Summary and Findings 1

Over the past several decades, scientists and policymakers have come to recognize that human activity can alter the global environment significantly. Concerns have focused particularly on global warrning, the anticipated result from emissions of greenhouse gases such as carbon dioxide, and on depletion of the stratospheric ozone layer, which is linked to anthropogenic emissions of chlorofluorocarbons (CFCS) and other chlorine-containing, molecular species. As part of an international effort to evaluate such risks, the U.S. Government established a comprehensive interagency research effort in January 1989 to ''monitor, understand, and ultimately predict," the nature of global changes and the mechanisms that cause them.[1] This effort, designated as the U.S. Global Change Research Program (USGCRP), consists of both pre-existing and new programs. Since its inception, cumulative government expenditures for US GCRP-related programs have totaled some $3.7 billion.

The largest single element of USGCRP research is the National Aeronautics and Space Administration's (NASA'S) Mission to Planet Earth (MTPE), a program that uses space and ground-based instruments to study and understand global

[1] Committee on Earth Sciences (CES), *Our Changing Planet: The FY 2990 Research Plan* (Washington DC: Committee on Earth Sciences, Executive Office of the President, 1989). The CES and its successor, the Committee on Earth and Environmental Sciences (CEES), were formed by the President's Office of Science and Technology Policy.

change. NASA's Earth Observing System (EOS),[2] which consists of a series of polar-orbiting and low-inclination satellites for global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans, is the central component of the MTPE (see ch. 3).

OTA's examination of the direction and scope of U.S. global change programs was prompted by issues that include:[3]

- public expressions of concern by several knowledgeable scientists that the science objectives of USGCRP might not be met,
- sharp reductions in NASA's long term funding plans for EOS and the curtailment of other complementary components and initiatives within the USGCRP, and
- concerns that the U.S. Global Change Research Program is focused too narrowly on scientific understanding of climate change.

Years of effort and billions of dollars could be misdirected if global change research programs do not focus on the right scientific and policy questions, or if planned research programs, instruments, and instrument platforms are inappropriate to address these questions.

As part of its assessment, OTA organized a 2-day workshop that examined how well USGCRP and its EOS component were fulfilling their scientific objectives, whether some program elements were missing or needed to be strengthened, and whether the programs were meeting the needs of policymakers. Workshop participants were asked to evaluate global change research programs with the spectific objective of improving the organization and execution of the USGCRP—they were not asked to debate the relative merits of funding global change research versus competing priorities.

Workshop discussions focused primarily on:

- areas of imbalance in each of the programs,
- how USGCRP-sponsored scientific research programs might better serve the needs of policymakers, and
- the organization and funding of both programs.

The workshop, held at OTA on February 25-26, 1993, assembled a small group of leading global-change researchers and current and former officials of the USGCRP and EOS programs. This background paper draws on the discussions of that workshop and on two previous OTA reports.[4] In preparing the background paper, OTA also gathered information from articles, reports, and private discussions with individuals representing a wide variety of scientific and policy viewpoints. This paper notes, where possible, areas of substantial agreement among workshop participants; however, the conclusions reached in this paper should be attributed to OTA unless stated otherwise.

In structuring the USGCRP, officials made difficult compromises to match existing and planned agency programs to authorized and appropriated funding. Workshop participants were not asked to pass judgment on the wisdom of specific programmatic decisions, for example, individual instrument selections for EOS satellites. Instead, starting with the premise that a

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[2] U.S. Congress, Office of Technology Assessment, *The Future of Remote Sensing from Space: Civilian Satellite Systems and Applications,* OTA-ISC-558 (Washington, DC: U.S. Government Printing Office, July 1993), ch. 5 and apps. A and B. For a chronology of program restructuring, and a complete description of EOS technology see Ghassem Asrar and David Jon Dokken, editors, *EOS Reference Handbook* (Washington DC: Earth Science Support OffIce-National Aeronautics and Space Administration, March 1993),

[3] Impetus for this background paper also came from two related OTA assessments: 'Civilian Earth Observation Systems, ' an assessment undertaken by OTA's International Security and Commerce Program, and 'Preparing for an Uncertain Climate,' an assessment within OTA's Oceans and Environment Program.

[4] U.S. Congress, Office of Technology Assessment *The Future of Remote Sensing from Space,* op. cit. footnote 2; U.S. Congress, Office of Technologyg Assessment, *Preparing for an Uncertain Climate, OTA-O-563* (Washington, DC: U.S. Government Printing Office, November 1993).

strengthened global change research program was desirable, OTA sought a broad look at the USGCRP to determine whether it would be possible to improve existing programs. Appendix A of this background paper presents OTA's workshop premise and questions to participants.

EOS AND THE USGCRP: THE CURRENT PROGRAM

1. The research now funded through the USGCRP will help answer some of the most important questions of global change. Nevertheless, the USGCRP and its largest component, the Earth Observing System, could be strengthened substantially by redirecting existing funding and by adding some relatively modest funding for several critical areas. Suggestions for improvement include:

   l.a Increasing funding for focused, process-oriented [5] research to facilitate the detailed measurements essential to answering some of the key questions that underlie the USGCRP'S research agenda (box l-A). Instruments flown on aircraft and balloons, and instruments placed at strategically located sites on land, and on and beneath the oceans, facilitate unique andcomplementary measurements to those planned for satellites. They are also better able to meet particular measurement needs on a shorter term basis than satellite systems.[6]

   I.b Funding some comparatively inexpensive correlative (ground-truth) measurements via airborne or ground-based remote sensing methods to support satellite systems and to monitor changes over time. According to OTA workshop participants, these critical measurements have lacked funding and professional attention. Workshop participants agreed that such measurements would greatly enhance the scientific value of measurements by the planned EOS system of satellites. Costs for such efforts could range up to a few tens of millions of dollars each year.[7]

   1.c *Increasing funding for the development and procurement of Unpiloted Air Vehicles (UAVS) and lightweight instruments specifically designed to gather data in currently inaccessible regions of the atmosphere (see* ch. 3).

   l.d Making greater use of smaller satellites. In rescoping EOS to accommodate a substantially reduced funding program, program officials deleted instruments necessary to maintain continuity in the measurement of several important climatological variables. Small satellites could help fill these gaps while also providing relatively low-cost test beds for advanced technology.[8]

   l.e Adding a component speciafically tailored to long-term monitoring of key indices of global change. The Earth undergoes major processes of change that are reckoned in

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5 Process studies will typically be designed to elucidate the details of a particular mechanism of some geophysical, chemical, or biological interaction for example, ozone depletion. They should be contrasted with the regular collection of data on climatological and other variables, which is frequently referred to as monitoring.

6 They are also needed for longer term measurements. This can be seen, for example, in the ongoing aircraft measurements that seek to understand the phenomena responsible for ozone depletion through high resolution in-situ measurements.

7 Programs to verify and calibrate Earth observation satellites (and to provide coverage when satellites are not operating) have been funded at lower levels than originally planned. One workshop participant attributes this to the tendency to treat correlative measurements as merely a secondary adjunct to the satellite measurements. In fact, correlative measurements: 1) are essential to the credibility of satellite measurements; 2) have proved unexpectedly difficult to perform; 3) are serious research endeavors in themselves.

8 However, small satelites have significant weight and volume constraints that limit applications. For example, using near-term technology, small satellites would be unable to acquire high spatial resolution data over wide swaths. For further discussion of small satellites and advanced technology sensors see *The Future of Remote Sensing from Space*, op. cit., footnote 2, pp. 16-17; 128-135.

Box I-A–Understanding the Mechanisms of Global Change

U.S. Global Change Research Program (USGCRP) officials believe their programs will address the most pressing scientific questions related to global change. However, participants at the OTA workshop reflected divisions within the scientific community when they considered the question of whether USGCRP and its largest component, EOS, had an appropriate strategy to expose the mechanisms that govern global change phenomena. Much of this dispute centers on the balance in USGCRP between satellite-based measurements and ground-and airborne-based measurements.

The overarching questions related to global change are obvious. In climate, for example, they include whether the average global climate is changing; if it is, what are its causes; and what would be the effect of exercising different policy options. However, to address these questions requires answers to a series of much more detailed questions, many of which cannot be answered using only satellite-based instrumentation. For example, water vapor and clouds are the dominant regulators of the radiative heating of the planet. However, continuous in-situ observations from the surface to some 25 km altitude are required to answer the following questions:

1. How do clouds and water vapor affect the amount and distribution of solar energy that is available to the planet;
2. How **do clouds and water vapor regulate the amount of thermal** energy that leaves the planet; and
3. How might this balance might be affected in response to *climate changes,* for example, a future atmosphere that contains larger concentrations of greenhouse gases.

Understanding the mechanisms responsible for the onset of ozone depletion also requires in-situ and ground-based studies. Average ozone concentrations over wide areas can be monitored by satellite, but an understanding of the interacting processes governing the formation of the Antarctic ozone 'hole' has been possible only by analyzing in-situ data gathered by high-altitude aircraft and balloons. In fact, scientists were surprised to learn that extremely high resolution simultaneous measurements of several species of gases were required to understand the chemical and physical mechanisms responsible fort deformation of the Antarctic ozone hole. This knowledge has direct bearing on a question of keen interest to U.S. decision makers-where and how fast ozone loss might occur over northern latitudes.

scales of decades to millennia.[9] Decades of continuous calibrated global observations from space and at strategically located sites on the Earth's land and oceans will be required to document climate and ecosystem changes and for differentiating natural variability from human-induced changes.

Determining an appropriate architecture for the space-based segment of a long-term monitoring system has proved especially controversial. As planned, EOS will last only 15 years; however, program officials expect some research instruments may eventually be transferred to the National Oceanic and Atmospheric Adstration (NOAA) for routine data collection (the NOAA "operational" satellite program) over a longer term. NOAA would require augmentation of its budget to incorporate the costs of better instrument calibration and other features necessary to make them suitable to document global change. Some participants expressed doubt that future administrations or Congresses would provide the necessary additional funding; they advocated the design and launch of small

[9] *Our Changing Planet:* op. cit., footnote 1.

A balanced program to study and monitor global change would include long-term local, regional, and global observations, process studies, theoretical modeling, and assessments. iVWrkshop participants agreed that a carefully balanced program of in-situ and satellite observations is necessary to address the fundamental scientific issues that underlie the USGCRP research agenda.

Much of the controversy over whether USGCRP is "scientifically sound" is centered on the plans for the Earth Observation System program. Embedded in this dispute is the issue of whether large and comparatively expensive polar-orbiting satellites are suitable both for studying Earth processes and for long-term monitoring of climatologicai and other variables related to global change. Some participants believe that the high cost and scientific imitations of the present EOS program argue for comprehensive reviews followed by program restructurings. Others believe the program has already undergone sufficient review. Related to this is the argument that the best is the enemy of the good, and timely execution of research plans will yield greater scientific return than that which might follow a further restructuring.

EOS officials reject the criticism that planned sateillte-based instruments have not been designed to answer specific key questions. Furthermore, they argue that the program cannot tolerate substantive restructurin~t least in the near term. However, as noted in the text, a successful long-term program will be possible only if mechanisms are in place to facilitate mid-course corrections in project planning to account for shifting scientific priorities, changes in technology, and scientific surprises. Workshop proposals to strengthen global change programs included redirecting some funds for "ground-truth" and correlative measurements and for augmenting such potentially cost-effective programs as unpiloted air vehicles (see ch. 3).

SOURCE: Office of Technology Assessment, 1993.

satellites specifcally tailored for environmental monitoring.[10] Chapter 3 summaries one such proposal for a small satellite to measure global climate radiative ''forcings and feedbacks. ' [11]

Other elements in the debate over whether EOS should be restructured include:

- concerns that the funding for satellites planned to overlap and succeed the frost series of EOS polar orbiters will not materialze;
- questions about whether NASA is the appropriate agency to undertake long-term monitoring of global change; and
- interest in possible ' 'convergence' of satellite systems designed to meet the needs of the USGCRP, NOAA, and the Department of Defense. [12]

Workshop participants differed on whether or not funds for augmenting the USGCRP (and its EOS component) should come from redirecting already tight budgets. In particular, this dispute separated those participants who believed NASA could achieve its scientific objectives for EOS with the planned system and those who believed the program would benefit from an independent, comprehensive review, followed by restructuring.

10 Small satellites are already part of the NASA'S Mission to Planet Earth. As part of its Earth Probes program NASA is funding small satellites that are precursors or adjuncts to the EOS missions. These include the Total Ozone Mapping Spectrometer (TOMS), the Sea-viewing, Wide-Field-of-View Sensor (Sea-WiFS), which will be launched on Orbital Science Corp. 's SeaStar satellite, and the Tropical Rainfall Measuring Mission (TRMM).

11 Radiative forcings are changes imposed on the planetary energy balance; radiative feedbacks are changes induced by climate change (see box 3-D).

12 See app. B and app. *C* of *The Future of Remote Sensing from Space*, op. cit., footnote 2.

Both sides in this debate agreed that substantive restructuring of EOS could not be accomplished without, in effect, designing a new global change research program. EOS has already been pared to a system ''with a minimum set of instruments to pursue the focused objective of global climate change, "[13] According to NASA, ''undoubtedly, further budget cuts would require wholesale elimination of instruments, thus information critical to understanding global climate change [would be lost]. [14] Attempting to design a restructured global change research program—either to refocus the program scientifically, or to accommodate possible future funding shortfalls—was beyond the scope of the OTA workshop.

USGCRP: FUTURE DIRECTIONS

2. As currently structured, USGCRP will not be able to provide decisionmakers and natural resource managers with the information they will need to respond to global change. The USGCRP is overwhelmingly a physical sciences program aimed at observing, understanding, and predicting climate change. However, global change encompasses possible alterations in the Earth's environment other than climate. If the USGCRP is to become a comprehensive program to study the causes and potential responses of global change, it would benefit from the following suggested improvements:

   2.a *Broadening the scientific scope of USGCRP to include aspects of global environmental change other than climate change.* Several workshop participants believe that determining the extent, causes, and regional consequences of global climate change, the highest priorities in USGCRP, are not the most pressing issues in global change research. Issues cited as more pressing include the consequences of loss of ecosystems and biodiversity, increases in population, and changes in land-use. [15] A broadened program would include research on ozone depletion, changes in biodiversity and forest distributions, desertification, and changes in ocean and coastal ecosystems.

   2.b *Strengthening research efforts on the impacts of climate change on society and the natural world.* This would include research on adaptation to, and mitigation of, climate change. In particular, USGCRP should strengthen research on potential changes in ecosystems, such as species composition, and the effects of climate change on agriculture, energy use, and other economic activities. Research on important ecological changes have been either ignored by USGCRP or addressed only to the extent that they interact with the climate system.

   2.C *Defining and giving greater emphasis to the newly established assessment element in USGCRP.* Maintaining the policy relevance of scientific research to the decisionmaking process over the long term requires effective methods to integrate and communicate research results from diverse disciplines (box l-B). USGCRP integrated assessments can be used to identify key societal concerns related to global change, integrate research results from multiple disciplines, analyze potential responses,

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[13] *EOS Reference Handbook,* Op. Cit., footnote 2, p. 12.

[14] Ibid.

[15] Biodiversity was cited as a critical issue because, according to one participant, "we are in the middle of an extinction that is unsurpassed in the geological record that is clearly due to human influence. ' Population changes and land-use changes are of critical importance to densely settled developing nations.

and assist in the definition and periodic review of scientific research programs.[16]

Scientific research should inform the policy process by bringing to the attention of policymakers the research results that could affect political decision making. Past research efforts, such as the National Acid Precipitation Assessment Program (NAPAP), have suffered because policymakers have not always understood the limitations of scientific research and scientists have not always understood the needs and time-scales for decisions of the policy making community (app. B). The OTA workshop concluded that programs within the USGCRP would benefit if 1) policymakers had a better understanding of what they were buying with government research dollars; and 2) policymakers had better mechanisms for measuring program progress .17

USGCRP: STRENGTHENING THE PROGRAM

Fulfilling the USGCRP'S objectives will require long-term institutional and financial commitments, a greater commitment by non-NASA participating government agencies, and improved mechanisms for program review and coordination. A global environmental monitoring program will, by necessity, also require a broad-based international effort.

3. A successful global change research program—like any long-term research effort—must allow for redirection, substitution, or termination of program elements in light of new discoveries, advances in technology, and changing needs of policy makers.

Workshop participants had several suggestions for facilitating redirection and for improving the management of global change research. These included undertaking periodic, comprehensive reviews of the scientificc foundations of USGCRP and EOS programs under the auspices of an independent scientific body such as the National Academy of Sciences (NAS). These reviews should:

- be completed in 6 to 9 months (faster than the typical NAS study),[18]
- strive to include independent representatives from the science community and other relevant experts,
- not be so frequent as to delay progress, and
- be chartered to recommend both the elimination of ineffective programs and the creation of new programs.

Workshop participants were adamant that the review process should be sheltered from political pressures to redirect programs according to the ''crisis of the day. '

4. The U.S. Global Change Research Program has suffered from fragmentation of research efforts.

The USGCRP could benefit from closer connections with its Research Program on the Economics of Global Change. This program seeks to evaluate the likely magnitude of societal costs and benefits of global change, and evaluates options designed to limit adverse economic and social consequences. Similarly, the USGCRP

16 However, several workshop participants strongly cautioned against too much emphasis on ''top-down'' management of basic scientific research. As one participant explained, ''Basic science research can be guided by the assessment component only in part. The acceptance of the unpredictability of important parts of scientific progress is fundamental to optimal progress.'

17 on, of the more recent attempts to bridge the gap between science research and the policy process in USGCRP was to introduce scientific "milestones' or goals that can be easily identified by policymakers to help keep track of progress and program direction, However, this approach has had only limited success. According to one workshop participant, "the [scientific] community hasn't really bought off on those milestones . . . unless the community . . . feel[s] a sense of ownership of that list, it is not only worthless, it is counter productive. "

18 Unless it is part of an ongoing effort, a typical NAS study generally requires some 18 months.

Box l-B-Science, Public Policy, and Integrated Assessments

A central objective of the U.S. Global Change Research Program (USGCRP) is to gain a predictive understanding of global change phenomena A key assumption is that policymakers will be able to use this knowledge to mitigate global change and /or craft suitable adaptive responses.However, scientific understanding of global change will not be sufficient for policy purposes if it isn't also coupled with a mechanism to communicate results in an understandable manner. Even then, policy prescriptions will differ because of differences in veiwpoint that enter as part of the political process.1

Policymakers and scientists have different educational and professional backgrounds. Integrated assessments of global change area mechanism for synthesizing all of the scientific, economic, and social aspects of a particular issue and presenting findings in "policy-relevant" language. Although assessments were not included in the original USGCRP program, they are included in a rudimentary form in the fiscal year (FY) 1994 budget. The primary function of the Assessment working group is to:

> .,. document the state of scientific knowledge and address the implications of the science of global change for national and international poilcy-making activities **over a broad spectrum of globai and reginal environmental issues.z**

The group will also help coordinate the scientific assessments of global change with related assessments on environmental impacts, technologies for adaptation and mitigation, risk assessment and policy-response strategies.[3]

Although the FY 1994 budget proposal reflects these changes, it is unclear how much money agencies will allocate for assessment and how the assessments will be structured. The Fy 1994 budget does not show Assessment separately but, instead, embeds it within the other three USGCRPactivity streams-docu mentation, process research, and integrated modeling and prediction (see ch. 2). Comprehensive assessments cannot be carried out withhout expanding the ecological and socio-economic aspects of the program and incorporating impacts research. The FY 1994 budget does not reflect any significant expansion in these areas.

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1 Ronald D. Brunner and William Ascher, "Science and Social Responsibility," Social Sciences, vol. 25, No. 4, 1992, pp. 295-331. This view is recognized by the National Academy of Sciences, which has noted, "NO matter how good the science, environmental problems cannot be solved without integrating the science withenvironmental policy." National Research Council, Research to Protect, Restore, and Manage the Environment (Washington, DC: National Academy Press, 1993).

2 Committee on Earth and Environmental Sciences (CEES), Our Changing Planet: The FY 1994 U.S. Global Change Research Program (Washington, DC: CEES, 1993),

3 Corell, R.W., Committee on Earth and Environmental Sciences, Subcommittee on Global Change Research, and Geosciences, National Science Foundation, testimony before the House Subcommittee on Space, Committee on Science, Space, and Technology, Mar, 30, 1993,

could benefit from closer coordination with ongoing Federal efforts to develop "environmental technologies' appropriate to global change mitigation and adaptation strategies. Currently, such research is not a formal element of the USGCRP (figure l-l), nor is ecosystem-wide research on natural resources and impacts of climate change.[19] With these elements fully incorporated, USGCRP would be better able to address the full spectrum of issues associated with global change.

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19 See U.S. Congress, Office of Technology Assessment, *Preparing for an Uncertain Climate*, Op. Cit., footnote 4, for a discussion Of these issues.

Nonetheless, the Clinton administration has expressed interest in significantly broadening the USGCRP to include studies of environmental and socio-economic impacts and of mitigation and adaptation strategies.[4] If t his research materializes, it could be integrated with research on Earth systems processes to conduct integrated assessments. The expanded program is expected to be reflected in the IV 1995 USGCRP budget.

Integrated assessments could help determine the importance of the problems presented by global change relative toot her policy problems, outline alternative policies to respond to global change, and explain the benef its and drawbacks of various responses and implementation strategies. Just as important, integrated assessments may help guide research by identifying key assumptions, uncertainties, gaps, and areas of agreement. However, integrated assessments have important limits. In particular, their predictive power is limited because they must implicitly or explicitly include assumptions about the political setting, which can be upset by dramatic and unpredictable changes in the structure of economic or political systems.

The accuracy of models of future energy consumption that were generated in the late 1970s provides an instructive lesson. The predictions of these models about per capita energy consumption, and the policy recommendations that followed from them, were dramatically undercut by the 1979 Arab oil embargo, which encouraged consumers to cut their oil consumption.[5] In addition, because energy models were necessarily comprehensive on national or global scales, they obscured regional differences that were critical to political debates in Congress.

The global change research community faces the challenge of devising assessments that minimize disruption of ongoing programs while still allowing for redirection of program elements in light of new discoveries, advances in technology, and changing long-term needs of policy makers.

[4] J.H. Gibbons, Assistant to the President for Science and Technology, memorandum to Frederick M. Bernthal, Acting Director, National Science Foundation, July 8, 1993.

[5] See Brunner and Ascher, Op. cit.

SOURCE: Office of Technology Assessment, 1993.

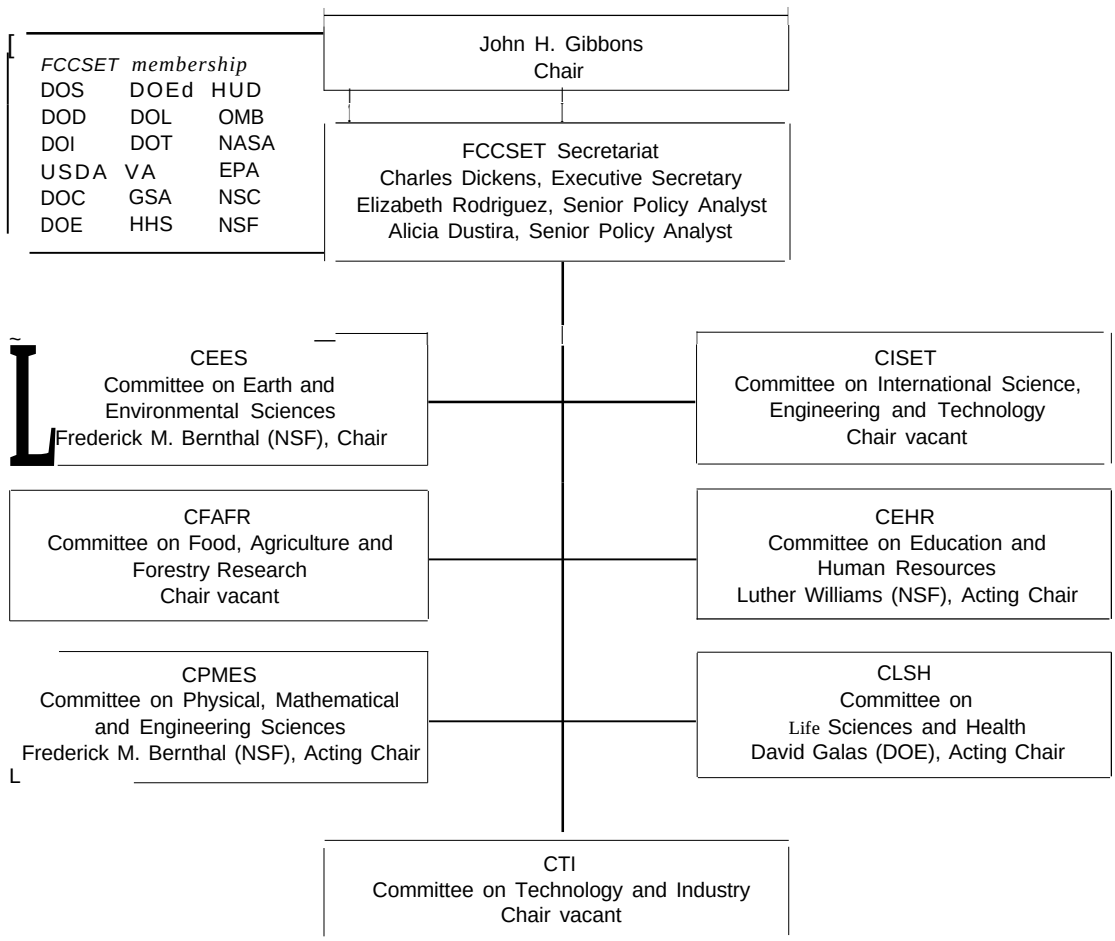
5. The current authorization and appropriations process guarantees that L'SGCRP, a multidiscipline, multiagency program to understand the Earth as a system, will be examined by Congress largely in disaggregate pieces. This affects the effectiveness of congressional oversight of the Program. It also results in agency shares of USGCRP remaining approximately fixed from year to year.

Jurisdictional barriers between authorizing committees and multiple appropriations from separate subcommittees limit Congress' ability to view the USGCRP as a whole. According to workshop participants, this capability is one of the strengths of the executive branch's FCCSET (Federal Coordinating Council for Science, Education, and Technology) process.

The congressional budget process typically only allows small percentage changes in agency budgets from year to year. As a result, funds for new global change research may be easier to obtain through a small percentage increase in NASA's USGCRP budget ($921 million in fiscal year (FY) 1993) than, for example, NOAA's USGCRP budget ($67 million in FY 1993) or DO1'S USGCRP budget ($37.7 million in FY 1993). The unintended effect of this budget process is that NASA plays a de facto leading role in both space and surface-based global change research programs,

6. Restoring the authority of the Committee on Earth and Environmental Science (CEES) of the FCCSET to fence off agency budgets might improve the balance of resource allocations among agencies and between

Figure I-IA—Organizational Chart for the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET)



NOTE: for definition of terms, see figure I-B, next page.

(Continueo)

satellite and non-satellite program elements (box 1-C and ch. 3).[20]

During the first years of the program, USGCRP required agencies to ''fence off,' or commit their global change research budget requests to the Program. Agencies could not later reprogram this money if overall funding was less than expected.

Several participants at the OTA workshop recommended the reinstatement of such a system.

7. NASA has been able to attract large amounts of funding for its Earth Observing System; however, potentially cost effective, but less glamorous programs outside NASA have languished.

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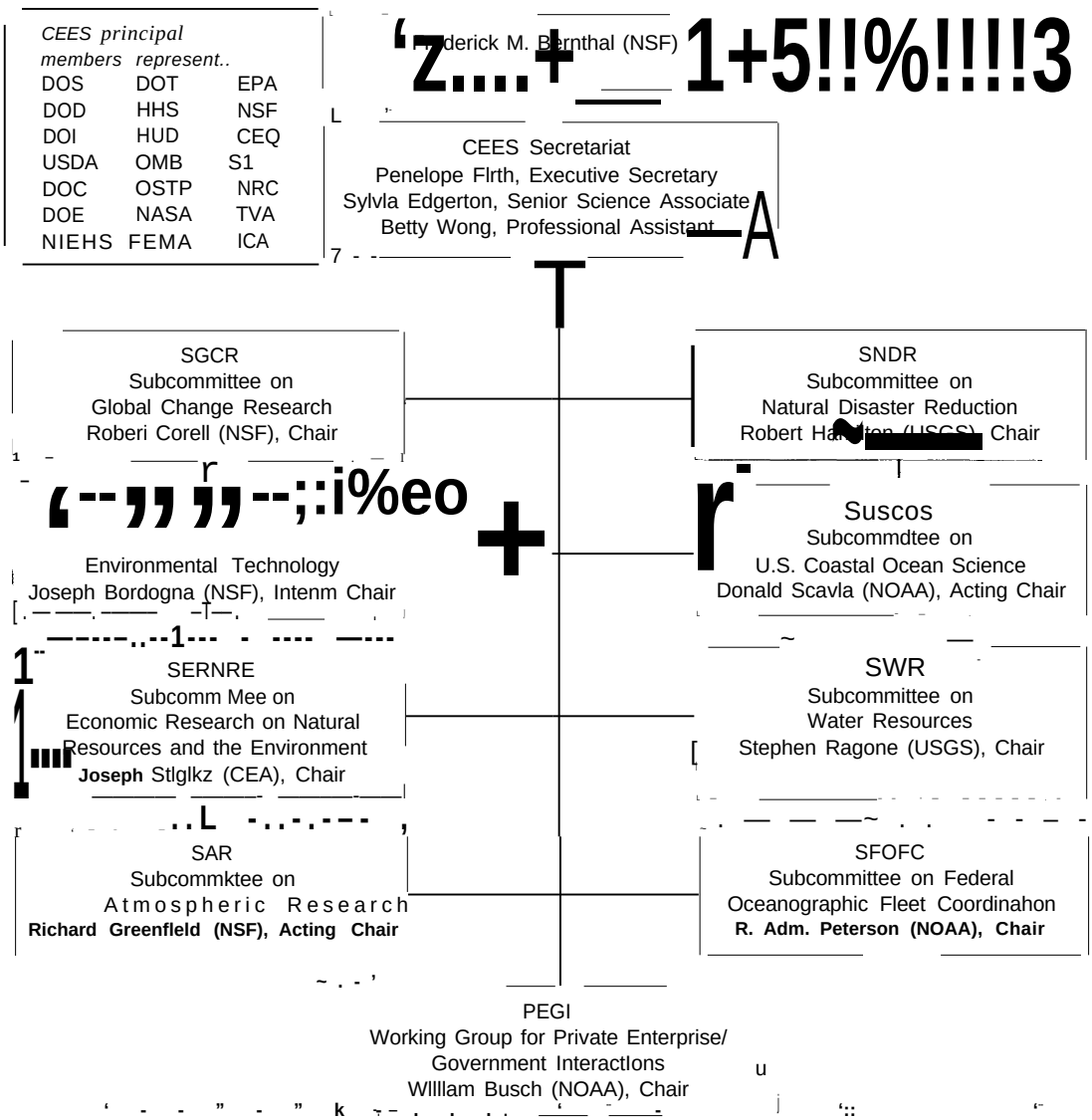
20 In September 1993, President Clinton announced the formation of a new science policy coordinating body, *the* "National Science and Technology Council. " It is unclear what effect of the Council on the FCCSET process for funding USGCRP will be.

Figure I-l B—Organizational Chart for the Committee on Earth and Environmental Sciences (CEES)



NOTE: DOS= Department of State; DOD= Department of Defense; DOI=Department of the Interior; USDA=U.S. Department of Agriculture; DoC=Department of Commerce; DOE_ Department of Energy; DOEd=Department of Education; DOL_Department of Labor; DOT_ Department of Transportation; VA= Department of Veterans Affairs; GSA_ General Services Administration; HHS=Department of Health and Human Services; HUD= Department of Housing and Urban Development; OMB=Office of Management and Budget; NASA= National Aeronautics and Space Administration; EPA-Environmental Protection Agency; NSC=National Security Council; NSF-National science Foundation; NIEHS=National Institute of Environmental and Health Sciences; OSTP=Office of Science Technology Policy; FEMA=Federal Emergency Management Agency; CEO-Council on Environmental Quality; SI=Smithsonian Institution; NRC-National Research Council; TVA_ Tennessee Valley Authority; ICA=Intelligence Community Affairs; CEA=Council of Economic Advisors; USGS=U.S. Geological Survey; NOAA-National Oceanic and Atmospheric Administration.

SOURCE: Committee on Earth and Environmental Sciences (CEES), *Our Changing Planet: The FY 1994* U.S. *Global* Change Research *Program* (Washington, DC: CEES, 1993).

Box 1-C-FCCSET and USGCRP Budgets

The U.S. Global Change Research Program (USGCRP) is designed to integrate the research programs from 11 agencies through the Federal Coordinating Council for Science, Education,andTechnology (FCCSH) Committee on Earth and Environmental Saences (CEES). As a result the development of its budget within the Executive Branch follows a somewhat unusual process. USGCRP'S budget, like that of individual agencies, is negotiated through the Office of Management and Budget (OMB).The process begins with OMB supplying terms of reference that guide agency submissions. Each agency participating in USGCRP then submits detailed proposals to the CEES for what they believe to be their best contribution to the USGCRP. The Committee, with guidance from OMBand OSTP, evaluates these proposals, makes recommendations on program allocations, and returns the budget for agency comment. The CEES then prepares a recommendation to the OMB. After negotiations with participating agencies, this recommendation is integrated into the Agency Budget submission to the OMB.

Internal budget negotiations culminate with the presentation of a single budget for global change research that spells out individual agency responsibilities in detail. By evaluating agency proposals as part of an integrated program, CEES and OMB attempt to avoid duplication of effort and make optimal use of agency expertise.

An agreement that had been in effect between OMB and agencies during the first 3 years of the USGCRP required agencies to fence off monies for global change research in return for an OMB commitment to an overall funding envelope over 5 years. In effect, agency heads agreed to their global change research budgets once t he process of negotiation with OMB and CEES was complete. Thus, an agency could not reprogram global change funds if it later suffered an unexpected cut in its overall budget.

The prohibition on reprogramming global change funds ended in FY 1993. However, several workshop participants believe that agency freedom to reprogram budgets is detrimental to program financial stability. They also believe it exacerbates the problem of insufficient contributions by agencies other than NASA, which has led to a comparative lack of funding for non space-based program elements.

In September 1993, President Clinton approved the formation of the National Science and Techhnology Council. The President expects the Council to oversee the administration's research and development budget, coordinate science policy, and ensure that the administration's research and development priorities are reflected in agency budgets. According to the President's science adviser, John Gibbons, the Council will have "great powers of persuasion" as individual agencies develop their research and development budgets each year and it will operate "in parallel" with preliminary discussions between each agency and OMB.1 The effect of the Council on the FCCSET process for funding USGCRP was unclear at the time this report went to press.

1 Gimns quoted in Jeffrey Mwvis, "Clinton Moves **to Manage Science," Science, vol. 261, No. 5129, *pt. 24, 1993, pp. 1666-1669.**

SOURCE: office of Technology Asses.smenL 1993.

To date, funding for non space-based components of USGCRP has been difficult to secure, in part because it requires support from agencies other than NASA.[21] For example, workshop participants believe that instruments based on ground, ocean, or airborne platforms, sponsored by agencies such as NSF, NOAA, and DOE, could provide more cost-effective return on new

21 For example, participants noted thatthe success of U.S. participation in international programs such as the World Ocean Circulation Experiment (W(XE), the Tropical Oceans Global Atmosphere (TOGA), and the Joint Global Ocean Flux Study (JGOFS) depended on contributions from NASA, NOAA, and the National Science Foundation (NSF). However, in a recent budget cycle, NASA received more than it asked for these programs white NOAA and NSF received no money. (To maintain these programs, NASA was forced to fill the financial gap left by inadequate funding from NOAA and NSF.)

global change finds than instrument alternatives placed in orbit as part of NASA's Earth Observing System. Others, while agreeing that non space-based elements in USGCRP should be augmented, noted that satellite-based instruments facilitate global, synoptic, and repeatable measurements of many Earth systems.

8. Gathering sufficient data to resolve global change issues requires financial and institutional commitments that transcend political and budgetary cycles.

Global change programs must be sustained for decades to study ecological system processes, to monitor the planetary energy balance and understand climate forcing and feedbacks, to monitor the storage and transport of heat within the ocean, and to monitor the movement of carbon between the oceans and atmosphere. The timescale for documenting global change vastly exceeds the periods that characterize budget and election cycles.

9. An effective global environmental monitoring network cannot be achieved without the cooperation of nations throughout the world.

A credible global environmental monitoring system would utilize satellite-based instruments, aircraft-based instruments, and literally thousands of surface-based instruments sited around the globe. It would also require countries to cooperate much more closely on global change research than they now do.

There are both scientific and practical reasons for developing such collaborations. Quantitative assessments of changes in the global environment will require systematic, continuous, long-term (decades to centuries), calibrated measurements of Earth systems. A commitment from all nations, especially those in developing regions of the world, is necessary to develop and sustain such an effort. Furthermore, international cooperation is necessary to fashion a monitoring system appropriate to different gee-political regions. Regional differences affect scientific methodology; for example, discovering appropriate indices of global change. They also have a profound influence in determing g which policies will be sustainable in the long term.