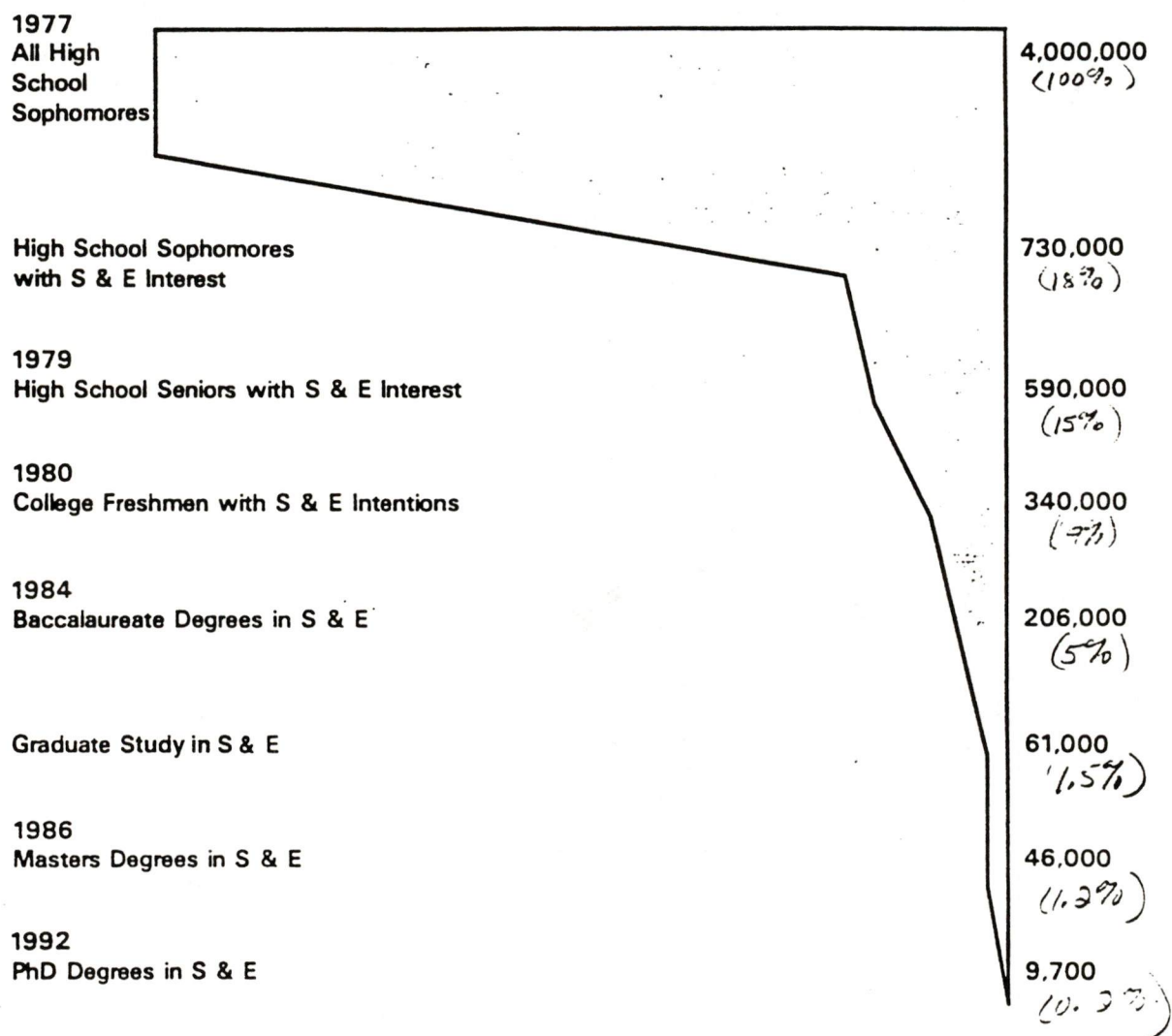
Student Interest in Science & Engineering, 1977-1987



Freshman interest in science majors has declined by one-third over the past two decades; the largest drop occurred in mathematics and the physical sciences. Interest in engineering is down by one-quarter since 1982, and interest in computing careers has fallen by more than two-thirds in four years.

Source: U.C.L.A. Higher Education Research Institute.

Science & Engineering Pipeline, from High School through Ph.D. Degree



Analysis of the 4 million students in the 10th grade in 1977 shows the pattern of attrition as they move through the educational pipeline. Approximately 9,700 or 0.24 percent are expected to attain the Ph.D. in science and engineering.

Source: National Science Foundation.

**JOINT STATEMENT
OF THE
PRESIDENT AND THE GOVERNORS**

SEPTEMBER 28, 1989

THE PRESIDENT'S EDUCATION SUMMIT WITH GOVERNORS

UNIVERSITY OF VIRGINIA

September 27 - 28, 1989

Joint Statement

The President and the nation's Governors agree that a better educated citizenry is the key to the continued growth and prosperity of the United States. Education has historically been and should remain, a state responsibility and a local function, which works best when there is also strong parental involvement in the schools. And, as a Nation we must have an educated workforce, second to none, in order to succeed in an increasingly competitive world economy.

Education has always been important, but never this important because the stakes have changed: Our competitors for opportunity are also working to educate their people. As they continue to improve, they make the future a moving target. We believe that the time has come, for the first time in U.S. history, to establish clear, national performance goals, goals that will make us internationally competitive.

The President and the nation's Governors have agreed at this summit to:

- establish a process for setting national education goals;
- seek greater flexibility and enhanced accountability in the use of Federal resources to meet the goals, through both regulatory and legislative changes;
- undertake a major state-by-state effort to restructure our education system; and
- report annually on progress in achieving our goals.

This agreement represents the first step in a long-term commitment to reorient the education system and to marshal widespread support for the needed reforms.

NATIONAL EDUCATION GOALS

The first step in restructuring our education system is to build a broad-based consensus around a defined set of national education goals. The National Governors' Association Task Force on Education will work with the President's designees to

recommend goals to the President and the Nation's Governors. The process to develop the goals will involve teachers, parents, local school administrators, school board members, elected officials, business and labor communities, and the public at large. The overriding objective is to develop an ambitious, realistic, set of performance goals that reflect the views of those with a stake in the performance of our education system. To succeed we need a common understanding and a common mission. National goals will allow us to plan effectively, to set priorities, and to establish clear lines of accountability and authority. These goals will lead to the development of detailed strategies that will allow us to meet these objectives.

The process for establishing these goals should be completed and the goals announced in early 1990.

By performance we mean goals that will, if achieved, guarantee that we are internationally competitive, such as goals related to:

- the readiness of children to start school;
- the performance of students on international achievement tests, especially in math and science;
- the reduction of the dropout rate and improvement of academic performance, especially among at-risk students;
- the functional literacy of adult Americans;
- the level of training necessary to guarantee a competitive workforce;
- the supply of qualified teachers and up-to-date technology; and
- the establishment of safe, disciplined, and drug-free schools.

THE FEDERAL/STATE PARTNERSHIP

Flexibility and Accountability

The President and the Governors are committed to achieving the maximum return possible from our investment in the Nation's education system. We define maximum return as the following: significant and sustained educational improvement for all children. Nothing less will meet the Nation's needs for a strong, competitive workforce; nothing less will meet our children's needs for successful citizenship and economic opportunity.

Federal funds, which represent only a small part of total education spending, are directed particularly toward services for

young people most at risk. Federal laws and regulations control where and for whom states and localities spend this money. State and local laws and regulations control what is taught, and how, for all students.

At present, neither Federal nor State and local laws and regulations focus sufficiently on results, or on real educational improvement for all children. Federal and State executives need authority to waive statutory and regulatory provisions in return for greater accountability for results.

The President and the Governors have agreed:

- to examine Federal regulations under current law and to move in the direction of greater flexibility;
- to take parallel steps in each state with respect to State laws and administrative rules.
- to submit legislation to Congress early next year that would provide State and local recipients greater flexibility in the use of Federal funds, in return for firm commitments to improved levels of education and skill training.

The President and the Governors have agreed to establish a working group of Governors and the President's designees to begin work immediately to accomplish these tasks.

We know that other voices need to be heard in this discussion -- voices of educators, parents, and those whose primary interest is the protection of the disadvantaged, minorities, and the handicapped. We need to work with the Congress. The processes we will set up immediately following this conference will involve all parties.

The urgent need for flexibility in using Federal funds can best be illustrated by a few examples.

First, the Federal Vocational Education Act, which mandates specific set-asides that often result in individual awards that are too small to be meaningful and that prohibit the money from being spent to achieve its purpose. One state reported being required to divide \$300,000 in aid among far too many categories and set-asides.

Second, similarly, the Chapter 1 program requires that equipment purchased to provide remedial education services cannot be used for non-Chapter 1 institutions in areas such as adult education. Several States report that large numbers of computers purchased by Federal funds are idle at night, while adult education classes that need them either do without or use scarce tax dollars to buy other equipment.

Third, the requirements that children who benefit from Federal

funds for compensatory and special education be taught separately often undermines their achievement. Waivers that permit these students to return to regular classes and receive extra help have produced large increases in their test scores. This option should be available for all school districts.

These commitments are historic steps toward ensuring that young people with the greatest needs receive the best our schools and training programs can give them, and that all children reach their highest educational potential.

In a phrase, we want to swap red tape for results.

The Federal Government's Financial Role

State and local Governments provide more than 90 percent of education funding. They should continue to bear that lion's share of the load. The Federal financial role is limited and has even declined, but it is still important. That role is:

- to promote National education equity by helping our poor children get off to a good start in school, giving disadvantaged and handicapped children extra help to assist them in their school years, ensuring accessibility to a college education, and preparing the workforce for jobs;
- and second, to provide research and development for programs that work, good information on the real performance of students, schools, and states, and assistance in replicating successful state and local initiatives all across the United States;

We understand the limits imposed on new spending by the Federal deficit and the budget process. However, we urge that priority for any further funding increases be given to prepare young children to succeed in school. This is consistent with the President's recommendation for an increase in the number of children served by Head Start in this year's budget. If we are ever to develop a system that ensures that our children are healthy and succeed in school, the Federal Government will have to play a leading role.

Further, we urge that the Congress not impose new Federal mandates that are unrelated to children, but that require States to spend state tax money that could otherwise go to education.

COMMITMENT TO RESTRUCTURING

Virtually every State has substantially increased its investment in education, increased standards, and improved learning. Real gains have occurred. However, we still have a long way to go. We must make dramatic improvements in our education system. This cannot be done without a genuine, National, Bipartisan commitment to excellence and without a willingness to dramatically alter our

system of education.

The President and the Nation's Governors agree that significant steps must be taken to restructure education in all states. We share the view that simply more of the same will not achieve the results we need. We must find ways to deploy the resources we commit to education more effectively.

A similar process has been going on in American manufacturing industry over the last decade with astonishing results: An increase in productivity of nearly 4 percent a year.

There are many promising new ideas and strategies for restructuring education. These include greater choice for parents and students, greater authority and accountability for teachers and principals, alternative certification programs for teachers, and programs that systematically reward excellence and performance. Most successful restructuring efforts seem to have certain common characteristics.

- a system of accountability that focuses on results, rather than on compliance with rules and regulations;
- decentralization of authority and decision-making responsibility to the school site, so that educators are empowered to determine the means for achieving the goals and to be held accountable for accomplishing them;
- a rigorous program of instruction designed to ensure that every child can acquire the knowledge and skills required in an economy in which our citizens must be able to think for a living;
- an education system that develops first-rate teachers and creates a professional environment that provides real rewards for success with students, real consequences for failure, and the tools and flexibility required to get the job done; and
- active, sustained parental and business community involvement.

Restructuring efforts are now underway in many states. The Nation's Governors are committed to a major restructuring effort in every state. The Governors will give this task high priority and will report on their progress in one year.

ASSURING ACCOUNTABILITY

As elected chief executives, we expect to be held accountable for progress in meeting the new National goals and we expect to hold other accountable as well.

When goals are set and strategies for achieving them are adopted,

we must establish clear measures of performance and then issue annual Report Cards on the progress of students, schools, the states, and the Federal Government.

Over the last few days we have humbly walked in the footsteps of Thomas Jefferson. We have started down a promising path. We have entered into a compact -- a Jeffersonian compact to enlighten our children and the children of generations to come.

The time for rhetoric is past; the time for performance is now.

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**PCAST BACKGROUND PAPER
MATHEMATICS AND SCIENCE EDUCATION**

There is widespread agreement that mathematics and science education at the precollege level needs to be revitalized. At the same time, there is a growing awareness that our system of higher education, long the envy of our competitors abroad, faces challenges that threaten its preeminence.

The President has requested your advice on how the Federal government can assist in strengthening American mathematics and science education at all levels. A few issues that PCAST might choose to address in this context are indicated below. Recognizing that you have devoted considerable thought to the overall problem, we have kept our discussion brief and our listing incomplete. We have, however, included an appendix that provides more detailed information on the crisis in precollege education and on the Administration's response to date.

Graduate and Undergraduate Math and Science Education

By all accounts, the overall quality of math and science education at the graduate and undergraduate levels is excellent. Maintaining this excellence, and making it more uniform among our colleges and universities, will require a concerted effort in the face of the changes taking place in the environment in which these institutions are embedded.

o Institutions of higher education have a critical interest, and can play a number of important roles, in rectifying the failures of our precollege education system. Are there ways in which the Federal government can assist colleges and universities in this effort?

o The increasingly strong coupling between basic research, technical development, and product commercialization is changing the way many university scientists -- and universities -- conduct their activities. How will this affect math and science education? How should the Federal government, as the primary supporter of basic research at universities, respond?

o A major strength of our best research colleges and universities has been their ability to supplement classroom lectures with hands-on participation -- for both graduate and undergraduate students -- in research projects. In most cases, these research projects are funded by the Federal government. Should research projects be funded at other, geographically diverse, colleges and universities as a means of improving math, science and engineering education? If so, under what conditions?

o Many colleges and universities have deferred repair and renovation of existing, and construction of new, academic research

facilities to the point that the long-term financial viability of the institutions may be threatened. Should the Federal government play a role in addressing this problem? Should a portion of the indirect costs recovered from research grants be channeled specifically toward solving this problem?

o There is a trend, encouraged by the Federal government, toward increased international cost-sharing and collaboration in research projects in many areas of academic research. Are there consequences or higher education in mathematics, the sciences and engineering?

Precollege Education

American precollege education in mathematics and science is, on average, poor in quality and poorly suited to the demands of the late twentieth century. This appears to be particularly true for math, science, and technical preschool education. (Please see appendix for a more detailed statement of the extent of the crises and an indication of the government's response to date.) For example:

o Our economy has shifted dramatically toward a high technology and services-oriented base, but our schools have not changed to meet these new needs. How can the Federal government help ensure that our children are taught the specific skills they will need when they graduate? How can we stimulate programs to supplement the education of undertrained graduates?

o The increasing need for scientists, engineers and technicians in our economy can be met only if an increasing fraction of students from currently under represented groups -- women and minority group members -- opt for careers in these areas. How can we make these career choices more attractive to youth at the critical K-9th grade stage?

o The average achievement levels in math and science of our high school graduates fall well below those of students in many other nations. Some of our teachers and schools produce outstanding students, year in and year out. Should we be doing more to stimulate wider adoption of their techniques?

o The mathematics community has devoted considerable effort to national curriculum reform, and the AAAS is sponsoring a reform effort in the sciences. Should the Federal government sponsor, or encourage other groups to sponsor, efforts to develop curricula leading to technician careers in various areas?