Implementing Climate and Global Change Research: A Review of the Final U.S. Climate Change Science Program Strategic Plan

Committee to Review the U.S. Climate Change Science Program Strategic Plan, National Research Council

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IMPLEMENTING CLIMATE AND GLOBAL CHANGE RESEARCH

A REVIEW OF THE FINAL U.S. CLIMATE CHANGE SCIENCE PROGRAM STRATEGIC PLAN

Committee to Review the U.S. Climate Change Science Program Strategic Plan
Division on Earth and Life Studies
Division of Behavioral and Social Sciences and Education
Division on Engineering and Physical Sciences

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Preface

In September 2002, Assistant Secretary of Commerce for Oceans and Atmosphere James R. Mahoney asked the National Academies to undertake a fast-track review of the U.S. Climate Change Science Program's (CCSP's) draft strategic plan for climate and global change studies and the final strategic plan after it had been revised. In response the 17-member Committee to Review the U.S. Climate Change Science Program Strategic Plan was formed (see Appendix C for committee biographies). The committee was given a two-phase statement of task (see Appendix B for full statement of task). The committee's first report, which reviewed the November 11, 2002, draft strategic plan, was issued in February 2003 and addressed Phase I of the committee's task. This report, which provides an overall assessment of the revised strategic plan and CCSP's strategic planning process, addresses Phase II of the committee's task (see Box P-1).

Chapter 1 of this report summarizes the committee's overall assessment of the revised strategic plan. Chapters 2 and 3 examine in more detail how those aspects of the draft plan that were identified in the committee's first report as particularly challenging have evolved in the revised plan. The scientific scope of the plan and decision support activities that need further development during implementation are addressed in Chapter 2. The major management challenges in implementing the plan are addressed in Chapter 3. The committee responds to the five questions in the Phase II statement of task (see Box P-1) and provides recommendations for future planning efforts in Chapter 4.

The committee held two meetings since the release of the revised strategic plan to gather information and prepare this report. The first meeting was held on August 25-27, 2003, in Washington, D.C. At this meeting Ghassem Asrar, associate administrator for Earth Science at the National Aeronautics and Space Administration, and Richard Moss, executive director of the U.S. Global Change Research Program, presented an overview of the changes to the strategic plan and how the CCSP addressed the committee's major recommendations. Lead authors of selected chapters of the plan also discussed the changes that were made to their chapters. We thank Ghassem Asrar and Richard Moss along with the following individuals who also participated in this meeting: David Allen, CCSP Office; Susan Avery, National Oceanic and Atmospheric Administration (NOAA) and CCSP Office; Louis Brown, National Science Foundation (NSF); Margarita Conkright, NOAA and CCSP Office; David Conover, Climate Change Technology Program; Jay Fein, NSF; Janet Gamble, U.S. Environmental Protection

BOX P-1 Statement of Task for Phase II

In the second phase, the committee will provide an overall assessment of the revised (final) plan, with an emphasis on how the plan has evolved in response to NRC and other community input. The committee also will address the following questions related to the processes used to solicit and consider input from the scientific and stakeholder communities throughout the strategic planning process:

- Were the mechanisms for input from the scientific and stakeholder communities throughout the program's strategic planning process adequate?
- Did the format of the workshop promote the open exchange of ideas and suggestions for improvement?
- Was the process used to make decisions on potential changes to the draft plan clearly communicated to workshop participants and others who submitted comments during the public comment period?
- Was this process consistent with generally accepted practices for considering community input during public comment periods?
- What specific improvements should be reflected in future planning efforts for the program?

The results of phase II will be provided in a report to be delivered to the program within 6 months after the revised (final) plan is published.

Agency (USEPA); Susan Herrod Julius, USEPA; Chester Koblinsky, NASA and CCSP Office; Kathryn Parker, USEPA; Toral Patel-Weynand, Department of State; Steve Shafer, U.S. Department of Agriculture; and Caitlin Simpson, NOAA. The committee held a second meeting in Irvine, California, in October 2003, during which the committee received an update from James Mahoney and Richard Moss on the status of plan implementation, and prepared this report. We extend our gratitude to James Mahoney and Richard Moss for their support, insights, and openness throughout the study process.

The committee and staff have worked diligently to make this report as useful as possible to the CCSP. We wish the CCSP leadership well as it takes on the challenging task of implementing this ambitious strategic plan. In the opinion of many of the committee members the issues addressed by the CCSP are among the most crucial of those facing humankind in the twenty-first century.

Thomas E. Graedel, Chair

Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Mark Abbott, Oregon State University, Corvallis
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Although the reviewers listed above have provided constructive comments and suggestions, they were not asked to endorse the report's conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Robert A. Frosch (Harvard University). Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

Executive Summary

The U.S. Climate Change Science Program (CCSP) was established in February 2002 to coordinate climate and global change research conducted in the United States. Drawing on information from the U.S. Global Change Research Program of the previous decade, as well as from other sources, the CCSP developed a 10-year strategic plan to guide its activities. The CCSP requested that the National Academies review both a discussion draft of this strategic plan, released in November 2002, and a revised version, released in July 2003 (see Appendix B for statement of task). The revised strategic plan is reviewed in this report.

The *Strategic Plan for the U.S. Climate Change Science Program* articulates a guiding vision, is appropriately ambitious, and is broad in scope. It encompasses activities related to areas of long-standing importance, together with new or enhanced cross-disciplinary efforts. It appropriately plans for close integration with the complementary Climate Change Technology Program. The CCSP has responded constructively to the National Academies review and other community input in revising the strategic plan. In fact, the approaches taken by the CCSP to receive and respond to comments from a large and broad group of scientists and stakeholders, including a two-stage independent review of the plan, set a high standard for government research programs. As a result, the revised strategic plan is much improved over its November 2002 draft, and now includes the elements of a strategic management framework that could permit it to effectively guide research on climate and associated global changes over the next decades. Advancing science on all fronts identified by the program will be of vital importance to the nation.

Recommendation: The CCSP should implement the activities described in the strategic plan with urgency.

The revised strategic plan identifies a much broader scope of activities than has historically been supported under the auspices of the Global Change Research Program. To succeed, such an expansion in scope will require a concomitant expansion in funding. A fully informed assessment of whether adequate funding is available for the proposed program was not possible because the CCSP did not provide the committee with prospective budget information and because many of the objectives in the plan are too vaguely worded to determine what will constitute success. However, the present CCSP budget does not appear to be capable of supporting all of the activities in the strategic plan. While well-established program elements have a track record of funding, the newer or expanded areas in the strategic plan lack clear budget lines and agency homes, and are therefore likely to be under supported. The major expansion in climate modeling and the observing system that the plan calls for will also require an increase in funding above current levels. There is no evidence in the plan or elsewhere of a commitment to provide the necessary funds for these newer or expanded program elements. Whatever the budget allocations, the CCSP and participating agencies need to start making budget decisions and setting priorities to allow the program to meet the ambitious overarching goals of the plan.

Recommendation: The CCSP and its parent committees should (1) develop a clear budgetary process linking tasks to agency and program budgets; (2) secure the financial resources, for the present and the future, that will ensure the overall success of the plan; and (3) consider new approaches to funding that will enable new initiatives and the shifting of resources to respond to the nation's evolving needs.

Significant hurdles face the CCSP and participating agencies as they implement the plan. First, meeting all program goals will require advances in previously underemphasized but societally relevant elements of the program. Second, a clearer strategic approach is needed to achieve the necessary expansion of observation systems and modeling capabilities. Third, the management structure proposed by the CCSP is very complex, will require significant interagency cooperation, and is essentially untested. Fourth, given the political sensitivities associated with climate and associated global change, special measures may be needed to ensure the scientific independence and credibility of the program and its products. Finally, the CCSP needs to evaluate the available capacity within the community to implement the plan, and address any capacity gaps that are revealed. The recommendations that follow identify ways to ensure effective implementation of the strategic plan.

ENSURING A BALANCED AND SOCIETALLY RELEVANT PROGRAM

The revised strategic plan addresses much of the critical science relevant to climate and associated global change in a strategic framework that places the research it proposes in the context of national needs. It includes five overarching goals (see Box ES-1) that are consistent with the vision, roughly balanced among the areas of emphasis for the program, and of appropriate scope needed to address climate and associated global change. The fourth and fifth goals, in particular, will be crucial in ensuring the societal relevance of the program, as they focus on understanding impacts on ecosystems and human systems as well as supporting decisions related to prevention and response options. The committee applauds this emphasis, but finds it will require significant new efforts in areas that are not presently well supported by the CCSP. **The CCSP should accelerate efforts in previously underemphasized program elements, including ecosystems, the water cycle, human dimensions, economics, impacts, adaptation, and mitigation, by rapidly strengthening the science plans and institutional support for these areas.**

The plan's attention to research and decision support related to the regional and international aspects of climate and associated global change is particularly welcome. As these elements are implemented, the program will need to do a better job of identifying stakeholders and the types of decisions they need to make. The CCSP should provide the scientific knowledge and analyses needed to support national and international policy decisions, including those aimed at mitigating climate change, as well as local, state, and regional decisions. Correcting the plan's continuing systematic weakness with regard to economic analyses will be critical, because such analysis is crucial for evaluating impacts and weighing possible response options. The purpose of the plan's proposed synthesis and assessment products also must be clarified, because it is unclear whether they either will meet the 1990 Global Change Research Act requirement for impact assessments or will satisfy the program's need to evaluate progress toward program goals or other management objectives. **The CCSP should further develop its decision support activities, making sure to meet the needs of local, regional, national, and international decision makers. The synthesis and assessment products should be chosen to explicitly address the range of needs for decision makers and program management, as well as the broad scope specified in the Global Change Research Act.**

OBSERVATIONS AND MODELING

The plan appropriately calls for major upgrades in global observing capabilities and for significant advances in climate modeling. It falls short, however, in providing a strategy for implementing, sustaining, and evolving an observing system necessary to answer the crucial questions pertaining to climate and associated global changes that will be asked of it over this century. Such a strategy for observations should be well coordinated with related international efforts for maximum effectiveness. A strategy is also needed for meeting the stated modeling goals, particularly for delivering a wide range of products, including long-term climate projections, seasonal to interannual climate predictions, regional climate models, and projections of societal and ecosystem impacts. **The CCSP should develop more comprehensive strategies for implementing and sustaining a global Earth observing system and for meeting climate modeling goals.**

BOX ES-1 Overarching CCSP Goals in the Revised Strategic Plan

CCSP Goal 1: Improve knowledge of the Earth's past and present climate and environment, including its natural variability, and improve understanding of the causes of observed variability and change.

CCSP Goal 2: Improve quantification of the forces bringing about changes in the Earth's climate and related systems.

CCSP Goal 3: Reduce uncertainty in projections of how the Earth's climate and related systems may change in the future.

CCSP Goal 4: Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes.

CCSP Goal 5: Explore the uses and identify the limits of evolving knowledge to manage risks and opportunity related to climate variability and change

EFFECTIVELY MANAGING THE PROGRAM

The new management structure described in the strategic plan is designed to integrate the activities of 13 federal agencies, oversee progress toward implementing the strategic plan, and integrate research, technology development, and decision support activities. This structure engages high-level officials who could ensure that the program has the necessary resources and could monitor progress toward program goals. The management structure also provides an explicit linkage between climate change science and climate change technology, an important, heretofore under addressed component of the program. As the CCSP matures, continual attention should be paid to clarifying strategic plan priorities derived from the plan vision, mission, and goals; applying priorities and criteria in the program selection and budgeting process of the participating agencies; and defining measurements (metrics) that can indicate success in achieving goals. **The CCSP should establish and institutionalize effective management processes that create accountability for meeting program goals.**

The complex management structure proposed by the CCSP is essentially untested, however, and thus needs to remain flexible and open to adjustments as program leaders learn from experience. As the strategic plan is implemented, the CCSP leadership should adopt an adaptive management approach for the program as a whole by carefully monitoring its progress and periodically revisiting and adjusting the plan, its timelines, and its deliverables to address any shortcomings. Future strategic planning efforts should build upon the successes of this first one, particularly by maintaining the level of transparency and opportunities for scientist and stakeholder input in the process. **The CCSP should plan for the generation of an updated strategic plan every three to five years.**

MAINTAINING THE SCIENTIFIC CREDIBILITY OF THE PROGRAM

Involving high-level political leaders in CCSP management helps to provide the program with the resources that it requires, but also allows the possibility that the program's priorities or scientific results could be influenced by political considerations. Either the reality or perception of such influences could serve to discredit the program unless independent evaluations of the program and its products are conducted on a regular basis. **The CCSP should establish a mechanism for independent oversight of the program as a whole in order to maintain its long-term scientific credibility.** This committee still believes (as in its first report) that establishing a standing advisory body charged with independent oversight of the entire program will be more effective than using a number of ad hoc external advisory mechanisms. Maintaining scientific credibility is especially important for the synthesis and assessment products designed to summarize and evaluate the implications of the program's cumulative knowledge for scientific research and policy formation. **The CCSP should ensure the credibility of synthesis and assessment products by producing them with independent oversight and review from the wider scientific and stakeholder communities throughout the process.**

ADDRESSING CAPACITY NEEDS

The CCSP likely faces shortages in the human and institutional capacity needed to implement the strategic plan, especially in new and expanded program areas. Within the agencies, the capability and inclination to provide decision support—as opposed to basic scientific results—may be limited. In particular, preparing and reviewing the synthesis and assessment products may place high demands on the scientific community. **The CCSP should carefully assess the needs in capacity implied by the strategic plan and address any gaps by coordinating ongoing capacity building efforts at participating agencies and initiating new programs as needed.** Given the expanded attention to decision support, communication with stakeholders, and interagency coordination, the committee sees a much larger role and responsibility being placed on the CCSP Office. **The CCSP Office should be appropriately resourced to reflect its expanded roles.**

The nation and the global community will be better prepared to address the challenges of climate and associated global change if the CCSP's vision and overarching goals are achieved. In this effort, the CCSP represents a transition from the science-based Global Change Research Program of the past decade to a program that employs science in the service of societal objectives. While many opportunities exist to improve the plan, as discussed in this report, the major challenge ahead is for vigorous implementation.

1

Overall Assessment of the Strategic Plan

The U.S. Climate Change Science Program (CCSP) was established in February 2002 to coordinate climate and global change research conducted as part of the U.S. Global Change Research Program (GCRP) and Climate Change Research Initiative (CCRI). The interagency CCSP retains the responsibility for compliance with the requirements of the Global Change Research Act of 1990, including its provisions for annual reporting of findings and short-term plans, scientific reviews by the National Academies, periodic publication of a 10-year strategic plan for the program, and assessments of climate change impacts. At the same time, the U.S. Climate Change Technology Program (CCTP) was created to coordinate and develop interagency research efforts focused on developing new technologies related to climate change and its mitigation. An important initial undertaking of the CCSP was development of a 10-year strategic plan for global change research. The discussion draft of the plan, *Strategic Plan for the U.S. Climate Change Science Program* (CCSP, 2002), was released on November 11, 2002 on the CCSP website (<http://www.climatescience.gov>). Over 1,000 scientists, agency representatives, and other stakeholders discussed the plan at a major planning workshop in Washington, D.C., on December 3-5, 2002. The CCSP also requested that the National Academies review both the discussion draft of the strategic plan and a revised version (see Appendix B for statement of task). In response, the National Academies formed the Committee to Review the U.S. CCSP Strategic Plan, which released its first report reviewing the draft plan in February 2003 (NRC, 2003b; see excerpts in Appendix A). The CCSP responded to the committee's and other comments in a revised strategic plan released on July 24, 2003 (CCSP, 2003). This second NRC report represents the results of the committee's review of the revised strategic plan.

The committee finds that the CCSP has responded constructively to the NRC review and other community input in revising the strategic plan. The revised strategic plan is much improved over its November 2002 draft, and includes the elements of a strategic management framework for effectively guiding research on climate and associated global change over the next decades. The plan articulates a guiding vision, is appropriately ambitious, and is broad in scope. It encompasses activities related to areas of longstanding importance as well as new or enhanced cross disciplinary efforts. Advancing science on all fronts identified by the program will be of vital importance to the nation.

Recommendation: The CCSP should implement the activities described in the strategic plan with urgency.

ELEMENTS OF A STRATEGIC PLAN

The revised strategic plan explicitly includes most essential elements of a strategic plan, representing a substantial improvement. In particular, it now contains several of the strategic elements identified in this committee's review of the draft plan (see Box 1-1), such as a guiding vision, executable goals, clear timetables, and a management plan, as well as a statement of the program's mission and core approaches (see Box 1-2). The vision and goals are consistent with statements by President George W. Bush,[1] indicating that the program is responsive to the national needs that he articulated, and to the NRC report on climate change science requested by the Administration in 2001[2] (NRC, 2001). Further, the committee finds that the CCSP vision and goals are well matched to this program. The mission and core approaches enhance the strategic plan, because they clearly state the main types of program activities necessary to meet the vision and goals.

[1] For example, "America and the world share this common goal: we must foster economic growth in ways that protect our environment. We must encourage growth that will provide a better life for citizens, while protecting the land, the water, and the air that sustain life. We must also act in a serious and responsible way, given the scientific uncertainties. While these uncertainties remain, we can begin now to address the human factors that contribute to climate change" (George W. Bush, February 14, 2002).

[2] "Initial CCSP priorities have developed in response to a report requested by the Administration by a committee of the National Academies' National Research Council. The NRC report, *Climate Change Science: An Analysis of Some Key Questions*, characterized areas of uncertainty in scientific knowledge concerning climate change, and identified research areas that will advance the understanding of climate change" (CCSP, 2003, p. 8).

BOX 1-1

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised strategic plan should articulate a clear, concise vision statement for the program in the context of national needs. The vision should be specific, ambitious, and apply to the entire CCSP. The plan should translate this vision into a set of tangible goals, apply an explicit process to establish priorities, and include an effective management plan.

Revisions to the CCSP Strategic Plan
The vision, goals, core approaches, prioritization, and management plan for the program are articulated in the revised strategic plan (See Box 1-2). A new Chapter 2 (Integrating Climate and Global Change Research) has been added, providing an overview of how the goals constitute a comprehensive, program-wide framework for coordinating interdisciplinary research activities and observations to focus on key climate and associated global change issues (CCSP, 2003, pp. 11-28). The revised plan states how priorities were chosen and lists "criteria for prioritization" (see Box 1-2), but does not clearly explain how the program will apply priorities in the budget process to support newer or expanded research areas, especially if the program funding remains level.

The five overarching goals are consistent with the vision (see Box 1-2), are generally balanced among the areas of emphasis for the program, and encompass the scope necessary to address climate and associated global change. The research needs related to ecosystems, human dimensions, impacts, and adaptation have appropriately been brought forward in the plan as the fourth overarching goal. Also, the application of scientific information to "policymaking and adaptive management" can potentially support the decisions highlighted in the fifth goal. The committee notes that objective measures remain to be established, however, for evaluating the program's performance against its five overarching goals.

The alignment of research activities with program goals has been improved compared with the draft plan in that "examples of key research activities" are highlighted for each goal in Chapter 2. However, the plan does not thoroughly map the five goals to research and other program activities or identify sufficient activities to meet the fourth and fifth overarching goals. For example:

- Research on impacts and adaptation described in Chapters 8 and 9 needs to be more strongly linked to research on climate and land-use change in Chapters 4 and 6, respectively.
- Research on impacts and adaptation also needs to be better linked with near-term syntheses and work with stakeholders described in Chapter 11, "Decision Support Resources Development."
- The discussion of the CCSP modeling strategy in Chapter 10 identifies as priorities the development of model outputs to inform decision makers and impacts research, but does not describe actions to facilitate this usage.
- The discussion of observing and monitoring in Chapter 12 devotes only a single paragraph to climate-related social, economic, and health data.

In general, these new and expanded areas of emphasis, which will be vital for accomplishing CCSP Goals 4 and 5, are less developed than the areas addressed by CCSP Goals 1, 2, and 3, and therefore, need to be accelerated. In a more thoroughly integrated plan, the goals of the program would dictate which individual research projects would be supported and how they would be sequenced. During implementation, these linkages need to be made so that program gaps can be identified and progress toward program goals can be assessed.

It is also important that the CCSP have an explicit and defensible process for prioritization and decision making. The revised strategic plan describes how initial priorities were chosen, based in part on the 2001 NRC report *Climate Change Science: An Analysis of Some Key Questions*, and identifies several "Criteria for Prioritization" (see Box 1-2). The CCSP and participating agencies will need to make budget decisions and set priorities based on the contribution of research activities to accomplishment of the overarching CCSP goals. An explicit approach to priority setting is required, but is not explained in the plan. One reason that an explicit approach is essential is that the revised strategic plan expands the scope of the program beyond that of the GCRP, while providing no new resources. The prioritization approach should make sure to support emerging research areas that fit the program objectives even with little established track record of previous performance.

The revised strategic plan identifies timelines of 0-2 year, 2-4 year, and greater than 4 years for many deliverables (see Table 1-1). This approach is an important and essential component of the strategic plan. However, many of the milestones, products, and payoffs are too vaguely worded (e.g., many call for "greater understanding," "improved descriptions," or "updated trends") to ascertain what will constitute success. For example, does a progress report constitute a milestone of

BOX 1-2 CCSP Guiding Vision, Mission, Goals, Core Approaches, and Criteria for Prioritization (CCSP, 2003, pp. 2-8).

CCSP Vision
A nation and the global community empowered with the science-based knowledge to manage the risks and opportunities of change in the climate and related environmental systems.

CCSP Mission
Facilitate the creation and application of knowledge of the Earth's global environment through research, observations, decision support, and communication.

CCSP Goals
CCSP Goal 1: Improve knowledge of the Earth's past and present climate and environment, including its natural variability, and improve understanding of the causes of observed variability and change.

CCSP Goal 2: Improve quantification of the forces bringing about changes in the Earth's climate and related systems.

CCSP Goal 3: Reduce uncertainty in projections of how the Earth's climate and related systems may change in the future.

CCSP Goal 4: Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes.

CCSP Goal 5: Explore the uses and identify the limits of evolving knowledge to manage risks and opportunity related to climate variability and change.

CCSP Core Approaches
1. Scientific Research: Plan, sponsor, and conduct research on changes in climate and related systems.
2. Observations: Enhance observations and data management systems to generate a comprehensive set of variables needed for climate-related research.
3. Decision Support: Develop improved science-based resources to aid decision making.
4. Communications: Communicate results to domestic and international scientific and stakeholder communities, stressing openness and transparency.

CCSP Criteria for Prioritization
1. Scientific or technical quality;
2. Relevance to reducing uncertainties and improving decision support tools in priority areas;
3. Track record of consistently good past performance and identified metrics for evaluation of future progress;
4. Cost and value.

success on one of these topics? Does a 0-2 year timeline indicate that work is already underway, and that an update or a revision to an existing model will be regarded as satisfactory realization of the milestone? The committee finds that many of the 0-2 and 2-4 year deliverables are too short to attain any significant progress on scientific goals for which work is not already underway. Clear definition of deliverables is particularly important for research that addresses challenging unanswered questions or involves major advances in capabilities, such as the development of an integrated observing system or upgraded climate models; it may take longer than 4 years to make significant progress in these areas. Moving into the implementation phase, the program should specify the milestones and products more clearly, while ensuring that associated timelines are realistic.

CLARITY AND INTEGRATION OF THE PLAN

This committee identified a lack of clarity about the relationship between the Global Change Research Program (GCRP) and the Climate Change Research Initiative (CCRI) as one weakness of the draft report (see Box 1-3). The integration of GCRP and CCRI activities has been clarified in the revised plan, which portrays the CCSP as a single integrated program combining longer-term research efforts with shorter-term, targeted decision support and

research foci. This change in the document adds clarity to the organization of the program.

More generally, in the revised strategic plan, the critical linkages across program elements are more precisely delineated; facilitated in large part by the new Chapter 2, "Integrating Climate and Global Change Research." The revised plan has a more comprehensive and well-organized treatment of the CCSP's strategies for climate modeling (CCSP Chapter 10) and for observing and monitoring (CCSP Chapter 12); these are critical crosscutting activities of the CCSP. As the CCSP moves forward, the program managers should ensure that implementation of these research elements is well coordinated with other parts of the program.

TABLE 1-1 Number of Deliverables from Each Research Element in the CCSP Strategic Plan

Research Element	< 2 years	2-4 years	> 4 years
Atmospheric composition	0	11	5
Climate variability and change	3	27	5
Water cycle	5	19	14
Land use/Land cover change	13	12	17
Carbon cycle	3	17	22
Ecosystem	2	10	7
Human contributions and responses	3	12	4
TOTAL	29	108	74

BOX 1-3

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised strategic plan should: (1) present clear goals for the CCRI and ensure that its activities are consistent with these goals; (2) maintain CCRI's strong emphasis on support for near-term decisions as an ongoing component of the program; and (3) include an explicit mechanism to link GCRP and CCRI activities.

Revisions to the CCSP Strategic Plan
The revisions to the plan clarified the relationship between the CCRI and the GCRP. The revised plan makes it clearer that the CCSP is a single program, in which the longer-term GCRP activities and the near-term higher-priority CCRI activities share a common vision and set of goals. The revised plan includes a strengthened chapter on Decision Support Resources Development, which is clearly designed to be an ongoing component of the program, not just a near-term activity.

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The CCSP should strengthen the treatment and integration of crosscutting research areas in all substantive chapters. The revised strategic plan should address the interactions and synergies of climate change with other associated global changes.

Revisions to the CCSP Strategic Plan
Chapter 2 of the revised plan (Integrating Climate and Global Change Research) outlines "Critical Dependencies" among the program elements described in Chapters 3-9, with examples of how research and observations in one element will provide results needed by other elements (CCSP, 2003, pp. 23-25). Crosscutting linkages, interdependencies, and collaborative efforts across elements are also identified in Chapters 3-9. The revised plan includes improved chapters on observations and monitoring, data management, and climate modeling, three crosscutting program activities. The revised plan has two new questions that address the interactions and synergies of climate change with land-use and land-cover change (CCSP, 2003, pp. 68-69) and with ecosystems (CCSP, 2003, pp. 84-86).

MOVING FORWARD

Climate and associated global changes are now recognized as among the most important challenges facing humankind in the twenty-first century. The challenges transcend national boundaries, as well as normal decision making timeframes. Recognizing these verities, 187 nations, including the United States, generated and subsequently ratified the United Nations Framework Convention on Climate Change.[3] The Framework's relevance to the present strategic plan is expressed clearly: "All parties shall promote and cooperate in scientific, technological, technical, socio-economic, and other research, systematic observation, and development of data archives related to the climate system and intended to further the understanding and reduce or eliminate the remaining uncertainties regarding the causes, effects, magnitude, and timing of climate change, and the economic and social consequences of various response strategies." The CCSP constitutes the United States' commitment to this portion of the Framework challenge. The revised *Strategic Plan for the U.S. Climate Change Science Program* is thus of vital importance for the coming decade and beyond. If the CCSP's vision and overarching goals for addressing climate and associated global change are achieved, the nation and the global community will be better prepared to manage the impacts of climate and environmental changes during the twenty-first century, and to make informed decisions about options to forestall or mitigate some of these changes.

In the remainder of this report, key aspects of the strategic plan needing improvement are identified. The committee does not advocate that the CCSP undertake another major revision to the strategic plan, because the plan provides a wholly adequate framework for the CCSP and a major revision would divert resources from the activities described in the plan. In this context, the committee has focused on assisting the CCSP in implementing the revised plan and in managing the program. Chapter 2 discusses scientific scoping and decision support efforts that need further development in the implementation phase. The major management challenges in implementing the plan are addressed in Chapter 3. Issues associated with this and future planning efforts are discussed in Chapter 4.

[3] The United Nations Framework Convention on Climate Change treaty was signed in 1992 and entered into force in 1994. More information on the treaty is available at <http://unfccc.int>.

2

Science Focus and Scope

The *Strategic Plan for the U.S. Climate Change Science Program* (CCSP, 2003) is farsighted in calling attention to several areas that had previously been underemphasized in the U.S. Global Change Research Program, specifically, human dimensions, ecosystems, the water cycle, impacts, adaptation, and mitigation. The plan's attention to research and decision support related to the regional and international aspects of climate and associated global changes is particularly welcome. The plan's explicit linkage of climate change science and climate change technology is an important, heretofore under addressed component. This chapter highlights those parts of the plan where additional attention is needed to refine the objectives and ensure effective implementation.

ENSURING A BALANCED PROGRAM

In defining Goals 4 and 5, the CCSP proposes a dramatic enhancement of research and understanding of the sensitivity and adaptability of human systems and natural and managed ecosystems, and proposes the development of greater knowledge in management of the resulting risks and opportunities. Accomplishing these goals will require effective and well-resourced research programs addressing impacts, adaptation, and mitigation strategies. These issues are covered in the plan's chapters on ecosystems, human contributions and responses to environmental change, and the water cycle (Chapters 8, 9, and 5, respectively), three aspects of the plan which have improved over the draft (see Box 2-1). Predictions and assessments at the regional scale, as yet imperfectly addressed, are particularly important for these topics. Although at least one product addresses mitigation strategies (CCSP, 2003, p. 82), the plan's overarching goals emphasize adaptation rather than mitigation.

The science programs presented in Chapters 8, 9, and 5 are at a lesser state of readiness than those found in other chapters of the plan. All three call for significant new research in areas that are not presently well supported by the CCSP (NRC, 2003b). As in the draft plan, chapters on ecosystems and human dimensions, although improved, continue to lack sufficient focus and scientific depth, perhaps reflecting insufficient input from relevant scientists and stakeholders before or early in the planning process. Targeted workshops or working groups should be put in place to rapidly and significantly strengthen these science plans. In terms of the CCSP, each of the three topic areas (ecosystems, human dimensions, and the water cycle) has functions embedded in several agencies, and lacks clear leadership, coordination across agencies, and effective advocates in annual CCSP budget processes.

The committee is concerned that implementation of previously underemphasized research programs, such as those on ecosystems, human dimensions, and the water cycle, will lag behind the rest of the plan because they entail a scientific scope much broader than the one presently supported by CCSP agency staff and budgets. Such an outcome would greatly undermine the CCSP's ability to make progress against Goals 4 and 5 and therefore limit its overall success. These program elements should be rapidly strengthened with adequate institutional support, improved science plans, targets, and timelines. The balanced scientific approach that will result is essential to CCSP's overall success.

Recommendation: The CCSP should accelerate efforts in previously underemphasized program elements including ecosystems, the water cycle, human dimensions, economics, impacts, adaptation, and mitigation, by rapidly strengthening the science plans and institutional support for these areas.

SYNTHESIS AND ASSESSMENT PRODUCTS

An essential component of any research program is the periodic synthesis of cumulative knowledge and the evaluation of the implications of that knowledge for scientific research and policy formation. In the context of the CCSP, such syntheses and assessments can serve at least five functions.

1. They can define current scientific understanding and uncertainties, informing future research directions. The primary audiences for these state-of-science reports are the CCSP leadership team and the scientific community.

2. They can inform policy decisions related to climate and associated global changes.

3. They can inform operational management decisions at spatial and societal scales influenced by climate and associated global changes, for example the integrated management of a watershed or the operation of societal response mechanisms, such as health alerts and water restrictions.

4. They can be used to evaluate progress toward program goals and other management objectives. The primary audiences for these progress evaluations are the CCSP leadership team and the Interagency Working Group on Climate Change Science and Technology.

5. They can be used to inform international assessments, such as the IPCC Fourth Assessment Report.

An additional benefit of conducting assessments is that they can serve to build and sustain constituencies, educate stakeholders, and build capacity in affected communities, while ensuring that communication channels between the scientific and decision-making communities remain effective avenues for decision support.

The strategic plan explicitly describes considerable synthesis and assessment activity. The revised plan calls for 21 synthesis and assessment products to be produced in either a 0-2 year or a 2-4 year timeframe. The CCSP classified the products as follows (CCSP, 2003, p. 115): nine of these synthesis and assessment products are intended to serve as state-of-the-science reports, five are intended to inform policy decisions, and seven are intended to inform operational management decisions. There are no obvious products devoted to evaluating progress toward program goals, which thereby handicaps the long-term management of the CCSP.

The strategic plan (CCSP, 2003, p. 11) also states that its synthesis and assessment products are intended to fulfill the requirements for synthesis and assessment contained in Section 106 of the 1990 Global Change Research Act (see Appendix D), which specifies that:

> On a periodic basis (not less frequently than every 4 years) the Council through the Committee, shall prepare and submit to the President and the Congress an assessment which:
>
> 1. Integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings;
> 2. Analyzes the effects of global change on the environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity;
> 3. Analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

All 21 of the synthesis and assessment products in the strategic plan represent efforts to "integrate, evaluate, and interpret" the findings of the program, and therefore appear to fall under the first assessment component of the Global Change Research Act. The committee could not determine that the proposed products also meet the second and third requirements of the Act because the descriptions in the plan are vague in the context of the Global Change Research Act. Even so, it appears that only seven of the synthesis and assessment products are related to the effects of global change. And, some areas specified in the Act, such as

BOX 2-1

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised plan should strengthen its approach to the human, economic, and ecological dimensions of climate and associated global changes to ensure it supports the research necessary to project and monitor societal and ecosystem impacts, to design adaptation and mitigation strategies, and to understand the costs and benefits of climate change and related response options.

Revisions to the CCSP Strategic Plan
The revised plan identifies "the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes" as its fourth overarching goal, appropriately calling attention to these research areas. The plan's chapters on human contributions and responses to environmental change (Chapter 9) and ecosystems (Chapter 8) are improved over the draft. Integrated assessment analyses discussed in Chapter 11 (Decision Support Resources Development) include impacts modeling of the environment as well as socio-economic systems. Other research activities relevant to economics are only weakly addressed in the plan. Although at least one product addresses mitigation strategies (CCSP, 2003, p. 82), the plan's overarching goals emphasize adaptation rather than mitigation.

analyzing the effects on energy production and use, human health and welfare, and human social systems, are only peripherally addressed by this portfolio of products. Not a single synthesis or assessment product explicitly addresses the nation's water supply. Some of the very broadly worded products, such as "scenario-based analysis of the climatological, environmental, resource, technological, and economic implications of different atmospheric concentrations of greenhouse gases," "risks of abrupt changes in global climate," and "uses and limitations of observations, data, forecasts, and other projections in decision support for selected sectors and regions" could cover these areas. The synthesis and assessment products should be more clearly defined, including statements of intended uses and audience for each product.

The plan also does not make clear how the key questions and research activities identified in each research component of the plan relate to the topics chosen for synthesis and assessment products. In addition, because the list of synthesis and assessment products were generated during the brief revision process, the scientific and stakeholder communities did not have much input in deciding which of these products would be included in the plan. As a result, the list of products appears somewhat ad hoc rather than a coherent portfolio of priority synthesis and assessment products.

Recommendation: The synthesis and assessment products should be chosen to explicitly address the range of needs for decision makers and program management, as well as the broad scope specified in the Global Change Research Act.

CCSP synthesis and assessment products must be credible in order to be useful. The program is developing detailed guidelines for the preparation of the synthesis and assessment products, but the committee was unable to review these guidelines because they were not finalized when this report was completed. The strategic plan (CCSP, 2003, pp. 111-112) indicates that all of the decision support activities in the plan will adhere to the following guidelines:

- Analyses structured around specific questions;
- Early and continuing involvement of stakeholders;
- Explicit treatment of uncertainties;
- Transparent public review of analysis questions, methods, and draft results; and
- Evaluation of ongoing CCSP analyses and building on the lessons learned.

The committee believes that these approaches could contribute to the credibility of the synthesis and assessment products and also help address the gaps identified above. It is especially important that CCSP synthesis and assessment products be independently prepared, or evaluated, by the science community. This will provide a level of credibility that reports produced exclusively within the government sometimes fail to achieve. The only previous centralized assessment effort by the CCSP agencies, the U.S. National Assessment on the Potential Consequences of Climate Variability and Change (NAST, 2001), followed these credibility assurance guidelines. The National Assessment's Overview and Foundation reports are important contributions to understanding the possible consequences of climate variability and change. The processes of stakeholder engagement and transparent review of the National Assessment reports were exemplary (see Box 2-2).

Recommendation: The CCSP should ensure the credibility of synthesis and assessment products by producing them with independent oversight and review from the wider scientific and stakeholder communities throughout the process.

BOX 2-2

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised strategic plan should build upon the lessons learned in applied climate studies and stakeholder interaction from prior environmental and climate assessment activities.

Revisions to the CCSP Strategic Plan
This recommendation has been embodied in the principal guidelines for the CCSP decision support approach: "Evaluate ongoing CCSP analyses and build on the lessons learned" (CCSP, 2003, p. 112). The decision support management strategy also states that the CCSP Office will be responsible for "evaluating, reporting, and communicating results from the decision support activities" (CCSP, 2003, p. 122). The revised plan still generally overlooks the insights into the assessment process and the networks of researchers and stakeholders that were developed during the U.S. National Assessment.

Another concern regarding the synthesis and assessment products is the magnitude of human resources, both within the scientific community and for CCSP staff, needed to coordinate and prepare them. The CCSP has not yet evaluated the feasibility of producing 21 of these products in the next 2-4 years without unduly impairing the progress of its research. Many of these products are significant scientific assessments and will require input and review by numerous scientists, as was learned during the U.S. National Assessment process of the late 1990s. In addition, the synthesis and assessment products will be generated over the same timeframe as the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). The AR4 lead authors (including U.S. scientists) will be writing and revising AR4 chapters during 2005 and 2006, with final government review in early 2007. There is considerable overlap of the CCSP synthesis and assessment products and the AR4 chapters in terms of content. It is therefore important for the CCSP to actively coordinate the timeframe and content of the synthesis and assessment products with the IPCC AR4. For example, a set of peer-reviewed, authoritative CCSP products that appear by mid-2005 would likely contribute substantially to AR4. On the other hand, if the CCSP products are simply progress reports produced without involvement of the scientific community and with no independent review they will add little value to the IPCC process. Effective coordination with the IPCC could avoid possible conflicts with the international climate assessment, improve efficient use of resources, and could raise the image and impact of U.S. climate change science.

Recommendation: The CCSP should ensure that the synthesis and assessment products are produced without unduly affecting the ability to conduct research and in coordination with the IPCC assessment.

DECISION SUPPORT

The CCSP has appropriately made decision support an integral component of the strategic plan. Chapter 11, "Decision Support Resources Development," emphasizes development of methods, tools, and processes for effective decision support. Effective implementation of the proposed decision support activities is vital to fulfilling the CCSP's vision of providing the regional, national, and global communities with capabilities for managing the risks and opportunities of changes in climate and related environmental systems. This chapter has much more depth and specificity than did the comparable chapter in the draft strategic plan (see Box 2-3).

Managing risks and opportunities requires stakeholder support on a range of scales and across multiple sectors, which in turn implies an understanding of the decision context for stakeholders. The revised plan identifies three categories of decision makers by decision type (see Box 2-3). As the decision support elements of the program are implemented, the CCSP will need to do a better job of identifying stakeholders and the types of decisions they need to make. This will improve the matching of decision types with the tools and methods most appropriate to that type of decision.

The strategic plan stresses the value of open communication between scientific and stakeholder communities, mentioning "frequent use of 'draft for comment' methods" (CCSP, 2003, p. 7) and "advisory mechanisms . . . including workshops, committees, or NRC activities" (CCSP, 2003, p. 122). The committee lauds this aspect of the plan. However, the program needs to specify more clearly where stakeholder input will enter the process. The current plan should more effectively build upon a growing capability within the U.S. climate and global change research community to interact with potential users of climate and global change science, as was demonstrated in the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (NAST, 2001). The revised plan generally overlooks the insights and relationships that were developed by the National Assessment. For example, the experience developed in assembling and maintaining networks of university researchers and stakeholders in different regions of the country is extraordinarily valuable, as are the networks themselves. These relationships should be supported if the CCSP is going to maintain strong stakeholder involvement. The plan also does not include areas of research relevant to regional-scale assessments identified as a result of the National Assessment. The committee reiterates the recommendation from its first report that the CCSP should "build upon the lessons learned in applied climate studies and stakeholder interaction from prior environmental and climate assessment activities." This deficiency needs to be remedied quickly so that the program's decision support activities reflect what the scientific community now knows, what it can accomplish, and what users would like to know.

Effective implementation of the plan's goals requires focused research to develop decision support resources and methods, as noted in this committee's review of the draft strategic plan.[4] The revised plan provides several good illustrations of information and resources that will assist in decision support, but it does not present a strong research plan to bolster the development of assessments, adaptive

[4] "The draft plan fails to adequately distinguish between research to develop new decision support tools and understanding on the one hand, and operational decision support activities, on the other. It then does not successfully identify state-of-the-art undertakings in both" (NRC, 2003b, p. 5).

BOX 2-3

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised strategic plan should better describe how decision support capabilities will be developed and how these efforts will link with and inform the program's research to improve understanding of climate and associated global changes.

Revisions to the CCSP Strategic Plan
The revised plan includes a much improved treatment of decision support in Chapter 11 (Decision Support Resources Development), which lays out a framework for the types of decision support activities to be undertaken by the program and how these will help identify decision information needs to guide the evolution of the CCSP science agenda. The decision support activities proposed are threefold: (1) prepare scientific syntheses and assessments; (2) develop resources to support adaptive management and planning; and (3) "develop and evaluate methods (scenario evaluations, integrated analyses, alternative analytical approaches) to support climate change policymaking and demonstrate these methods with case studies" (CCSP, 2003, p. 111). CCSP's decision support research should also draw on other well-developed research methods, best practices, and basic insights from the social and behavioral sciences.

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised strategic plan should identify which categories of decision makers the CCSP serves and describe how the program will improve two-way communication with them.

Revisions to the CCSP Strategic Plan
Three categories of decision making have been identified by decision type in Chapter 11 of the revised plan: (1) public discussion and planning; (2) "operational adaptive management decisions by managers of natural resources and build infrastructure;" and (3) support for policy formulation (CCSP, 2003, p. 113). Stakeholder interaction is one of the principal guidelines for the decision support approach. This interaction has been identified for problem identification and framing; review of analysis questions, methods, and draft results; codevelopment of decision support tools with interdisciplinary teams; and feedback from experiences with CCSP decision support projects and analyses (CCSP, 2003, p. 122). The chapter on communications (Chapter 14) in the revised plan better recognizes the importance of interactive communications, though few details are provided on how the program will improve this type of communication (CCSP, 2003, pp. 152-153).

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The CCSP should encourage participation of those agencies whose research or operational responsibilities would strengthen the ability of the program to deliver products that serve national needs.

Revisions to the CCSP Strategic Plan
In Chapter 11 of the revised plan, Objective 2.2, focuses on the need to "promote the transition of resources from research to operations for sustained use" (CCSP, 2003, pp. 116-117). The revised plan's chapter on program management mentions the need to ensure that mission agencies have access to "observations, methods, and information developed through CCSP" (CCSP, 2003, p. 172). No clear mechanism for engaging mission-oriented agencies is described in either chapter.

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised strategic plan should identify what sources and magnitudes of reductions in key climate change uncertainties are especially needed and where an improved characterization of uncertainty would benefit decision making, and should use this information to guide the research program.

Revisions to the CCSP Strategic Plan
The revised strategic plan does not clearly identify key climate change uncertainties of relevance to decision making, though some information can be inferred from the overarching program goals and the selection of synthesis and assessment products. The document does not explicitly link program priorities for research to specific policymaker needs.

management, and interactions with stakeholders. The decision support research activities in the plan emphasize integrated assessment modeling and scenario development. CCSP's decision support research should also draw on other well-developed research methods, best practices, and basic insights from the social and behavioral sciences. Employing these approaches will improve the synthesis and validation of information, the communication of uncertainty, understanding stakeholder needs and constraints, and the economics of decision making. These efforts would include learning how to better explain uncertainty by defining and communicating its source, its current magnitude, and the potential for that magnitude to increase in some areas, as well as the potential for it to be reduced. The plan retains a pervasive weakness with regard to economic analyses and economic modeling, although such approaches could yield powerful results for evaluating impacts and weighing possible response options. In addition, regional products and communication systems are important aspects of climate and associated global change that are not yet completely addressed in the strategic plan.

The effective use of the "decision support toolbox" to be developed and tested within the plan is fully dependent upon the transfer of these tools from the research and developmental domain to the decision-making domain. The plan recognizes the need to "promote the transition of research to operations" (CCSP, 2003, p. 116). In the implementation phase the CCSP should specify the agencies or programs responsible for this transition, and describe the involvement of additional mission-oriented agencies that are not currently participants in the program. As discussed in this committee's first report, mission-oriented agencies—such as the Federal Emergency Management Agency, water resources and land management agencies within the Department of the Interior and the Army Corps of Engineers, and the extension and farm program agencies within U.S. Department of Agriculture—could be instrumental in making CCSP research results operational (see Box 2-3). The CCSP should work to support public-private-academic partnerships that could facilitate the transfer of research results to operational applications, borrowing where appropriate from the successful model used in the provision of weather services (NRC, 2003a).

The CCSP should move forward aggressively in creating an effective decision support component of the program. To address the inherent challenges in this endeavor, the CCSP should adopt the approach and procedures outlined in *Understanding Risk: Informing Decisions in a Democratic Society* (NRC, 1996). It should organize a variety of deliberation activities (e.g., workshops, focus groups, working panels, citizen advisory groups) and involve a broad range of stakeholders, including those from government, industry, academia, users of decision support tools, and representatives of the public. The goals of these deliberation activities would be (1) to expand the range of decision support options being developed by the program; (2) to match decision support approaches to the decisions, decision makers, and user needs; and (3) to capitalize on the practical knowledge of practitioners, managers, and laypersons.

Recommendation: The CCSP should further develop its decision support activities, making sure to meet the needs of local, regional, national, and international decision makers.

OBSERVATIONS AND MODELS

Two priority components of the CCSP are enhanced observations and modeling that are relevant to climate and associated global changes. The plan calls for significant advances in the capability of climate models to simulate future climate conditions and their associated regional impacts, and for major upgrades in the global Earth observing system. Both of these challenges have a degree of difficulty that will require systematic, sustained investments for a minimum of a decade if their full contributions to climate research and applications are to be realized. As discussed below, the CCSP needs to develop more comprehensive strategies for prioritizing and sequencing these investments to meet the stated goals.

Observations

The strategic plan recognizes the benefits of a robust and comprehensive observing system to monitor changes in climate, to support modeling efforts, and to expand understanding of the climate system (CCSP, 2003, p. 237). For example, the revised plan has an increased emphasis on the role of paleoclimate observations in providing information about the long-term context of climate change. Unfortunately, a comprehensive climate observing system is not yet in place and the CCSP will have to make a substantial commitment to support, coordinate, and better manage its observational activities if it is to attain such a system (see Box 2-4). The program will have to address the facts that no one agency now has the lead in climate observations, some parts of the existing observing system are in decline, and observational capabilities are only just being developed in some areas. For example, the quality and coverage of surface-based atmospheric monitoring systems have actually declined over the past decade (IPCC, 2001a), and the establishment of the climate observing system in the ocean has just begun and needs significantly greater support to be implemented and sustained. Chapter 12, "Observing and Monitoring," identifies many goals for climate observing that have been previously articulated by

the community and a preliminary strategy for developing such a system. The chapter falls short, however, in providing a comprehensive strategy for implementing and sustaining such a system.

Improving observational capabilities is a major challenge that requires the science community to rethink how to evolve a focused Earth observing system. Additional short-term investments called for in the plan (CCSP, 2003, p. 141) can serve as an initial increment toward achieving the system that will be required in the next several decades. Establishing and sustaining a truly robust and comprehensive observation system, however, will require a significant expansion in activities, and therefore a longer-term increase in funding above current levels. For example, many components of the existing observing system rely on expendable platforms, such as atmospheric radiosondes and profiling floats deployed in the ocean, and replacement costs will be ongoing; the cost of these expendables, as well as associated labor costs, has played a role in recent decisions to reduce surface-based observing capabilities. Attaining climate quality observations will require infrastructure, such as calibration facilities, to support and document instrumental accuracy, as well as investments to replace or update obsolete hardware. Other investments will be needed to establish new observing capabilities in regions critical for climate change analysis, such as the Southern Ocean and polar regions, and to meet the needs for improved assessments and predictions.

A number of other aspects of the program's climate observations strategy need improvement as well. First, the plan should explicitly build upon the National Polar-orbiting Operational Environmental Satellite System (NPOESS), which will become the primary space-based climate observing system for the United States in a few years. The CCSP should make sure that NPOESS is an important part of its observations and monitoring strategy. Second, the program should emphasize the periodic reanalysis of satellite observations to improve not only the current climate data records but also past climate data records. Third, the program should pay more attention to the use of surface-based and *in situ* observations of aerosols, clouds, and surface fluxes in validating satellite observations and in providing a robust baseline. Lastly, the program needs to better integrate itself with the international context for climate observations, as for example, coordinated by the international Global Climate Observing System (GCOS) and now receiving new attention as a result of the Earth Observing Summit hosted by the United States in the summer of 2003.

In addition to improving climate observations, the CCSP faces challenges in strengthening monitoring of societal and ecosystem impacts. For example, the plan's chapter on "Human Contributions and Responses to Environmental Change" does not discuss observational needs and only a few examples are listed as part of the chapter on "Observing and Monitoring the Climate System" in Appendix 12.2 of the revised plan. Indeed, the integration of biogeochemical, ecosystem, demographic, land-use, and water-use observations will be critical for decision support and human impacts data, and is already integrated into IPCC assessments (e.g., IPCC, 2001b). The CCSP should carefully consider the detailed nature of its commitment to establish and sustain a global Earth

BOX 2-4

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised strategic plan should better describe a strategic program for achieving an integrated observing system for detecting and understanding climate variability and change and associated global changes on scales from regional to global.

Revisions to the CCSP Strategic Plan
The revised plan's treatment of climate system observing and monitoring is much improved over the draft plan in that it devotes all of Chapter 12 to describing the CCSP's goals for climate system observing and monitoring. The plan still falls short in providing a comprehensive strategy for implementing and sustaining a global climate observing system. This is a major challenge and will require the program to develop an approach to sequencing investments over many years.

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The global and long-term historical context of climate change and variability should receive greater emphasis in the revised strategic plan.

Revisions to the CCSP Strategic Plan
The revised plan has increased the emphasis on the global and long-term context of climate variability and change in the chapter on this topic. In particular, the plan includes more attention to global modes of variability other than the El Niño Southern Oscillation (CCSP, 2003, pp. 44-47) and to analyses of the paleoclimate record (CCSP, 2003, pp. 47-48).

observing system. Indeed, the program should take the lead in identifying, securing, and coordinating the investments necessary to establish, maintain, and evolve the observing system that will be required to answer the crucial questions pertaining to climate and associated global change that will be asked of it over this century.

Recommendation: The CCSP should develop a more comprehensive strategy for implementing and sustaining a global climate observing system.

Modeling

Improving climate models is widely recognized as a major national and international priority. The strategic plan appropriately calls for greatly improved climate models both for "synthesizing observations, theory, and experimental results to investigate how the Earth system works and how it is affected by human activities" (CCSP, 2003, p. 101) and for "sustained and timely delivery of predictive model products that are required for assessments

BOX 2-5

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised strategic plan should more fully describe how models and knowledge that support regional decision making and place-based science will be developed.

Revisions to the CCSP Strategic Plan
The revised plan more fully describes regional climate modeling activities as well as some other activities to support regional decision making. In Chapter 10 (Modeling Strategy), Objective 1.6 focuses on CCSP efforts to "accelerate the development of science-based predictive models to provide regional and fine-scale climate and climate impacts information relevant to scientific research and decision support applications" (CCSP, 2003, pp. 105-106). Further efforts are needed to ensure that these models are developed with stakeholder involvement and that they integrate simulations of societal and ecosystem impacts. The discussion in Chapter 11 (Decisions Support Resource Development) of adaptively managing natural and human systems affected by climate change (CCSP, 2003, pp. 114-117) also identifies many regional-scale decisions and the activities CCSP will pursue to help inform these decisions.

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The discussion of applied climate modeling should be revised to better describe how model projections will be incorporated into the broader suite of decision support activities and to better address the key challenges to attaining the applied climate modeling goals set forward in the plan.

Revisions to the CCSP Strategic Plan
The revised plan includes a new chapter articulating the program's modeling strategy. Applied climate modeling activities are described in Goal 3 of this chapter, "Coordinate and accelerate climate modeling activities and provide relevant decision support information on a timely basis" (CCSP, 2003, pp. 108-110). Integrated assessment modeling is also discussed as one of the tools the program will develop for decision support (CCSP, 2003, pp. 117-120).

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised strategic plan should provide details about how the CCSP will acquire the computing resources necessary to achieve its goals

Revisions to the CCSP Strategic Plan
The revised plan's Chapter 10 (Modeling Strategy) states that the CCSP will "provide the computing, data storage and retrieval, and software engineering resources required to support a world-class U.S. climate modeling activity" (CCSP, 2003, p. 106). Priorities under this objective include: "support researchers in developing more comprehensive coupled models," "provide researchers at the major modeling centers with access to steadily growing computational resources that increase by a factor of four each year," coordinate with the Office of Science and Technology Policy's High-End Computing Revitalization Task Force, support development of software, and develop and maintain tailored information technology infrastructure. Based on available budgets for acquiring new computers and the expected rate of improvement in computing technology over the next five years, the increase in computing capabilities is unlikely.

and other decision support needs" (CCSP, 2003, p. 101). The revised plan includes a new chapter (Chapter 10) in which climate models are discussed, a substantial improvement over the scattered treatment of models in the draft plan. However, to achieve the climate modeling goals, the CCSP should develop a strategy for sequencing investments to address long-term research challenges. The CCSP should revisit its promise to increase computational resources by a factor of four each year for five years (see Box 2-5). Based on available budgets for acquiring new computers and the expected rate of improvement in computing technology over the next five years, this increase in computing capabilities is unlikely.

For the most part, Chapter 10 presents a strategy for producing climate change projections through two modeling centers, but fails to present a national strategy for the seasonal-to-interannual climate predictions so important to many stakeholders. The operational demands, requirements, and mandate for the National Center for Environmental Prediction (NCEP) are relegated to a middle-level status and little attention is given to obtaining and providing the computational resources needed for multiscale climate prediction. Without a fundamental change in approach to fully support seasonal-to-interannual climate prediction, the United States will be unsuccessful in the delivery of climate services.

The continued development and application of regional climate models will also be essential to the delivery of climate services. An improved understanding of climate change and its impacts at the regional scale will require an enhanced regional climate modeling capability. The last few years have brought significant improvements in these capabilities, improvements that are not fully recognized in the strategic plan. Even so, there are many unresolved issues about regional climate models. In implementation, the CCSP should support the development and application of regional climate models to a greater extent than described in the revised plan (see Box 2-5). The CCSP should also support development of a research and applications infrastructure that enables stakeholder involvement to ensure valuable societal use of information produced by these models. This research and stakeholder community, along with the necessary infrastructure, is still in the formative stage. In the future, CCSP should launch new efforts to develop modeling approaches for projecting societal and ecosystem impacts and for designing and evaluating response options.

Recommendation: The CCSP should develop a more comprehensive strategy for meeting climate modeling goals.

LINKAGES BETWEEN CCSP AND CCTP

The committee's review of the draft strategic plan recommended that the CCSP "assess the scientific implications of technologies under consideration by the CCTP and develop realistic emissions scenarios for climate and associated global changes with these technologies in mind" (see Box 2-6). The CCSP, in cooperation with the CCTP, has made commendable efforts to address this recommendation. In particular, joint activities of the CCSP and the CCTP to develop improved scenarios of greenhouse gas emissions are described in the revised plan. Comments by CCSP and CCTP representatives at the committee's August 2003 meeting indicated that efforts are already yielding benefits in coordinating the two programs.

The committee is concerned, however, that efforts to coordinate CCSP and CCTP activities are not identified beyond these scenario development activities. One area that has been overlooked is the evaluation of social and environmental impacts of potential new technologies, such as land-use requirements for developing bioenergy or the necessity to divert massive economic resources to develop the infrastructure to support a hydrogen economy. Another area for coordination involves research on the extent to which mitigation or adaptation strategies developed under the CCTP might produce climate or other environmental

BOX 2-6

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The CCSP should assess the scientific implications of technologies under consideration by the CCTP and develop realistic scenarios for climate change with these technologies in mind. The program management chapter of the revised CCSP strategic plan should clearly describe mechanisms for coordinating and linking its activities with the technology development activities of the CCTP.

Revisions to the CCSP Strategic Plan
The cabinet-based management structure described in the revised plan's chapter on program management provides executive direction under which CCSP and CCTP activities will be coordinated. Planning and implementation for activities relevant to both programs will be coordinated through interagency working groups (CCSP, 2003, pp. 172-174). The plan identifies only a few specific areas where the CCSP and CCTP will coordinate, focusing primarily on the development of scenarios (CCSP, 2003, pp. 119-120).

impacts, such as those that may be associated with large-scale sequestration of carbon dioxide in geological or oceanic reservoirs. The CCSP strategic plan does include research to evaluate "environmental effects of mitigation options that involve reduction or prevention of greenhouse gas emissions" (CCSP, 2003, p. 82), which should in turn be coordinated with CCTP activities. Of particular concern is the poorly defined role of economic analyses in the coordination between CCSP and CCTP. Although the need for economic analyses is identified in Chapter 9, "Human Contributions and Responses to Environmental Change," the plan does not explain how these efforts would be coordinated with CCTP technology development or with economic analyses that might be conducted under the CCTP. The milestones, products, and payoffs relevant to research in economics are limited in scope, indicating that the program is not positioned to address these research needs.

Though these coordination issues may be resolved as the CCTP completes its strategic planning and as both programs mature, there remains a risk that critical research areas may be overlooked at the interface of the two programs, particularly as the science and general understanding develop in parallel. The CCSP and CCTP should establish a systematic mechanism for identifying research areas that require coordination between their two programs, and develop administrative and financial approaches, as well as external review, for supporting research activities that fall at their interface.

3

Implementing and Managing the Program

The revised strategic plan is a more complete and articulate presentation of the federal government's scientific plan for the U.S. Climate Change Science Program (CCSP). The plan addresses much of the critical science in a strategic framework that places the research it proposes in the context of national needs. The committee is concerned, however, about some aspects of how the CCSP and participating agencies propose to implement the plan. In some cases, the plan does not recognize inherent challenges on the pathway to implementation. In other cases, the plan puts forward ambitious goals that exceed currently available resources, without presenting a strategy for prioritization that addresses barriers to achieving the stated research agenda. The management structure proposed by the CCSP is complex, will require significant interagency cooperation, and is essentially untested. In this chapter, such factors that may hinder implementation of the plan are addressed.

MATURING PROGRAM MANAGEMENT

The new management structure described in the strategic plan is designed to coordinate the activities of 13 federal agencies, oversee implementation of the strategic plan, and integrate research, technology development, and decision support activities. Chapter 16, "Program Management and Review," provides a broad description of the roles and responsibilities of the thirteen participating agencies, briefly describes the complex budgeting and appropriations process, references management mechanisms to ensure that data needs are coordinated across disciplines and research areas, and explains five management mechanisms in detail.

Despite these improvements to the program management chapter of the plan, the plan still lacks a process by which higher levels of management will ensure that program goals are met. As the program matures, continual attention should be paid to refining strategic plan priorities; applying priorities and criteria in the program selection and budgeting process of the participating agencies; and defining measurements (metrics) that can indicate success in achieving goals. These management processes should be institutionalized to ensure a lasting research enterprise. At the same time, the management structure needs to remain flexible and open to adjustments as program leaders learn from experience.

Institutionalizing Accountability at All Leadership Levels

The management structure for the CCSP (see Figure 3-1) engages high-level officials who could ensure that the program has the necessary resources and could monitor progress toward program goals. It involves a CCSP interagency governing body, chaired by the CCSP director; an Interagency Working Group on Climate Change Science and Technology to supervise the CCSP and the complementary Climate Change Technology Program (CCTP); and above that, a cabinet-level Committee on Climate Change Science and Technology Integration to link both programs into the White House Office of Science and Technology Policy. The Interagency Working Group and the CCSP Program Office will need to work closely together to ensure effective plan execution. Ultimately, successful implementation of the CCSP will depend on whether these high-level management groups can influence individual agency programs and budgets.

Involving high-level political leaders in CCSP management helps to provide the program with resources that it requires, but also allows the possibility that the program's priorities or scientific results could be influenced by political considerations. Either the reality or perception of such influences could discredit the program unless independent evaluations of the program and its products are conducted on a regular basis. In its first report, this committee recommended that the CCSP establish a standing advisory body charged with independent oversight of the entire program. The CCSP considered this recommendation (see Box 3-1), but decided that it would provide independent program oversight through "a number of external advisory mechanisms, including periodic overall program reviews by the NRC or other groups, rather than a single body" (CCSP, 2003, p. 175). The committee still

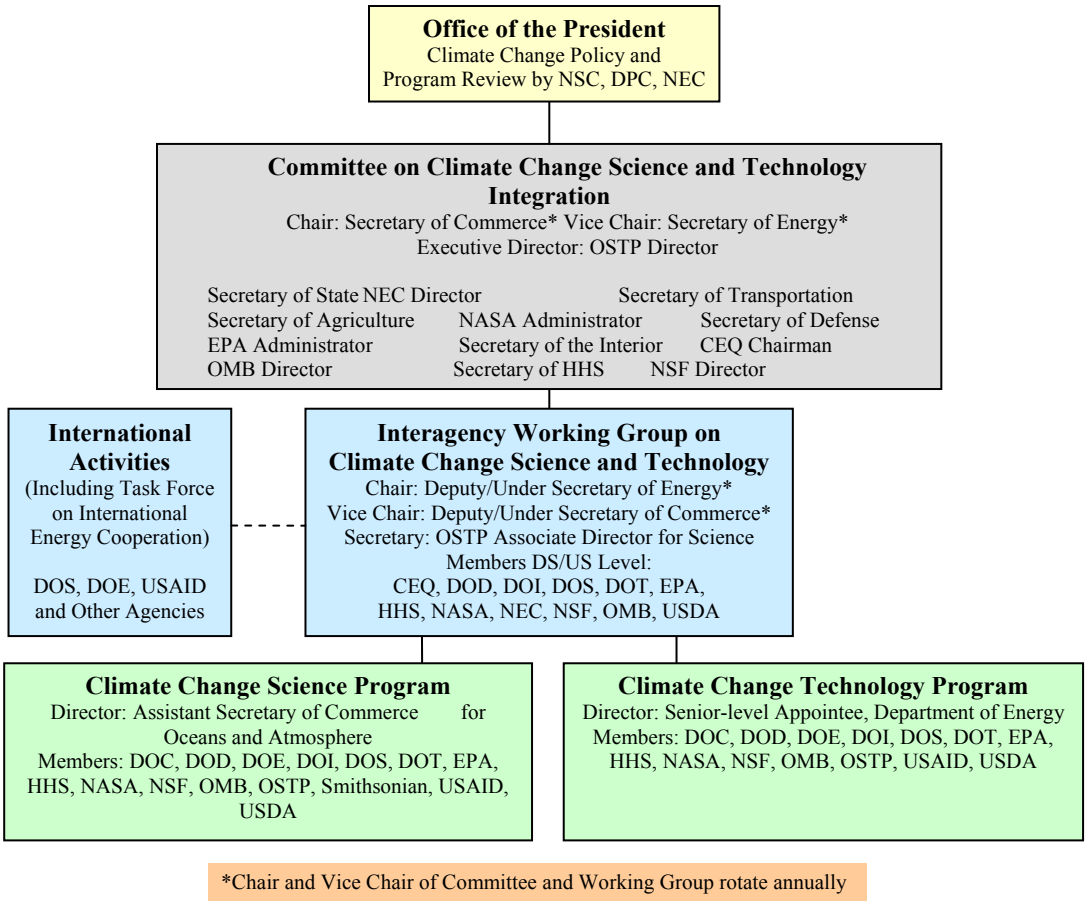

FIGURE 3-1 Climate Science and Technology Management Structure. SOURCE: CCSP. Available online at <http://www.climatescience.gov>.

BOX 3-1

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The CCSP should establish a standing advisory body charged with independent oversight of the entire program.

Revisions to the CCSP Strategic Plan
The revised strategic plan includes a section in Chapter 16 (Program Management and Review) on "External Interactions for Guidance, Evaluation, and Feedback" (CCSP, 2003, p. 175). In this section, the plan states that the CCSP considered this recommendation to establish a standing advisory body, but chose not to implement it at this time. The plan states: "CCSP believes that essential program oversight is better provided by the use of a number of external advisory mechanisms, including periodic overall program reviews by the NRC or other groups, rather than a single body. Additional mechanisms to seek external scientific input, such as workshops, steering committees, *ad hoc* working groups, and review boards, will be employed as needed. CCSP will continue to consider creation of a permanent overall advisory group as program implementation proceeds." The committee still believes that an independent, standing advisory body for the entire program would be the most effective way to maintain the long-term scientific credibility of the program.

believes that an independent, standing advisory body for the entire program would be the most effective way to maintain the long-term scientific credibility of the program. Such a group should include highly respected scientists and other stakeholders spanning the broad range of topics addressed by the program. This group would supplement advisory groups already established for many CCSP program areas. Whatever mechanism is chosen, the committee believes that independent program oversight will be essential to maintaining the long-term credibility of the CCSP.

Recommendation: The CCSP should establish a mechanism for independent oversight of the program as a whole in order to maintain its long-term scientific credibility.

Nearly all of the structural accountability for achieving the CCSP's goals appears to reside in practice at the program element level. All the strategic plan's chapters have clearly identified lead authors and contributors, providing an important accountability and openness for this document. This accountability has substantially strengthened the scientific and programmatic content of the plan, and sends a message that the U.S. scientific community is prepared to take on these research challenges provided the resources are available. The committee notes a more tenuous level of accountability for implementing activities to meet the goals of newer initiatives and program elements. Of greatest concern is the enormous gulf between the ambitious goals identified in the chapters on decision support and human dimensions and the likely level of implementation ascertained from comments by agency representatives.

The strategic plan states that the responsibility for ensuring that the program's five overarching goals are met falls to the interagency governing body that manages the CCSP (see Box 3-2). However, the plan is not specific about the mechanisms it will employ to ensure that the overarching CCSP goals are met. Because the goals do not provide any real target for accomplishment, it is difficult to ascertain what will be considered success. The description of accountability at levels above the CCSP is even less clear. The cabinet-level committee and the Interagency Working Group should regularly solicit independent plan evaluation to measure progress toward the program's goals and help ensure that overarching program goals are met by taking steps to clearly link strategic plan priorities and activities to the vision, mission, and goals of the plan.

To address concerns about program management and accountability, the committee recommends that the CCSP clearly codify accountability at all levels of the program. In particular, the program needs to more clearly identify what each level of leadership is accountable for, and put processes in place to ensure that the plan's five overarching goals are met. Having these responsibilities clearly laid out could help ensure that presently under supported activities move forward and that priority areas are properly addressed. The responsibilities of the cabinet-level

BOX 3-2

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised strategic plan should describe the management processes to be used to foster agency cooperation toward common CCSP goals. The revised plan also should clearly describe the responsibilities of the CCSP leadership.

Revisions to the CCSP Strategic Plan
Chapter 16 of the revised plan includes a much improved discussion of program management and review. The chapter describes the cabinet-based management structure, program criteria, principal areas of focus for CCSP agencies, and responsibilities of the CCSP Office. It is clearly stated in the revised plan that the CCSP interagency governing body, chaired by the CCSP director, is responsible for coordination of program activities.

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised strategic plan should more clearly outline agency responsibilities for implementing the research.

Revisions to the CCSP Strategic Plan
Box 16-1 of the revised plan describes the principal areas of focus for each CCSP participating agency in general terms (CCSP, 2003, pp. 170-172). Specific objectives in Chapters 3-13 are not associated with a responsible agency, making it difficult to link CCSP goals and objectives to programs supported at the individual agencies.

committee and the Interagency Working Group should include reviewing the CCSP's and CCTP's overarching goals, ensuring that they meet the nation's needs and are complementary, and making sure that the goals are accomplished. Special attention is needed to identify who is responsible for addressing the CCSP-CCTP interface and identifying gap areas of research. Given that addressing climate change will be a challenge for decades, implementation of the strategic plan will take place over a succession of administrations; consequently, the program should carefully document its management processes.

Recommendation: The CCSP should establish and institutionalize effective management processes that create accountability for meeting program goals.

Adaptive Management of the Program

As the strategic plan is implemented, the CCSP leadership should adopt an adaptive management approach for the program as a whole by carefully monitoring its progress and periodically revisiting and adjusting the plan, its timelines, and its deliverables to address any shortcomings. This activity will require independent plan evaluation to measure progress against plan goals, assessment of stakeholder input and feedback, and a review of the degree to which the individual program elements are integrated to form a larger and more useful overall perspective. One possible unintentional result of failure to revisit the plan could be that the 21 proposed synthesis and assessment products would become the default substitutes for program selection criteria, budgetary decision criteria, and strategic plan evaluation. Such an unproductive outcome should be avoided.

The complex management structure proposed by the CCSP is essentially untested. Coordination among more than a dozen agencies will be a formidable challenge. The strategic plan is a research framework that requires considerable buy-in by the agencies. The plan itself has no real mandate for command-and-control functions and hence the success of the program will require a management approach that enhances coordination, and is collaborative and adaptive. This is the charge of the Interagency Working Group and the CCSP Office.

An important core function of the CCSP Office will be using the strategic plan in making decisions concerning research investments, priorities, and direction. Because the program and its strategic plan is expected to evolve over time, explicit mechanisms are needed to continuously engage the agencies, the research community, and stakeholders in order to gauge progress and incorporate new developments and priorities into the program. This can be accomplished in many ways, some of which are discussed in the context of decision support in Chapter 2 of this report. Whatever mechanism is chosen, constant attention to the overarching goals and a matching of the results and deliverables against these goals will be crucial. In the early years of the CCSP, the use of specific identified products to evaluate progress against these goals will need to be explicit and routine. At the same time, the program should have a mechanism for making revisions to the goals and outcomes when it is important. Any such process should be grounded in science and transparently involve the science community.

The committee recognizes that the challenges for understanding and responding to climate and associated global change have both near-term and long-term management issues. There is a need to make progress early, but there is also a need for mechanisms that ensure continuity over time. It is unlikely that all the scientific questions and policy-relevant problems will be resolved in the near term, and hence the management of this program needs to be based on modalities that transcend different administrations and conditions. This will require institutionalizing a mature management process that can adapt and grow as priorities shift. The program should recognize explicitly those longer-term problems that will not be resolved in the near term, develop a mechanism for making the necessary investments today to enable longer-term payoffs, and create adaptive management mechanisms that transcend individual administrations, events, or conditions.

INTERNATIONAL LINKAGES

The plan's description of international linkages in Chapter 15 is improved (see Box 3-3), providing an impressive list of U.S. involvement in international climate and associated global change research programs. The chapters on modeling and observations, as well as the final section of many other chapters, explicitly recognize that expanded international cooperation is required and list some specific programs. But the plan is still weak in identifying explicit opportunities where international cooperation can enhance or leverage CCSP research, thus increasing the efficiency and effectiveness of the program. Many of the research programs in the strategic plan will benefit from strong links to the international community of climate and associated global change scientists; indeed, many of the programs *require* such linkage. To enhance the strategic aspect of the CCSP, opportunities to build on bilateral, regional, and international programs that meet U.S. information needs both in science and decision support should be identified and reinforced. Among the key reasons to work more diligently on the international programs is that efficiency of resource use can be improved.

BOX 3-3

***Planning Climate and Global Change Research* (NRC, 2003b) Recommendation**
The revised strategic plan should clearly describe how the CCSP will contribute to and benefit from international research collaborations and assessments.

Revisions to the CCSP Strategic Plan
Chapter 15 (International Research and Cooperation) of the revised plan provides an impressive list of U.S. involvement in international climate change research programs. The chapter describes international frameworks established to coordinate global change research, international assessment activities, bilateral discussions the United States has had with other countries, international efforts to build observing systems and shared data management, and capacity building in developing countries. Linkages with the international community are also identified within many of the program chapters. The plan could be more specific about how the CCSP will contribute to the international efforts and could provide more detail about how the United States would benefit from this involvement.

Two important sets of international linkages should be strengthened within the program. The first is the need for international capacity building through collaborations with developing countries such as those pursued through the International Geosphere Biosphere Programme (IGBP), International Human Dimensions Program (IHDP), World Meteorological Organization (WMO), Inter-American Institute for Global Change Research (IAI), Asia-Pacific Network for Global Change Research (APN), and a variety of bilateral programs. These collaborations can be very beneficial to U.S. climate change research in that they build understanding of regions that play key roles in the global climate system, such as the Amazon or the Asian monsoon region, and contribute to attempts to establish a global observing system. The plan includes some discussion of capacity building in developing countries (CCSP, 2003, p. 167). However, compared to the level of detail provided about domestic research initiatives, the plan fails to develop plans or identify resources for such programs.

Second, the CCSP should develop a more detailed recognition, review, and plan for collaboration with scientists in regions such as Europe, Japan, Australia, and China. The plan briefly describes bilateral discussions that the United States has had with several other nations (CCSP, 2003, p. 160-161). In some cases these international partners are funding science that greatly enhances or overlaps with U.S. activities. The International Group of Funding Agencies (IGFA) provides a venue for coordination of international research funding. Climate modeling in the United Kingdom, Germany, and Japan provides important comparative and competitive opportunities for the proposed two-center U.S. modeling initiative. European Union and national research programs are focusing considerable resources on questions of climate impacts, adaptation, mitigation, outreach to stakeholders, and assessments that can provide research implementation and funding models for the new U.S. programs. Some of these programs (e.g., the U.K. Climate Impacts Programme) focus on interaction with stakeholders and decision support and provide important lessons that could allow a faster startup for new U.S. initiatives.

RESOURCES TO IMPLEMENT THE PLAN

Feasibility Analysis

In clearly stating five overarching goals for the CCSP, the revised strategic plan is a significant improvement over its draft. However, the strategic plan does not provide enough information to allow the committee or the community at large to make a fully informed judgment as to whether there are sufficient financial and other resources to meet the program goals. This lack of information on resource needs coupled with an abundance of vaguely worded objectives, as discussed in Chapter 1 of this report, makes it difficult to assess the likelihood that the CCSP will succeed at reaching its overarching goals. In short, it appears that the CCSP has not carefully conducted a feasibility analysis of the activities proposed in the strategic plan.

The strategic plan would have been more convincing if the reader were able to draw a line from budgetary inputs through an implementing agency to final or even interim products. For example, the most clearly identified deliverables in the revised plan are the 21 synthesis and assessment products. As noted elsewhere in this report, the connection between each of these synthesis products and the overarching program goals is not clearly made. Moreover, it is not clear what these products are envisioned to encompass. At one extreme, they may simply represent summaries of the current state of knowledge about the selected topics. Although it would be feasible to produce such summaries quickly and at relatively low cost, this would represent at best a minimal step toward reaching the plan's overarching goals. On the other extreme, if these

synthesis products are intended to provide the scientific basis for achieving these higher-level goals, then the plan is unrealistically optimistic in what can be accomplished at current funding levels in two to four years. The true aim likely lies somewhere between these extremes, but without further clarification it is not possible to say whether the objectives are likely to be achieved.

Recognizing the difficulties of government officials commenting on future budgets, some indication of the financial and other resources that will be required to carry out the program is nonetheless needed. The CCSP has indicated that these details would be worked out as implementation of the plan moves forward, but no process by which this would occur has been proposed. It is absolutely critical to the success of the plan that such a process be formalized and initiated as soon as possible and that it involve scientists and stakeholders from outside the federal government in both the design and oversight of research programs. The committee believes that significant progress toward the plan's higher-level goals is possible at reasonable levels of funding and over a reasonable period of time. However, to ensure that progress is made, it is necessary to develop specific research programs, conduct careful feasibility analysis, and provide adequate funding, institutional, and other support required to achieve the stated objectives.

Ensuring Adequate Financial Resources

The revised strategic plan identifies a much broader scope of activities than has historically been supported under the auspices of the Global Change Research Program (GCRP). To succeed, such an expansion in scope will require a concomitant expansion in funding. A fully informed assessment of whether adequate funding is available for the proposed program was not possible because the CCSP did not provide the committee with prospective budget information and because many of the objectives in the plan are too vaguely worded to determine what will constitute success. However, the present budget for the CCSP does not appear to be capable of supporting all of the activities identified in the strategic plan. Whereas well-established program elements have a track record of funding, newer or expanded areas in the strategic plan lack clear budget lines and agency homes. The major expansion in climate modeling and climate observations that the plan calls for will also require an increase in funding above current levels. There is no evidence in the plan or elsewhere of a commitment to provide the necessary funds for these newer or expanded program elements. Whatever the budget allocations, the CCSP and participating agencies will need to start making budget decisions and setting priorities to allow the program to meet the ambitious overarching goals of the plan.

The CCSP needs strong leadership and effective management approaches to address problems in the distribution of current funding and to develop new funding as needed. The committee recognizes the major challenges associated with deciding how to allocate new resources and shift existing resources across 13 agencies and congressional jurisdictions. There are at least four management approaches to funding that could be used to address these challenges. One approach would be to designate a single agency to manage or coordinate the program. Such an approach would avoid some of the difficulties in coordinating programs and budget across so many agencies and congressional jurisdictions. However, this approach could weaken strong research programs that are currently managed by other agencies if these programs felt "disenfranchised" by the lead agency. A second approach would to provide the CCSP Office itself with a significant amount of funding to be used to support new and crosscutting initiatives and other program priorities. This would create a strong incentive for agency programs to coordinate with each other on these initiatives while leveraging existing programs within individual agencies. A potential downside to this approach would be that it could lead to significant reductions in funding in existing programs unless accompanied by major increases in funding for the CCSP as a whole. A third approach would be to require the CCSP agencies to prepare and submit a joint budget to the Office of Management and Budget (OMB), as was done in the early years of GCRP, and to empower OMB to recommend changes in funding allocations across the agencies. This approach would create incentives for agencies to cooperate in preparing a joint budget. If not implemented carefully, however, it could put OMB, rather than the CCSP leadership and others who are more knowledgeable about climate change science and technology issues, in a position of making decisions on programmatic priorities. A fourth approach would be to have the interagency CCSP make recommendations about funding and program allocations to the Interagency Working Group on Climate Change Science and Technology, which is the process described in the strategic plan. An advantage of this approach is that it allows those most knowledgeable about the program to make funding decisions. The division of authority among 13 agencies is likely to make it difficult to agree on changes in funding allocation and prioritization, as has been observed throughout the history of the GCRP (NRC, 2001).

Recommendation: The CCSP and its parent committees should (1) develop a clear budgetary process linking tasks to agency and program budgets; (2) secure the financial resources, for the present and the future, that will ensure the overall success of the plan; and (3) consider new approaches to funding that will enable

new initiatives and shifting of resources to respond to the nation's evolving needs.

Capacity Building

In reviewing the draft strategic plan, the committee recommended that the revised strategic plan "explicitly address the major requirements in building capacity in human resources that are implied in the plan" (see Box 3-4). The revised plan mentions capacity building in the context of the modeling strategy, decision support, and international research and cooperation, but does not discuss capacity needs spanning the entire program. The CCSP likely faces shortages in the human and institutional capacity needed to implement the strategic plan, especially in new and expanded program areas. Of particular concern is the need for a program to train the next generation of "adaptation specialists" that can work in sectors most impacted by climate, such as energy, water management, agriculture, fisheries, and ecosystems management. To meet the nation's needs for innovative solutions to challenging social problems associated with climate change, the CCSP should devise ways to support economists, sociologists, anthropologists, statisticians, lawyers, policy advisors, communications specialists, and other social science specialists in climate and adaptation programs.

Within the agencies, the capability and inclination to provide decision support—as opposed to basic scientific results—may be limited. Given the expanded attention to decision support, communication with stakeholders, and interagency coordination, the committee sees a much larger role and responsibility being placed on the CCSP Office. However, that office may not have the human resources necessary to meet the strategic plan objectives. As the provision of decision support is a central goal of the overall plan, failure in this area would represent a serious failure of the overall program.

Recommendation: The CCSP should carefully assess the needs in capacity implied by the strategic plan and address any gaps by coordinating ongoing capacity building efforts at participating agencies and initiating new programs as needed. The CCSP Office should be appropriately resourced to reflect its expanded roles.

BOX 3-4

Planning Climate and Global Change Research **(NRC, 2003b) Recommendation**
The revised strategic plan should explicitly address the major requirements in building capacity in human resources that are implied in the plan.

Revisions to the CCSP Strategic Plan
Capacity building is mentioned in three chapters of the revised plan: Chapter 10 (Modeling Strategy) states that the CCSP will "establish graduate, post-doctoral, and visiting scientist programs to cross-train new environmental scientists for multidisciplinary climate and climate impacts modeling research and applications" (CCSP, 2003, p. 107); Chapter 11 (Decision Support Resources Development) states that "the analyses and development of other decision support resources are intended to support the decision-making process and to be capacity-building activities" (CCSP, 2003, p. 112); and Chapter 15 (International Research and Cooperation) includes a section on CCSP efforts to "build scientific capacity in the developing world" (CCSP, 2003. p. 167). The plan does not present a discussion of human resources and institutional capacity needs spanning the entire program. Of particular concern is the capacity needed to achieve goals in new or expanded areas of the program.

4

Strategic Planning

EVALUATION OF THE PLANNING PROCESS

The draft plan was developed largely by the Climate Change Science Program (CCSP) Office and the participating agencies without involvement of the external community. As a consequence, and as pointed out in this committee's first report, the draft plan was of mixed scientific quality, with the result that those chapters drawing upon preexisting expert working groups and science initiatives (e.g., atmospheric composition and the carbon cycle) were better developed and more consistent with the community consensus about priorities than other chapters in the plan (NRC, 2003b).

Once developed, however, a number of steps were taken to solicit input on the draft strategic plan. The CCSP organized a Planning Workshop in December 2002, which was open to all interested parties. The effort it took to organize such a large workshop for the discussion of the draft report was notable and widely appreciated. Comments on the draft plan were solicited from numerous scientists and stakeholders, at the workshop, by e-mail, and by other means. These approaches succeeded in communicating the thoughts and ideas of hundreds of people; well over 1,000 people attended the workshop and some 900 pages of written comments were received. In addition, the CCSP requested and received a detailed report from this committee. Overall, the mechanisms for gathering and organizing input relevant to the draft plan were commendable. In the view of the committee, the approaches taken by CCSP to receive and respond to comments from a very large and very broad group of scientists and stakeholders sets a high standard for all government research programs related to the development and use of science and engineering information.

The workshop was structured to elicit a wide variety of ideas and suggestions for improvement. The agenda included keynote addresses by many top Administration and international officials, breakout sessions focused on individual chapters or crosscutting issues, and plenary session summaries of the breakout sessions. In each breakout session, an overview presentation was made by an agency employee, two to four invitees then presented a critique of the designated section of the plan, and finally the session was opened to comments from the audience. The workshop attendees were able to engage openly in discussions, to express ideas, and to offer suggestions for improvement. A message of transparency and openness was constantly communicated to all participants. The format of plenary sessions, breakout groups, and breakout group summaries was generally effective in facilitating the exchange of ideas at such a large gathering.

There are opportunities for improvements in future workshops of this type. First, in several sessions, the balance between presentation and discussion should have been modified to permit more of the latter. The constrained schedule for the conference meant that the printed document dominated the agenda, leaving insufficient time to discuss questions about the underlying assumptions and gaps in the program's intellectual underpinning. Second, particular efforts should be made to attract stakeholders and scientists from programs now targeted for enhancement, such as decision support. Participation in the workshop was dominated by agency employees and scientists supported by federal funding, with significantly smaller attendance by scientists from previously underemphasized program elements, the private sector, state and local natural resource and land-use decision makers, and the environmental community.

It was clear that the comments elicited were welcomed and would receive consideration. The process used to make decisions regarding the comments was not well communicated. The committee recognizes the difficulty associated with specifying exactly how comments would be evaluated, as such activities inevitably involve extensive discussions among the plan drafters and managers. At the same time, more transparency would have been desirable regarding how comments would be weighed, how conflicting comments would be resolved and how the program would respond to suggestions not to be implemented. For the most part, the CCSP's revisions to the strategic plan are quite responsive to comments expressed at the workshop, in written input, and by this committee. One notable exception is the fact that the revised plan does

not acknowledge the substantive and procedural contributions of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (NAST, 2001), a major focus of the Global Change Research Program (GCRP) in the late 1990s. Many participants at the December workshop criticized how the draft strategic plan treated the National Assessment, as did this committee in its first report (NRC, 2003b). The revised plan does not reflect an attempt to address these concerns, and no rationale for this decision has been provided.

As the program moves forward from planning to implementation, regular opportunities should be provided for interested parties to comment on the specific details of the program. The overall plan, and its individual components, will benefit from review boards, steering committees, and other structures that can provide external expert advice to the program's managers. In fact, at the committee's August 2003 meeting, several chapter authors indicated that they are planning workshops with research and stakeholder communities to further revise their portions of the strategic plan and to develop implementation plans. The committee commends the program managers for seeking input from expert communities in this manner. These smaller expert workshops would have been of even more value if they had taken place before the strategic plan was prepared and before the large planning workshop. Increasing the involvement of the decision support community and various stakeholders is an important way to improve future planning. This involvement should be given a high priority in the near term, starting with areas where there is already a receptive decision-making group, such as water resource managers.

THE NEXT GENERATION OF STRATEGIC PLANNING

The current strategic planning effort of the CCSP has been impressive. It has identified goals and objectives for the program, proposed an ambitious series of products that will shed light on issues perceived to be important for national decision makers, and stimulated a great amount of cooperation among the many participating agencies. But, as the CCSP itself has pointed out, planning and implementing such an ambitious program is itself something of an experiment. It is an experiment not only in managing activities among a diverse group of agencies but also in trying to produce near-term results and analyses helpful to decision makers while simultaneously assuring that the long-term nature of the climate change issue continues to receive sufficient attention. Even with the substantial history of the GCRP behind it, continued planning and management of the CCSP remains a work in progress.

While many of the activities that are envisioned in the current strategic plan will succeed, some will fail, and others will achieve their goals more slowly than anticipated. Some agencies will perceive their involvement in the CCSP to have advanced their missions; others will not. The science will proceed quickly in some areas and frustratingly slowly in others. It is critical that the program management and the agencies use these experiences in an adaptive way to adjust their own management practices as they identify the next series of tasks in a dynamic scientific, budgetary, and political environment. Embracing adaptive management for the program as a whole will require ongoing and rigorous evaluation and redirection. As discussed in Chapter 3 of this report, to identify which program elements are succeeding and which are lagging, the CCSP will need to conduct rigorous independent program reviews.

The committee believes that one way to ensure that adaptive learning occurs will be for the CCSP to conduct future strategic planning exercises, perhaps in collaboration with relevant international programs. The CCSP should update the strategic plan every three to five years. The updated strategic plan need not be as extensive as the current plan; it could instead focus largely on those areas of the science and the program for which adjustments are needed, and should spell out what those adjustments are intended to be. It will be critical that the updated plan be developed in cooperation with scientific and stakeholder communities, and that the updated plan identify the management responsibility and accountability for all the elements of the program, including its crosscutting functional components, such as communications and data management.

Recommendation: The CCSP should plan for the generation of an updated strategic plan every three to five years.

The process of producing the updated plan should reflect the learning that has accompanied the current CCSP strategic plan. Any strategic plan is a balance between the top-down goals of the organization and its bottom-up capabilities to deliver information and products. The current plan reflects this tension in the often poor linkage between the products and milestones identified in the individual science chapters and the five goals for the overall CCSP. The updated plan should resolve persisting linkage problems. This can be done effectively only by engaging the scientific community responsible for generating measurements and knowledge in each of the program's areas. This engagement should happen early and often, to provide timely feedback to the CCSP.

Involving the potential users of climate science (broadly defined) early in the updated strategic planning

effort will be equally important. Many of the activities proposed in the current plan could be used to structure such engagement, and their success will be critical to the overall success of the CCSP. Engaging users in an open and transparent way will strengthen the credibility of the plan. The CCSP should hold open workshops to review users' needs as a precursor to the development of an updated strategic plan.

Another improvement to the planning process should be a greater interaction with the global audience than has been achieved to date. This interaction should be rooted in both the science and decision support activities of the CCSP. By engaging the scientific and user communities in critical countries, the CCSP could be more effective in addressing its scientific objectives and in investing resources.

The CCSP should document and publish its process for strategic planning and implementation. The CCSP intends to become a learning organization, and one of the characteristics of such organizations is their documentation of what they have learned. Because documentation typically leads to institutionalization, the CCSP will be able to learn effectively from the current process of planning and implementation, and will be able to demonstrate the progress that the nation can reasonably expect in the future.

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Appendixes

Appendix A

Excerpts from Planning Climate and Global Change Research: A Review of the Draft U.S. Climate Science Program Strategic Plan

Contents

Preface

On September 17, 2002, Assistant Secretary of Commerce for Oceans and Atmosphere James R. Mahoney wrote to Bruce Alberts, president of the National Academy of Sciences, to request that the National Academies undertake a fast-track review of the U.S. Climate Change Science Program's (CCSP's) draft strategic plan for climate and global change studies. The letter (see Appendix D) asked the National Academies to form a committee to review both the discussion draft of the strategic plan and the final strategic plan after it has been revised. The letter also requested that the National Academies examine the CCSP's strategic planning process, focusing on the program's efforts to solicit input from the scientific and stakeholder communities between November 2002 and January 2003. In response the 17-member Committee to Review the U.S. Climate Change Science Program Strategic Plan (see Appendix B for committee biographies) was formed. This report is the committee's assessment of the discussion draft strategic plan dated November 11, 2002 and addresses phase I of the committee's statement of task (see Box P-1). A second report by this committee will review the final strategic plan after it has been released, addressing phase II of the committee's task (see Appendix B).

A challenging aspect of the committee's work has been to come to a clear understanding and agreement about the intended scope of the CCSP; that is, does the program focus exclusively on issues of "climate change"—as one might infer from the name of the *Climate Change* Science Program itself and its constituent, the *Climate Change* Research Initiative—or does it encompass all, or some, other global changes—as one might infer from the name of the CCSP's other constituent, the U.S. *Global Change* Research Program? While climate change has clearly been the major focus of past work by the GCRP and current work of the CCSP, the answer to this question has implications for the program's future. Specifically, it will determine which research areas belong in the program and, accordingly, the level of resources needed. In terms of the committee's work the answer to this question has a profound effect on how the committee responds to its task statement, in particular, to the question, "Is the plan responsive to the nation's needs for information on *climate change and global change*, their potential implications, and comparisons of the potential effects of different response options?"

The natural place to look for insights on this question was the draft strategic plan itself, which clearly indicates that the program is not designed to focus exclusively on climate change issues. For example, the title of the introductory chapter is "Climate and Global Change: Improving Connections Between Science and Society," and two of the five "climate and global change issues" to be informed by the program explicitly mention global changes other than climate change.[5] What is not clear in the draft plan is whether the program is designed to address all or some subset of issues pertaining to global change. As discussed in Chapter 2 of this report, part of the problem is that the draft strategic plan does not present a clear, concise statement of vision for the program.

Without that clear vision the committee developed its own working understanding of the intended scope of the CCSP. The committee believes that it will be important for the CCSP to consider those processes (1) that interact with climate change to produce significant impacts of societal relevance and therefore must be integrated into research to understand impacts and to develop adaptation and mitigation approaches, and (2) that have large feedbacks to climate change. In this report the committee uses the term "climate and associated global changes" as a general term encompassing those global changes included in the two categories above.

The CCSP will need to consider whether these or other criteria will determine the program's coverage of various global change processes. This is important from a planning perspective because the number of factors identified for CCSP's attention is likely to grow as the program's work with decision makers expands. Many decision makers deal with climate change as only one of a suite of factors affecting the people, economy, and ecosystems of an area. Not all of these factors will necessarily be appropriate for the CCSP's attention. An obvious tradeoff will be between depth and breadth, and the risk is a program spread so thin that it fails to make meaningful progress in core research areas. The CCSP's decisions about scope will have important implications for the portfolio of research to be funded initially, and for how this portfolio evolves over the program's lifetime.

[5] In particular, "How much have *climate and other aspects of the Earth system* changed since the industrial revolution…?" and "What is the sensitivity of natural and managed ecosystems to *climate and other global changes*" (CCSP, 2002, p. 4-5, emphasis added).

The committee was asked to review the draft strategic plan by focusing on nine questions (see Box P-1). Five of the first six questions, which apply to the draft strategic plan as a whole, are addressed in Part I of this report. The last three questions, which apply to each major section of the plan, are addressed in Part II of this report.

The third question in the statement of task ("Is there an appropriate balance (1) between short-term (2-5 years) and longer-term goals, (2) among substantive research areas, and (3) between research and nonresearch activities, such as observations, modeling, and communicating results?") is not addressed explicitly in this report. One way to assess these elements of balance would be through budget data accompanied by cost estimates for the underpinnings of individual research components (e.g., supercomputers, satellite instruments, socio-economic surveys) and categorized as in the task statement (e.g., short-term versus longer-term, research versus nonresearch). The draft strategic plan does not include such data, nor was it possible for the committee or the CCSP to generate it in the time available. Even if available, these data would reflect only the current balance of the program and not the future directions outlined in the draft plan (e.g., whether new activities, such as those in decision support, applied climate modeling, and land-use and land-cover change, will be supported through new funding or by redirecting funds currently devoted to other research areas). The fiscal year 2004 budget request for the CCSP provides some insights into the CCSP's plans for the program, but it also was not available in time for detailed analysis at the time this report was written. Another way to assess issues of balance would be from clearly stated program goals and priorities, which are not well articulated in the draft. Therefore, the committee was not able to evaluate the balance of the plan in a detailed way. Chapter 3 of this report provides some insights on balance issues by identifying elements of the draft plan that are appropriate short-term and longer-term objectives, and by pointing out areas needing additional research. The committee will address the balance question in its second report, when the draft has been revised and relevant budget data are available.

This report is not the only mechanism through which the CCSP has received input on the draft strategic plan. On December 3-5, 2002, the CCSP held a major workshop in Washington, D.C., to obtain input from scientific and other stakeholder communities. The workshop was attended by over 1000 scientists, agency representatives, and other stakeholders who participated in breakout sessions focused generally on the strategic plan chapters and selected crosscutting themes (see <http://www.climatescience.gov /events
/workshop2002/>). In the second phase of this study the committee will assess the effectiveness of this workshop as a mechanism for gathering scientists' and other stakeholder's comments on the draft plan, as directed in the statement of task. The CCSP also provided a mechanism for interested parties to submit written comments on the draft strategic plan. The committee was able to examine comments received by the CCSP before its last meeting on January 8-10, 2003, and this report is written in light of those viewpoints.

The committee held three meetings to gather information and prepare this report. The first meeting was held on November 22, 2002, in Washington, D.C. At this meeting James R. Mahoney and Richard Moss, executive director of the U.S. Global Change Research Program, presented an overview of the draft strategic plan and the strategic planning process. Representatives from participating departments and agencies also discussed with the committee their agency's strategic planning process and how their agency's research relates to the CCSP program. We thank the following individuals who participated in this meeting: James R. Mahoney, U.S. Climate Change Science Program; Richard Moss, U.S. Global Change Research Program; Mary Glackin, National Oceanic and Atmospheric Administration; Jack Kaye, National Aeronautics and Space Administration; Jerry Elwood, Department of Energy; Ari Patrinos, Department of Energy; Michael Slimak, Environmental Protection Agency; Steve Shafer, Department of Agriculture; Daniel Reifsnyder, Department of State; Harlan Watson, Department of State; Martha Garcia, U.S. Geological Survey; James Andrews, Office of Naval Research; Karrigan Bork, Department of Transportation.

Members of the committee attended the CCSP planning workshop on December 3-5, 2002, and then held a second meeting in Washington, D.C., on December 6, 2002. At this meeting the committee discussed the CCSP workshop and began to develop this report. In addition Robert Marlay, director of the Department of Energy's Office of Science and Technology Policy Analysis, briefed the committee on the Climate Change Technology Program. The committee's third meeting was held on January 8-10, 2003, during which the committee prepared this report.

The committee called upon a number of National Academies' boards and standing committees with expertise in issues of climate and global change. In the short period of time available these boards and standing committees and their staffs produced very thoughtful summaries of the strengths and weaknesses of the draft strategic plan. The committee acknowledges the efforts of the following individuals who took the lead in preparing the materials on behalf of these units:

- Board on Atmospheric Sciences and Climate: Eric Barron, Pennsylvania State University, University Park, and Amanda Staudt, National Research Council (NRC) staff;
- Ocean Studies Board: Jay McCreary, University of Hawaii, Manoa, and Morgan Gopnik, NRC staff;
- Polar Research Board: Richard Alley, Pennsylvania State University, University Park, and Chris Elfring, NRC staff;

- Climate Research Committee: Tony Busalacchi, University of Maryland, College Park, and Amanda Staudt, NRC staff;
- Committee on Human Dimensions of Global Change: Tom Dietz, George Mason University, Fairfax, Virginia, Tom Wilbanks, Oak Ridge National Laboratory, Tennessee, and Paul Stern, NRC staff; and
- Committee on Earth Studies: Michael Freilich, Oregon State University, Corvallis, and Arthur Charo, NRC staff.

The committee also received comments on the draft plan from several members of the Committee on Geophysical and Environmental Data and its staff director, Anne Linn. The contributions from these boards and committees were extremely useful in informing the committee's deliberations. Though these individuals provided many useful insights and suggestions, many of which are reflected in the report, they did not participate in the committee's closed session discussions and are not responsible for the final content of this report.

This study differs from most National Academies studies in three respects. First, the timeline for this first report was limited—approximately three months from the committee's first meeting to the deadline for delivery of this report. This timeline was driven by the CCSP's ambitious push to publish a final plan by the end of April 2003. Second, the committee was asked to review both a preliminary draft of the strategic plan and the final strategic plan, enabling the committee to provide advice at a stage in the strategic planning process when it could be most useful. Third, as discussed above, the CCSP convened a major workshop and solicited public comments on the draft plan while the study was underway. As a result, a number of the issues raised in this report have already been brought to the attention of CCSP leadership and recognized by them (see <http://www.climatescience.gov/Library/workshop2002/closingsession>).

The committee gratefully acknowledges the NRC staff who worked hard to facilitate its deliberations and the preparation of this report. Gregory Symmes and Amanda Staudt made major contributions to the report, at considerable personal sacrifice. Kristen Krapf was instrumental in coordinating input to the report from the committee and the NRC boards and committees. Byron Mason and Elizabeth Galinis were an extremely effective team in ensuring that the committee's meetings and report production went smoothly.

The committee has worked diligently to make this report as useful as possible to the CCSP. We wish the CCSP leadership well as it takes on the challenging task of revising the draft strategic plan to enhance the usefulness of the program to the decision makers who need to better understand the potential impacts of climate change and make choices among possible responses. In the opinion of many of the committee members the issues addressed by the CCSP are among the most crucial of those facing humankind in the twenty-first century.

Thomas E. Graedel, Chair

BOX P-1 STATEMENT OF TASK FOR PHASE I

An ad hoc committee will conduct an independent review of the U.S. Climate Change Science Program's strategic plan for global change and climate change studies, giving attention also to the program's strategic planning process. This review will be carried out in two phases.

Phase I

In the first phase, the committee will review the discussion draft of the plan. The review will address the following questions about the draft plan as a whole:

- Is the plan responsive to the nation's needs for information on climate change and global change, their potential implications, and comparisons of the potential effects of different response options?
- Are the goals clear and appropriate?
- Is there an appropriate balance (1) between short-term (2-5 years) and longer-term goals, (2) among substantive research areas, and (3) between research and nonresearch activities, such as observations, modeling, and communicating results?
- Are mechanisms for coordinating and integrating issues that involve multiple disciplines and multiple agencies adequately described?
- Does the plan adequately describe the roles of the public, private sector, academia, state/local governments, and international communities, and linkages among these communities?
- Does the written document describing the program effectively communicate with both stakeholders and the scientific community? Is the question format for driving the research program effective?

The review also will address the following questions for each of the plan's major topical areas:

- Does the plan reflect current scientific and technical understanding?
- Are the specific objectives clear and appropriate?
- Are expected results and deliverables (and their timelines) realistic given the available resources?

In its review, the committee will consider the scientific and stakeholder community comments at the U.S. Climate Change Science Program's workshop and other comments received by the program during the public comment period. If time permits, the committee also will comment on any significant process issues related to the workshop that could affect how the program revises the draft plan. The results of phase I will be provided in a report to be delivered no later than February 28, 2003.

Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

James Anderson, Harvard University, Cambridge, Massachusetts
D. James Baker, The Academy of Natural Sciences, Philadelphia, Pennsylvania
Roberta Balstad Miller, Columbia University, Palisades, New York
Christopher B. Field, Carnegie Institution of Washington, Stanford, California
Inez Fung, University of California, Berkeley
Gregory Greenwood, California Resources Agency, Sacramento
George M. Hornberger, University of Virginia, Charlottesville
Henry D. Jacoby, Massachusetts Institute of Technology, Cambridge
Charles F. Kennel, Scripps Institution of Oceanography, La Jolla, California
Richard S. Lindzen, Massachusetts Institute of Technology, Cambridge
Susanne C. Moser, Union of Concerned Scientists, Cambridge, Massachusetts
Edward A. Parson, Harvard University, Cambridge, Massachusetts
W. Richard Peltier, University of Toronto, Ontario, Canada
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Edward S. Sarachik, University of Washington, Seattle
Christine S. Sloane, General Motors Corporation, Warren, Michigan
Susan Solomon, NOAA Aeronomy Laboratory, Boulder, Colorado
B.L. Turner, II, Clark University, Worcester, Massachusetts
Robert M. White, Washington Advisory Group, Washington, D.C.
Oran R. Young, University of California, Santa Barbara

Although the reviewers listed above have provided constructive comments and suggestions, they were not asked to endorse the report's conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Richard M. Goody (Harvard University) and Robert A. Frosch (Harvard University). Appointed by the National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Executive Summary

For the last century human activities have been altering the global climate. Atmospheric abundances of the major anthropogenic greenhouse gases (carbon dioxide, methane, nitrous oxide, and tropospheric ozone) reached their highest recorded levels at the end of the twentieth century and continue to rise. Major causes of this rise have been fossil fuel use, agriculture, and land-use change. Observations show that Earth's surface warmed by approximately 0.6 ^{o}C (1.1 ^{o}F) over the twentieth century. This warming has been attributed in large part to increasing abundances of greenhouse gases, though it is difficult to quantify this contribution against the backdrop of natural variability and climate forcing uncertainties. The emerging impacts of this change on natural systems include melting glaciers and ice caps, sea level rise, extended growing seasons, and changes in the geographical distributions of plant and animal species. Because the Earth system responds so slowly to changes in greenhouse gas levels, and because altering established energy-use practices is difficult, changes and impacts attributable to these factors will continue during the twenty-first century and beyond. Uncertainties remain about the magnitude and impacts of future climate change, largely due to gaps in understanding of climate science and the socio-economic drivers of climate change.

Research to understand how the climate system might be changing, and in turn affecting other natural systems and human society, has been underway for more than a decade. Significant advancement in understanding has resulted from this research, but there are still many unanswered questions, necessitating a continuance of this effort. As society faces increasing pressure to decide how best to respond to climate change and associated global changes, there is a need to focus at least part of this effort on more applied research in direct support of decision making. In particular, research efforts are needed to explore response options and evaluate the costs and benefits of adaptation and mitigation.

The U.S. Climate Change Science Program (CCSP) was formed in 2002 to coordinate and direct U.S. efforts in climate change and global change research. The CCSP builds upon the decade-old U.S. Global Change Research Program (GCRP). Since its inception the GCRP has reported hundreds of scientific accomplishments and, together with other major international partners and programs, has been responsible for improving the understanding of climate change and associated global changes. The CCSP incorporates the GCRP and adds a new component—the Climate Change Research Initiative (CCRI)—whose primary goal is to "measurably improve the integration of scientific knowledge, including measures of uncertainty, into effective decision support systems and resources" (CCSP, 2002, p.15). A draft strategic plan for the CCSP was released to the scientific community and the public in November 2002. At the request of the CCSP, the National Academies formed a committee to review this draft strategic plan; the results of this review are reported herein. The committee's statement of task can be found in Appendix E of this report.

STRENGTHS OF THE DRAFT CCSP STRATEGIC PLAN

The committee commends the CCSP for undertaking the challenging task of developing a strategic plan. The current draft of the plan represents a good start to the process, particularly in that it identifies some exciting new directions for the program while building on the well-established foundation of the GCRP. Further, the CCSP has made genuine overtures to researchers and the broader stakeholder community to gain feedback on the draft strategic plan and how to improve it. These efforts indicate a strong interest on the part of the CCSP in developing a plan that is consistent with current scientific thinking and is responsive to the nation's needs for information on climate and associated global changes.

The CCRI portion of the plan introduces an admirable emphasis on the need for science to address national needs, including support for those in the public and private sectors whose decisions are affected by climate change and variability. For example, the discussion of applied climate modeling in the draft plan insightfully articulates a much-needed new direction for U.S. climate-change modeling, reaching out beyond the "business as usual" approach of the GCRP to provide tangible decision support resources, particularly tested and trusted projections (or "forecasts") of future climate. The draft plan correctly identifies the need to enhance research on options for adaptation to climate change. In addition, the plan appropriately recognizes that there are some short-term products that can and should be delivered by the program.

The committee finds that the draft plan identifies many of the cutting-edge scientific research activities that are necessary to improve understanding of the Earth system. For example, the acceleration of research on aerosols and the carbon cycle is consistent with priorities of the scientific

community. Indeed, the GCRP portion of the plan clearly builds upon the substantial and largely successful research programs of the last decade. The call for greatly improved observational capabilities reflects a well recognized priority for increasing understanding of climate and associated global changes. Further, the plan takes positive steps towards improved interdisciplinary research opportunities. Overcoming the substantial hurdles associated with the highly interdisciplinary nature of research on climate and associated global changes will continue to be a fundamental challenge for the program.

In general, the draft plan provides a solid foundation for the CCSP. With suitable revisions, the plan could articulate an explicit and forward-looking vision for the CCSP and clearly identifiable pathways to successful implementation.

Recommendation: The draft plan should be substantially revised to: (1) clarify the vision and goals of the CCSP and the CCRI, (2) improve its treatment of program management, (3) fill key information needs, (4) enhance efforts to support decision making, and (5) set the stage for implementation.

CLARIFY VISION AND GOALS

The committee found that the draft strategic plan lacks the kind of clear and consistent guiding framework that would enable decision makers, the public, and scientists to clearly understand what this research program is intended to accomplish and how it will contribute to meeting the nation's needs. The draft plan lacks most of the basic elements of a strategic plan: a guiding vision, executable goals, clear timetables and criteria for measuring progress, an assessment of whether existing programs are capable of meeting these goals, explicit prioritization, and a management plan. Many candidates for vision and goals are scattered throughout the draft strategic plan and in references to other documents, yet neither an explicitly stated vision nor a coherent set of goals are consistently presented. The draft plan lists a multitude of proposed activities, but does not identify which of these activities are higher priorities than others (either across the CCSP as a whole or within individual program areas of the CCRI or the GCRP) nor does it provide an explicit process for establishing such priorities. Finally, the plan lacks the kind of straightforward comparison of current programs to projected needs that will be essential to guide the plan's implementation. A systematic and coherent strategic plan is especially necessary when, as in the CCSP, the institutional environment is diverse and fragmented and when the program involves new directions and collaborations. Such a plan would provide a common basis for planning, implementation, and evaluation and would protect against a continuation of the *status quo*.

Recommendation: The revised strategic plan should articulate a clear, concise vision statement for the program in the context of national needs. The vision should be specific, ambitious, and apply to the entire CCSP. The plan should translate this vision into a set of tangible goals, apply an explicit process to establish priorities, and include an effective management plan.

The revised strategic plan also must present clear and consistent goals for the CCRI. The draft plan states that to be included in the CCRI, a program must produce both significant decision or policy-relevant deliverables within two to four years and contribute significantly to one of the following activities: improve scientific understanding; optimize observations, monitoring, and data management systems; and develop decision support resources. The decision support activities described in Chapter 4 of the draft plan are generally consistent with the above criteria. In fact, the committee considers the CCRI's emphasis on scientific support for decision makers one of the most promising and innovative features of the draft plan. Unfortunately, the plan's descriptions of decision support as a two to four year activity give the false impression that decision support is needed only in the near-term. While short-term deliverables are possible in this arena, decision support also will be needed as an ongoing component of the program. In addition, many of the activities described in Chapters 2 and 3 of the draft plan are not consistent with the CCRI focus on decision support and are not likely to produce deliverables within four years. This is not to say that these activities are unimportant, but simply that they are not consistent with the goals for CCRI as given in the draft plan. The committee believes that it is important for the program to correct these inconsistencies while maintaining a strong emphasis on near-term, ongoing decision support in the CCRI. The revised strategic plan also needs to describe more clearly how the research activities included in the GCRP support the decision support needs of the CCRI. Indeed, there should be a "rolling linkage" between the two programs, with CCRI objectives periodically redefined as a result of new scientific input from the GCRP.

Recommendation: The revised strategic plan should: (1) present clear goals for the CCRI and ensure that its activities are consistent with these goals; (2) maintain CCRI's strong emphasis on support for near-term decisions as an ongoing component of the program; and (3) include an explicit mechanism to link GCRP and CCRI activities.

IMPROVE PROGRAM MANAGEMENT

The management of an interagency program involving 13 agencies, each with a separate mission and a long history

of independent research on climate and associated global changes, is a challenging task. The GCRP has been criticized in the past for being unable to do much beyond encouraging multi-agency cooperation and support because it lacked the authority to redirect long standing programs and mandates of individual agencies. The creation of a cabinet-level committee with the authority to shift resources among agencies to meet the goals of the CCSP is an improvement over past approaches to managing the GCRP. However, the interagency approach to managing the program may not be enough to ensure that agencies cooperate toward the common goals of the CCSP because no individual is clearly identified in the draft plan as having responsibility for managing the program as a whole.

Recommendation: The revised strategic plan should describe the management processes to be used to foster agency cooperation toward common CCSP goals. The revised plan also should clearly describe the responsibilities of the CCSP leadership.

The plan does not describe the responsibilities and authorities of contributing agencies, such as which agencies will be responsible for implementing the work. Defining responsibilities is particularly important for new areas of research that have not been significant program elements of the GCRP in the past, such as land-use and land-cover change and decision support. It is also important for crosscutting research elements, notably water cycle and ecosystems research, which are carried out within multiple agencies. Another management challenge for the CCSP is to foster the participation of mission-oriented agencies in the strategic planning process. The committee believes that mission-oriented agencies—such as the Federal Emergency Management Agency, water resources and land management agencies within Department of the Interior, the Army Corps of Engineers, and the extension and farm program agencies within U.S. Department of Agriculture—could make important contributions to identifying research needs, collaborating on research problems, and testing research and modeling results.

Recommendation: The revised strategic plan should more clearly outline agency responsibilities for implementing the research. In addition, the CCSP should encourage participation of those agencies whose research or operational responsibilities would strengthen the ability of the program to deliver products that serve national needs.

The Climate Change Technology Program (CCTP) is an interagency program parallel to the CCSP and created to coordinate and develop technologies for stabilizing and reducing greenhouse gas levels in the atmosphere. The committee is concerned that the existing management and program links between the CCSP and the CCTP may not be extensive enough to take advantage of the synergies between these two programs. This may be due in part to the CCTP's early stage of development. Generally speaking, a program to define and understand a massive problem (i.e., the CCSP) and a program to develop options for solution to the problem (i.e., the CCTP) should be guided by a common strategy. At the very least the results from each program should be used as extensive guidance for the project portfolio of the other. For example, technology options should be pursued for the highest-risk problems and informed by the most robust knowledge of those problems. Likewise, the global change effects of implementation of various solutions (e.g., sequestration impacts) should be identified and studied as an integral part of technology programs.

Recommendation: The CCSP should assess the scientific implications of technologies under consideration by the CCTP and develop realistic scenarios for climate and associated global changes with these technologies in mind. The program management chapter of the revised CCSP strategic plan should clearly describe mechanisms for coordinating and linking its activities with the technology development activities of the CCTP.

The plan currently describes scientific planning committees that will be composed of independent experts to help the agencies plan specific program elements, as has been done for the carbon cycle, the water cycle, climate observations, climate modeling, and elsewhere. The committee supports this approach. Nonetheless, the committee believes that the most difficult research management challenges will occur at the level of the CCSP program itself. Scientific and other stakeholder guidance will be needed for the whole program to establish and communicate clear priorities, evaluate progress toward meeting the overarching goals, and ensure that the inevitable trade-offs in resources and allocation of time are done so as to meet the overall program goals. Otherwise, the individual needs and priorities of the agencies will tend to take precedence over the needs of the entire program.

Recommendation: The CCSP should establish a standing advisory body charged with independent oversight of the entire program.

FILL KEY INFORMATION NEEDS

The committee identified several weaknesses in the draft strategic plan that need to be addressed if the CCSP is to meet the nation's needs for information on climate and associated global changes. First, there is now a strong need to augment the GCRP research of the last decade, which focused on national- to global-scale phenomena, with research that applies an understanding of the global scale to developing an understanding of the variability and change

unique to regional scales. Such information would be useful to international, federal, state, and local decision makers facing environmental problems, including drought, flooding, or other climate impacts. Insufficient detail is provided in the draft plan about how current work on large-scale climate models will be adapted and combined with information to address regional issues and seasonal-to-interannual timeframes. Particularly important and challenging will be analyses and modeling of future regional climate and related effects on social, economic, and ecological issues. The need to develop regional research products is not adequately emphasized throughout the strategic plan or integrated through all program elements.

Recommendation: The revised strategic plan should more fully describe how models and knowledge that support regional decision making and place-based science will be developed.

The next decade of research must also support an increase in understanding the potential impacts of climate change on human societies and ecosystems, and related options for adaptation and mitigation. The need for research and applications in these areas logically follows from the CCSP's new emphasis on decision support. The plan's treatment of human dimensions and ecosystems, however, has several important gaps. It lacks research into consumption, institutions, and social aspects of technology as causes of climate and associated global changes. Further, the draft plan does not propose any research into the costs and benefits of climate change and related response options. Finally, the research plan for ecosystems needs a more cohesive and strategic organizational framework that places a clear priority on predicting ecosystem impacts and on providing the scientific foundation for possible actions and policies to minimize deleterious effects and optimize future outcomes. The committee finds that, while the draft strategic plan does address these topics to some extent, its coverage is insufficient to provide adequate input into the models and analyses necessary to reduce or clarify uncertainties, or to meet current and anticipated needs of decision makers.

Recommendation: The revised plan should strengthen its approach to the human, economic, and ecological dimensions of climate and associated global changes to ensure it supports the research necessary to project and monitor societal and ecosystem impacts, to design adaptation and mitigation strategies, and to understand the costs and benefits of climate change and related response options.

The draft strategic plan does a better job of identifying links between chapters and crosscutting themes than in the past, but, overall, the coordination among many individual program components is poor. Examples include the generally weak integration of the human dimensions, ecosystems, and water cycle issues across the plan; the nearly complete disconnect among the atmospheric composition, ecology, and land-use and land-cover chapters; and the uneven consideration of the role of the ocean in climate. The draft plan also does not adequately consider the interactions and synergies of climate change with other global changes. Climate change operates in concert with other significant changes, such as those related to land-use dynamics and hydrological cycles. Therefore, most scientists and decision makers typically do not find themselves dealing with climate change in isolation but rather as one of many factors affecting the people, economy, and ecosystems of an area.

Recommendation: The CCSP should strengthen the treatment and integration of crosscutting research areas in all substantive chapters. The revised strategic plan should address the interactions and synergies of climate change with other associated global changes.

The draft plan makes repeated reference to *the* global climate observing system, and yet to date the system is only a patchwork of observational networks maintained by various agencies within the United States and by other nations. Careful planning and major investments are needed to maintain and expand an integrated observing system that will support monitoring and modeling of climate and associated global changes. A critical weakness in the draft plan is that it does not adequately explain how existing observation systems will be integrated with a plan for expansion of them to add key climate-related ecological, biogeochemical, geophysical, and environmentally relevant socio-economic measurements. Especially for systematic integrated measurements, interagency and international cooperation could bring major advances. An integrated global climate observing system should also have a plan to make scientific products widely available in useful formats for climate-system researchers and for decision makers, to ensure continuity of observations, and to accommodate flexibility in response to changing scientific questions and societal needs.

Recommendation: The revised strategic plan should better describe a strategic program for achieving an integrated observing system for detecting and understanding climate variability and change and associated global changes on scales from regional to global.

The committee believes that the draft plan misses an opportunity to develop a forward-looking strategy for improving international research and observation networks, exchanges of knowledge, and joint assessments. There is little discussion in the draft plan of how and whether the CCSP will participate in such international efforts. The overall sense of insularity in the plan could hinder efforts to

improve linkages with the international community. International collaboration is especially valuable for building better *in situ* calibration and validation of satellite observations, for obtaining more globally distributed measurements, and for building synergy and reducing redundancy in the deployment of observation assets. Scientifically, there is a danger that the emphasis on U.S. issues and resources in the plan will result in agencies choosing not to work in geographic regions outside the United States that are significant for understanding particularly important processes.

Recommendation: The revised strategic plan should clearly describe how the CCSP will contribute to and benefit from international research collaborations and assessments.

A manifestation of the general insularity of the draft plan is that it fails to place sufficient weight on the need for the global and long-term historical context in observing, understanding, modeling, and responding to climate variability and change. This lack of context is not consistent with the global and long time-scale research perspectives of many climate scientists. The plan does not take into account, for example, how climate variability and change in North America is influenced by global variability involving the land surface, atmosphere, ocean, and cryosphere in regions remote to North America. A better presentation in the plan of the time and space scales associated with climate change also would point to the value of paleoclimate data as a descriptor of past natural variability.

Recommendation: The global and long-term historical context of climate change and variability should receive greater emphasis in the revised strategic plan.

STRENGTHEN DECISION SUPPORT CAPABILITY

The committee views the definition and development of decision support resources as a critical short-term goal of the CCSP. Although the draft strategic plan has incorporated general language about decision support in many places, it is vague about what this will actually mean. The draft plan fails to adequately distinguish between research to develop new decision support tools and understanding on the one hand, and operational decision support activities, on the other. It then does not successfully identify state-of-the-art undertakings in both. A significant problem with the draft plan is that an explicit connection to decision-making problems—both anticipated decision-making needs and past experiences—is absent. Indeed, the plan does not recognize the full diversity of decision makers and does not describe mechanisms for two-way communication with stakeholders.

Recommendation: The revised strategic plan should identify which categories of decision makers the CCSP serves and describe how the program will improve two-way communication with them. The revised plan also should better describe how decision support capabilities will be developed and how these efforts will link with and inform the program's research to improve understanding of climate and associated global changes.

The draft strategic plan's description of applied climate modeling is quite insightful, reasonably well focused, and well grounded with respect to the priorities for climate modeling research and applications over the next decade. Even so, the treatment of this topic does not adequately address several substantial challenges to meeting the ambitious goals it sets forward: (1) the optimistic, and likely unrealistic, objective of fully understanding cloud feedbacks and therefore significantly reducing climate sensitivity uncertainties within two to four years; (2) the challenge of making connections between the applied climate modeling results and the climate-impacts research community, and on to policy makers, resource managers, and other consumers of climate-change information; (3) how the current modeling community's efforts will support multiple objectives (e.g., producing scenarios for the Intergovernmental Panel on Climate Change, reducing climate sensitivity, evaluating regional impacts); (4) the lack of new resources to build the needed supercomputing and human resource capacity; and (5) the limitations of existing observation records for testing models.

Recommendation: The discussion of applied climate modeling should be revised to better describe how models will be incorporated into the broader suite of decision support activities and to better address the key challenges to attaining the applied climate modeling goals set forward in the plan.

The draft strategic plan identifies the reduction of uncertainty as a top priority for the CCSP and the CCRI. It recognizes three important points about uncertainty: (1) uncertainty is inherent in science and decision making and therefore not in itself a basis for inaction; (2) decision makers need to be well informed about uncertainty so that decisions can be made more knowledgeably; and (3) accelerated research should focus on those uncertainties that are important for informing policy and decision making. Unfortunately, having recognized these principles of decision making under uncertainty, the draft plan does not apply a systematic process to identify the key scientific uncertainties and to ascertain which of those are most important to decision makers. Thus, the plan's research objectives intended to address decision making under uncertainty are not necessarily those of optimum use to decision makers. Further, the plan does not adequately articulate the utility of better characterizing uncertainty.

The draft plan also does not build upon existing knowledge in the areas of risk estimation, assessment, perception, communication, and management.

Recommendation: The revised strategic plan should identify what sources and magnitudes of reductions in key climate change uncertainties are especially needed and where an improved characterization of uncertainty would benefit decision-making, and should use this information to guide the research program.

The draft strategic plan does not adequately use many prior assessments and consensus reports that have provided scientific information to decision makers. While the plan does refer to some of these reports with regard to scientific issues relating to the physical climate, it fails to build upon past experience in applied climate studies, including regional impacts, or in interactions with a wide range of user communities. In these facets the plan must build on lessons learned from the U.S. National Assessment of the Potential Impacts of Climate Variability and Change, the Third Assessment Report of the Intergovernmental Panel on Climate Change, the World Meteorological Organization/United Nations Environment Programme ozone assessments, and other environmental assessments.

Recommendation: The revised strategic plan should build upon the lessons learned in applied climate studies and stakeholder interaction from prior environmental and climate assessment activities.

SET THE STAGE FOR IMPLEMENTATION

The draft strategic plan calls for a multitude of research and decision support advances, including a greatly strengthened climate modeling infrastructure to address local, regional, national, and international needs; increased collaboration on key scientific challenges; a significantly upgraded global climate observing system that includes climate-quality data management; and a suite of sophisticated informational products for decision makers who in many cases are new to climate change science. It is not apparent that the CCSP has carefully evaluated the size, scope, and training of the appropriate researcher and stakeholder communities that will be needed to address these issues or how best to take advantage of those resources that do exist. The committee believes that the CCSP faces major challenges in "capacity building": systematically developing institutional infrastructure; growing new multidisciplinary intellectual talent; nurturing "networking" of diverse perspectives and capabilities; and fostering successful transition from research to decision support applications.

Recommendation: The revised strategic plan should explicitly address the major requirements in building capacity in human resources that are implied in the plan.

Another type of capacity building is necessary to acquire the computing, communication, and information management resources necessary both to conduct the extensive climate modeling called for in the draft strategic plan and to process and store the large amounts of data collected from a greatly expanded observation network. Applied climate modeling and especially the crucial regional-to-global scale climate change scenarios will require substantially enhanced supercomputer power. Improvements realized in research models need to be tested before transition to operational models; this testing requires substantial computing resources. The draft plan says nothing about what these computing requirements might be or how the CCSP might obtain them.

Recommendation: The revised strategic plan should provide details about how the CCSP will acquire the computing resources necessary to achieve its goals.

Because the draft strategic plan does not include details about present and projected levels of support for each program element and because the fiscal year 2004 budget request was not available to the committee during its deliberations, the committee had limited information to evaluate whether the "results and deliverables are realistic given available resources," one of its task statements. However, it is clear that the scope of activities described in the draft strategic plan is greatly enlarged over what has been supported in the past through the GCRP. Implementing this expanded suite of activities will require significant investments in infrastructure and human resources and therefore will necessitate either greatly increased funding for the CCSP or a major reprioritization and cutback in existing programs.

Shortly after this report entered National Academies review, the President's fiscal year 2004 budget request was made publicly available. It includes $182 million for the CCRI (compared to the fiscal year 2003 budget request of $40 million) within a total CCSP budget request of $1749 million (compared to the fiscal year 2003 budget request of $1747 million). The committee has not had the opportunity to analyze the fiscal year 2004 budget request in detail. Even so, a cursory review of the proposed budget indicates that the CCSP has chosen to increase funding for CCRI at the expense of existing GCRP program elements (or simply relabeled some activities previously considered part of the GCRP as CCRI activities) and has shifted funds from one agency to another. Even if program funding increases, CCSP management will continue to be faced with many funding decisions, such as which new programs should be initiated (and when), whether any existing programs should be scaled back or discontinued, how to balance short-term and longer-term commitments, and how to balance support

for international and U.S. programs. These resource allocation decisions must be based on the goals and priorities of the program, which should be clearly described in the revised strategic plan. The independent advisory body recommended by the committee also should be used to inform such decisions. The committee believes it is essential for the CCSP to move forward with the important new elements of CCRI while preserving crucial parts of existing GCRP programs.

Recommendation: The CCSP should use the clear goals and program priorities of the revised strategic plan and advice from the independent advisory body recommended by the committee to guide future funding decisions.

1

Introduction

The issues addressed by the U.S. Climate Change Science Program (CCSP) are among the most crucial of those facing humankind in the twenty-first century. Given increasing evidence of how humans have modified the Earth's climate over the last century, it is imperative for the nation to continue directing resources toward better understanding of what form future changes in climate and climate variability may take, the potential positive and negative impacts of these changes on humans and ecosystems, and how society can best mitigate or adapt to these changes.

Over the twentieth century the global mean surface temperature increased by 0.6±0.2°C (1.1±0.4°F) (IPCC, 2001c). Indeed, the 1990s was very likely the warmest decade for the planet since the mid-1800s. An increasing body of observations gives a collective picture of other climate changes including the widespread retreat of non-polar glaciers and the rise of global mean sea level by 10 to 20 cm during the twentieth century. The hydrology and ecosystems in many regions of the world also have been affected by changes in the climate. For example, the growing season in the Northern Hemisphere has lengthened, particularly at high latitudes, and plant and animal ranges have shifted poleward and toward higher elevations.

The role that human activities have played in causing these climate changes has been a subject of debate and research for more than a decade. There is no doubt that humans have modified the abundances of key greenhouse gases in the atmosphere, in particular carbon dioxide, methane, nitrous oxide, and tropospheric ozone (IPCC, 2001c). These gases are at their highest recorded levels. In fact, the ice-core records of carbon dioxide and methane show their twentieth century atmospheric abundances to be significantly larger than at any period over the past 400,000 years. The increase in these greenhouse gases is primarily due to fossil fuel combustion, agriculture, and land-use changes. Recent research advances have led to widespread acceptance that the human-induced increase in greenhouse gas abundances is responsible for a significant portion of the observed climate changes, though it is difficult to quantify against the backdrop of natural variability and climate forcing uncertainties.

Because the Earth system responds so slowly to changes in greenhouse gas levels, and because altering established energy-use practices is difficult, changes and impacts attributable to these factors will continue during the twenty-first century and beyond. Current models indicate a large potential range for future climates, with global mean surface temperature warming by 1.4 to 5.8ºC (2.5 to 10.4 °F) by 2100 (IPCC, 2001c). This range, which many consider to be too wide to guide policy making, is due to gaps in understanding of climate science and the socio-economic drivers of climate change. Research under the CCSP is critical to improve this basic understanding so as to make it possible to produce more reliable projections (or "forecasts") of future climate and associated global changes. Such tested and trusted "forecasts" of future climate would be of great use to a broad spectrum of stakeholders, ranging from national policy makers deciding whether to ratify international agreements to reduce greenhouse gas emissions, to regional water managers deciding how much river flow to allocate to irrigation, to individuals choosing which car or appliance to purchase.

Given the above, setting new strategic directions for the CCSP is particularly important. This new program must complement the research of the last decade, which focused on building an understanding of the Earth system, with research to explicitly support decision making. To do so, it will be necessary to continue research into the physical, chemical, and biological aspects of climate and associated global changes, and to add research that will enable decision makers to understand the potential impacts ahead and make choices among possible response strategies. Further, new collaborations among scientists, policy makers, and other stakeholders will be essential to developing a research agenda that is responsive to the nation's needs.

HISTORICAL CONTEXT OF THE U.S. CLIMATE CHANGE SCIENCE PROGRAM

A multidisciplinary approach to researching Earth's biogeochemical system was first considered in the mid-1970s, when scientists became aware that humans might be perturbing the climate, as well as the biology, physics, and chemistry of the global environment. A number of reports

published during the 1980s (e.g., by the U.S. Department of Energy [DOE, 1977, 1980], the National Research Council [e.g., NRC, 1983, 1986], the National Aeronautics and Space Administration [NASA] Earth System Sciences Committee [ESSC 1986, 1988]), suggested that a coordinated national research effort was needed to effectively observe and study the Earth system. The first efforts at a coordinated government research strategy came in late 1986, when NASA, the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF) began developing parallel global change programs. In 1987 eight agencies formed the federal interagency Committee on Earth Sciences (now known as the Committee on Environment and Natural Resources [CENR]). When the U.S. Global Change Research Program (GCRP) was created by a presidential initiative in 1989, CENR formed a Subcommittee on Global Change Research (SGCR)[6] to provide leadership and coordinate the activities of this new program.

The U.S. Global Climate Research Act of 1990 codified the existing interagency relationships. According to the act the GCRP was to be "aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, to promote discussions toward international protocols in global change research, and for other purposes" (see Appendix D). The act specifically called for a 10-year research plan to be submitted to Congress at least every three years specifying "the goals and priorities for Federal global change research which most effectively advance scientific understanding of global change and provide usable information on which to base policy decisions relating to global change." Other requirements of the 10-year research plan include descriptions of activities necessary to meet the plan's goals, identification of existing federal programs that contribute to the GCRP, description of the role of each federal agency and department in implementing the plan, recommendations for international coordination of research activities, and estimates, to the extent practical, of federal funding for the activities in the plan.

In addition to the responsibility for planning and coordinating national global change research, the Global Change Research Act mandated that the GCRP produce periodic scientific assessments of the research results, prepare an annual report to Congress summarizing the program's activities, and coordinate with other nations. In 2001 the GCRP published its first assessment of results from the research program and implications for the United States (NAST, 2001). The Act also states that the GCRP should retain the NRC to "evaluate the scientific content of the plan" and to provide information and advice, in particular about "priorities for future global change research" (see Appendix D). The NRC has provided ongoing advice to the GCRP through many reports and has convened numerous public meetings of the several NRC boards and committees that focus on global change.

Since its creation in 1990, the GCRP has made substantial investments in the following general areas of climate change and global change research: measurements of the physical, chemical, and biological processes responsible for changes in the Earth system; documentation of global change; studies of past changes in the Earth system; prediction and simulation of global environmental processes; and research initiatives to understand the nature of and interactions among global change processes. The GCRP reports numerous scientific insights and accomplishments of the program in the annual publication of its report to Congress titled *Our Changing Planet* (e.g., GCRP, 2002, 2003). The program did not release publicly any ten-year plans for global change research before the draft plan this committee is reviewing. The annual publication of *Our Changing Planet* provides some indication of the GCRP's future plans and vision. For the most part, however, the GCRP has comprised atmospheric, oceanic, and land-surface research activities conducted by the individual agencies, which coordinate with each other in differing degrees.

During the late 1990s the GCRP began to develop a comprehensive ten-year research plan. It held three planning meetings with agency representatives and the science community between 1998 and 2001. The NRC was asked to provide guidance in the form of a report describing the scientific issues of global change, the key scientific questions that should be addressed by the GCRP, and research approaches to address these questions. In response to this request the NRC Committee on Global Change Research (CGCR) produced *Global Environmental Change: Research Pathways for the Next Decade* (NRC, 1999b). The CGCR also discussed a draft GCRP draft ten-year plan at a public meeting on January 23, 2001. In 2001 the new presidential administration reviewed U.S. climate change policy. Its review included another request to the National Academies to help identify "the areas in the science of climate change where there are the greatest certainties and uncertainties" and to provide "views on whether there are any substantive differences between the IPCC reports and the IPCC summaries." In response the NRC published *Climate Change Science: An Analysis of Some Key Questions* (NRC, 2001a). Days after receiving the report President George W. Bush announced the

[6] The membership of the Subcommittee on Global Change Research has since grown to 13 agencies and departments: NASA, NOAA, NSF, Environmental Protection Agency, DOE, Department of State, Department of Defense, Department of the Interior/U.S. Geological Survey, U.S. Department of Agriculture, Department of Transportation, Health and Human Services, U.S. Agency for International Development, and the Smithsonian Institution. The Office of Science and Technology Policy and the OMB provide oversight on behalf of the Executive Office of the President.

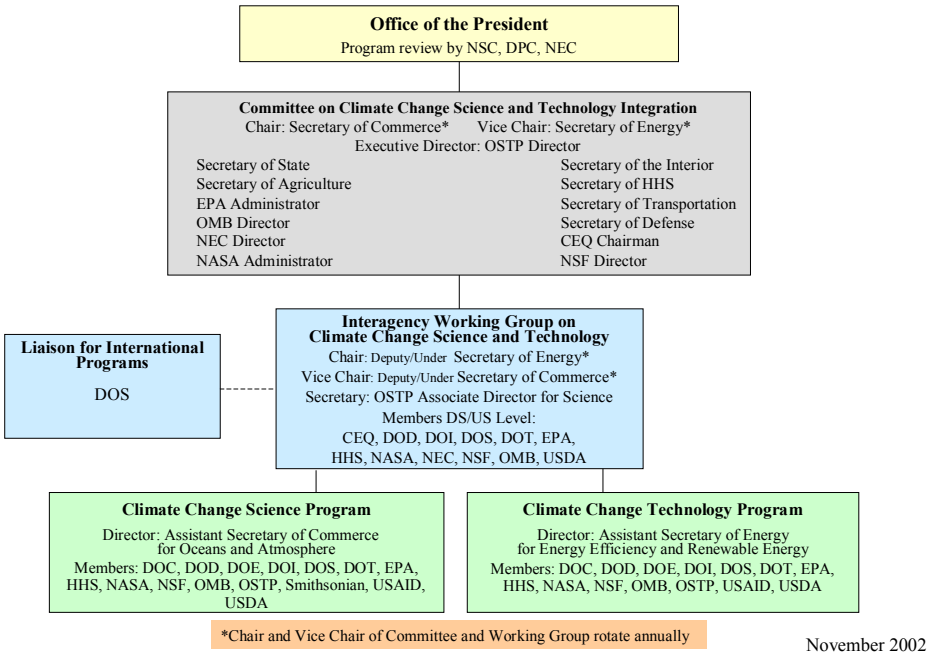

FIGURE 1-1 Climate Science and Technology Management Structure**.** Source: CCSP. Available online at <http://www.climatescience.gov>.

creation of the new Climate Change Research Initiative (CCRI). In his announcement the President directed that priorities be established for climate change research, including a focus on identifying the scientific information that can be developed within two to five years to assist the nation in the development of strategies to address global change risks. The President also called for improved coordination among federal agencies to assure that research results are made available to all stakeholders, from national policy leaders to local resource managers.

In February 2002 President Bush announced the formation of the U.S. Climate Change Science Program (CCSP), a new management structure that would incorporate the work of the GCRP and the newly launched CCRI. The CCSP is intended to be a single interagency committee responsible for the entire range of science projects sponsored by the two programs.[7] The Assistant Secretary of Commerce for Oceans and Atmosphere was named director of the CCSP. The interagency CCSP retains the responsibility for compliance with the requirements of the Global Change Research Act of 1990, including its provisions for annual reporting of findings and short-term plans, scientific reviews by the National Academies, and periodic publication of a 10-year strategic plan for the program. At the same time a Climate Change Technology Program (CCTP) was created to coordinate and develop interagency research efforts focused on developing new technologies related to climate change and its mitigation. The Assistant Secretary of Energy for Energy Efficiency and Renewable Energy was named the director of the CCTP. As illustrated in Figure 1-1, oversight for both the CCSP and the CCTP is provided by the Interagency Working Group on Climate Change Science and Technology, which in turn reports to a high-level Committee on Climate Change Science and Technology Integration.

The initial activities of the CCSP included an inventory of global change research activities at the 13 participating agencies. The fiscal year 2002 budget included $1670 million officially part of the GCRP plus an additional $1210 million in related and supporting research activities at the agencies. The fiscal year 2003 request for the CCSP was $1747 million and that for the newly established CCRI was $40 million. The fiscal year 2004 requests for CCSP and CCRI are $1749 million and $182 million, respectively.

Soon after the inventory was completed the CCSP began drafting a 10-year strategic plan for global change research. The discussion draft of the plan, *Strategic Plan for the U.S. Climate Change Science Program* (CCSP, 2002), was released on the CCSP website (<http://www.climatescience.gov>) on November 11, 2002. According to the draft plan's foreword, the plan was "prepared by the thirteen federal agencies participating in the CCSP, with input from a large number of scientific

[7] The SGCR retains responsibility for overseeing the GCRP in name, however the membership and leadership of the SGCR and the CCSP are identical.

steering groups and coordination by the CCSP staff under the leadership of Dr. Richard H. Moss," Executive Director of the GCRP.

This plan was the subject of extensive discussion by over 1,000 scientists, agency representatives, and other stakeholders at a major planning workshop in Washington, D.C., on December 3-5, 2002. The CCSP also requested that the National Academies undertake a fast-track review of the discussion draft of the strategic plan (see Appendix B for statement of task). This report represents the results of the committee's review of the November 11, 2002, draft strategic plan. This committee will issue a second report reviewing the final strategic plan and the CCSP's planning process.

2

Clarifying Vision and Goals

Are the goals clear and appropriate?

Whether the draft plan's goals are clear and appropriate is really a question of whether it succeeds as a strategic plan. Unfortunately, it does not. The document is not a coherent strategic plan, because it lacks most elements of a strategic plan, including:

- Clear and ambitious guiding *vision* of the desired outcome;
- Unambiguous and executable *goals* that address the vision and broadly describe what the program is designed to accomplish;
- Clear *timetable* for accomplishing the goals and *criteria for measuring progress*;
- *Assessment* of whether existing programs are capable of meeting these goals, thereby identifying required program changes and unmet needs that must be addressed in subsequent implementation planning;
- Set of explicit *prioritization criteria* to facilitate program design and resource allocation; and
- *Management plan* that provides mechanisms for ensuring that the goals are met and for coordinating, integrating, and balancing individual program elements and participating agencies.

A coherent strategic plan containing these elements is especially critical when, as in the CCSP, the institutional environment is diverse and fragmented and when the program involves new directions and collaborations. Such a plan would provide a common basis for planning, implementation, and evaluation and would protect against a continuation of the *status quo*. Unfortunately, these elements are either weakly identified, poorly developed, or missing altogether in the draft plan.

The information provided to the committee suggests that the draft plan was produced through a "bottom up" process in which individual committees designed plans for components of the program. While input from several scientific advisory committees guided some of these efforts, they also appear to have been influenced by existing programmatic responsibilities and funding priorities. The committee certainly recognizes that the involvement of federal program managers in the development of the draft plan will greatly facilitate the future implementation of the final plan. However, the result is that the overall CCSP plan does not articulate a clear and consistent guiding framework to enable policy makers and the public, as well as scientists, to understand what this research program is intended to accomplish and how it will contribute to meeting the nation's needs.

The committee recognizes the difficulty of producing an organization's first strategic plan and applauds the CCSP for taking on the challenge of drafting a plan that encompasses such diverse players and disciplines, particularly given the history of limited integration within the GCRP (NRC, 2001d). As the first step in a maturing strategic planning process, the draft plan successfully lays out parts of the guiding framework that should shape the final document, but they are scattered throughout the document.

ELEMENTS OF A STRATEGIC PLAN

Vision

The vision for a large government research program like the CCSP should address such national aims as understanding how humans affect global change; implementing efforts to minimize the most harmful effects; reducing vulnerability to global change; and protecting public health and natural resources. Indeed, the GCRP's authorizing legislation identifies as its purpose "to assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change" (see Appendix D).

In the view of the committee, perhaps the clearest vision for the CCSP was given by President Bush in announcing his Clear Skies and Global Climate Change Initiatives on February 14, 2002.

> America and the world share this common goal: we must foster economic growth in ways that protect our environment. We must encourage growth that will provide a better life for citizens,

> while protecting the land, the water, and the air that sustain life. We must also act in a serious and responsible way, given the scientific uncertainties. While these uncertainties remain, we can begin now to address the human factors that contribute to climate change. (Bush, 2002)

A guiding vision similar to this but specific to the CCSP should be succinctly stated in the final strategic plan.

In crafting its vision, the CCSP will need to explicitly consider the scope of the program; that is, does the program focus exclusively on issues of "climate change"—as one might infer from the name of the *Climate Change* Science Program itself and its constituent, the *Climate Change* Research Initiative—or does it encompass all, or some, other global changes—as one might infer from the name of the CCSP's other constituent, the U.S. *Global Change* Research Program? The answer to this question has implications on the research areas that belong in the program and, accordingly, the level of resources needed. The committee believes that it will be important for the CCSP to consider those processes (1) that interact with climate change to produce significant impacts of societal relevance and therefore must be integrated into research to understand impacts and to develop adaptation and mitigation approaches, and (2) that have large feedbacks to climate change. In this report the committee uses "climate and associated global changes" as a general term encompassing those global changes included in the two categories above.

The CCSP will need to consider whether these or other criteria will determine the program's coverage of various global change processes. This is important from a planning perspective because the number of factors identified for the CCSP's attention is likely to grow as the program's work with decision makers expands. Many decision makers deal with climate change as only one of a suite of factors affecting the people, economy, and ecosystems of an area. Not all of these factors will necessarily be appropriate for the CCSP's attention. An obvious tradeoff will be between depth and breadth, and the risk is a program spread so thin that it fails to make meaningful progress in core research areas. The CCSP's decisions about scope will have important implications for the portfolio of research to be funded initially, and for how this portfolio evolves over the program's lifetime.

Goals

Numerous potential goals for the CCSP, CCRI, and GCRP can be inferred from the draft plan (see Box 2-1). Many come from related legislation or recent presidential announcements. The text does not highlight most as overarching program goals, however. Whereas several might be quite appropriate for CCSP, in light of the absence of an overarching vision, it is unclear whether they are necessary or adequate goals for the program.

Whatever goals that CCSP selects for the final plan, they should be associated with clear time targets, as well as criteria for success and for selecting programs to meet the goals. Clear links should exist between these goals and specific deliverables identified in the plan.

Prioritization Criteria

The draft plan lists many proposed activities, yet it does not identify which of these activities have higher priorities than others, either across the CCSP as a whole or within individual program areas of the CCRI or GCRP, nor does it describe a process for establishing priorities.[8] The mismatch between these multiple proposed activities and the resources currently devoted to the program implies that not all of the projects will be pursued with the same intensity. Numerous participants in the CCSP public workshop held in December 2002 were concerned that without priority setting, resources would not be directed toward important new research areas.

The committee inferred possible CCSP priorities from the draft plan, such as those activities included in the CCRI, or that have deliverables in two to four years. Thus, the document's criteria for including activities in the CCRI implies prioritization, specifically whether the activity will (1) produce significant decision or policy-relevant deliverables within the next two to four years and (2) contribute substantially to one or more of the CCRI goals of reducing uncertainty, improving global observation capabilities, and developing resources to support policy- and decision making. Also, although no prioritization rationale is clearly stated, some process presumably took place in choosing which products and payoffs to include for each program element in the GCRP portion of the plan.

The committee believes that the revised strategic plan would be greatly improved if it provided specific prioritization criteria or outlined an overarching prioritization process for the CCSP. Key considerations might include the relative importance of an activity for meeting the program's goals, cost, positioning and leverage relative to the private sector and other U.S. and international research entities, and sequencing and scheduling considerations. Ideally the CCSP should make its funding decisions by carefully and explicitly considering which activities best meet the program's vision and goals and when particular research products are required. These future decisions need to be informed by the CCSP's

[8] The draft plan states that activities would be identified for "early action and support" using "agreed-upon criteria" in the following areas: relevance/contribution, scientific merit, readiness, deliverables, linkages, and costs (CCSP, 2002 p. 165).

BOX 2-1 Candidates for CCSP's Overarching Goals that Can Be Inferred from the Draft Strategic Plan, (CCSP, 2002).

CCSP GOALS:

- "balance the near-tem (2 to 4-year) focus of the CCRI with the breadth of the GCRP, pursuing accelerated development of answers to the scientific aspects of key climate policy issues while continuing to seek advances in the knowledge of the physical, biological, and chemical processes that influence the Earth system" (p. 2).

- "inform public debate on the wide range of climate and global change issues necessary for effective public policy and stewardship of natural resources" (p. 4).

- "[establish] and [apply] priorities for climate change research so the Nation can address and evaluate global and climate change risks and opportunities" (p. 149).

CCRI GOALS:

- "measurably improve the integration of scientific knowledge, including measures of uncertainty, into effective decision support systems and resources" (p.).

- "reduce significant uncertainties in climate science" (p. 2; p. 8).

- "[a]ddress key and emerging climate change science areas that offer the prospect of significant improvement in understanding of climate change phenomena, and where accelerated development of decision support information is possible" (p. 15).

- "improve global climate observing systems" (p. 2; p. 8).

- "[o]ptimize observations, monitoring, and data management systems of 'climate quality data'" (p. 15).

- "develop resources to support policymaking and resource management" (p 2).

- "develop resources to support policy- and decision-making" (p. 8).

- "[d]evelop decision support resources including scenarios and comparisons; quantification of the sensitivity and uncertainty of the climate system to natural and anthropogenic (human-caused) forcings through the implementation and application of models; and structured information for national, regional, and local discussions about possible global change causes, impacts, benefits, and mitigation and adaptation strategies" (p. 15).

- "synthesiz[e] scientific results and produc[e] decision support resources responsive to national and regional needs" (p. 38).

GCRP GOALS:

- "address key uncertainties about changes in the Earth's global environmental system, both natural and human-induced" (p. 55).

- "monitor, understand, and predict global change" (p. 55).

- "provide a sound scientific basis for national and international decision-making" (p. 55).

overarching vision, rather than only by the considerations of individual agencies as they implement the plan. This will be particularly important, for example, in developing budget support for new programs and for crosscutting

issues that are of high strategic importance but currently lack a strong institutional home or span multiple agencies and congressional appropriation committees (e.g., water cycle, decision support).

Assessment of Current Programs and Resources

The CCSP took an important step in mid-2002 when it inventoried federal activities related to global change research (<http://www.climatescience.gov/Library/Inventory_budgetsummary_26Aug02.pdf>). This inventory provides a baseline for the CCSP to assess, as a part of the strategic planning process, whether current programs are sufficient to accomplish the goals, performance metrics, and timelines that will be identified in the final strategic plan. Any gaps or unmet needs for information, capacity, or resources to address the program's goals and vision that are identified through this process will be a key input to implementing the plan. To be successful and to provide a clear map for the implementation phase that follows, the final strategic plan will need to include a more rigorous assessment that evaluates the match of existing programs and resources to the vision, goals, and priorities identified during the revision process.

Management Plan

A management plan describes the organizational structures and approaches to be used to ensure that program goals are met and to coordinate, integrate, and balance program elements. Chapter 15 of the draft strategic plan constitutes a preliminary management plan for the CCSP and describes at a general level the management structures and processes that will be used to coordinate and integrate federal research and technology development in climate and associated global change. As will be discussed in Chapter 4 of this report, the basic management structure appears sound and could provide a useful general framework for the management of the program. However, the chapter does not provide sufficient detail for the committee to have confidence that the management plan will be effective. A detailed management plan is especially important for the CCSP, because it is new and it is charged with coordinating and integrating the activities of 13 agencies, each with a separate mission and a long history of independent research on climate and associated global changes.

Recommendation: The revised strategic plan should articulate a clear, concise vision statement for the program in the context of national needs. The vision should be specific, ambitious, and apply to the entire CCSP. The plan should translate this vision into a set of tangible goals, apply an explicit process to establish priorities, and include an effective management plan.

RELATIONSHIP BETWEEN THE GCRP AND THE CCRI

The draft plan states that to be included in the CCRI, "a program must produce both significant decision or policy-relevant deliverables within two to four years and contribute significantly to one or more of the following activities: (1) address key and emerging climate change science areas that offer the prospect of significant improvement in understanding of climate change phenomena, and where accelerated development of decision support information is possible, (2) optimize observations, monitoring, and data management systems of 'climate quality data' […], and (3) developing decision support resources" (CCSP, 2002, p. 15). Focusing part of the CCSP on short-term investigations oriented principally toward decision support is a welcome addition to the longer-term research carried out under the GCRP.

The decision support activities described in Chapter 4 are generally consistent with the CCRI objectives. In fact, the committee considers this emphasis on scientific support for decision makers one of the most promising and innovative features of the draft plan. While there are valuable short-term deliverables in this arena, the committee feels that the CCSP should also commit to a long-term investment in decision support as an on-going component of the program. It is important for the revised plan to make clear how a decision support function in the CCSP will continue well beyond the current two- to four-year effort of the CCRI.

Many of the activities described in Chapters 2 and 3 of the draft plan, however, are not consistent with the CCRI focus on decision support and are unlikely to produce deliverables within four years. This is not to say that these activities are unimportant, but simply that they are not consistent with the CCRI objectives given in the draft plan. Most if not all of the science activities identified to address key and emerging climate change science areas in Chapter 2 seem to better meet an objective of accelerating efforts to understand well-defined, priority scientific questions that may or may not be of direct relevance for decision making. Those activities proposed in Chapter 3 to optimize observations, monitoring, and data management systems appear to be directed at "jump starting" a major new capacity-building initiative in a crosscutting element. These efforts will have few short-term deliverables but significant long-term benefits.

In revising the strategic plan there are a number of ways that the CCSP could address the major inconsistencies between the activities described in Chapters 2 and 3 and the stated goals for the CCRI. One approach would be to revise the objectives of the CCRI to be more consistent with the apparent objectives mentioned above for the activities currently included in Chapters 2 and 3 of the draft plan. This revision would tend to de-emphasize the importance of decision support within the CCRI. An alternative approach

would be move those activities in Chapters 2 and 3 of the draft plan that are not directly linked to near-term decision making to the relevant GCRP sections of the plan. Decision support activities would then likely become the primary focus of the CCRI. The committee believes that it is important for the program to correct these inconsistencies while maintaining a strong emphasis on near-term decision support in the CCRI.

In addition to addressing these inconsistencies, the revised strategic plan also needs to more clearly describe how the research activities included in the GCRP support the decision support needs of the CCRI. The revised plan should clearly describe how the program intends to enable the transition of research results into operations and decision making. Indeed, there should be a "rolling linkage" between the two programs, with CCRI objectives periodically redefined as a result of new scientific input from GCRP.

Recommendation: The revised strategic plan should: (1) present clear goals for the CCRI and ensure that its activities are consistent with these goals; (2) maintain CCRI's strong emphasis on support for near-term decisions as an ongoing component of the program; and (3) include an explicit mechanism to link GCRP and CCRI activities.

3

Meeting the Nation's Needs for Climate and Global Change Information

Is the plan responsive to the nation's needs for information on climate change and global change, their potential implications, and comparisons of the potential effects of different response options?

The nation has diverse information needs on climate and associated global changes, their implications, and different response options. These needs arise from decision makers across the public and private sectors dealing with issues ranging from energy to public health and the environment and operating at the local, state, national, and international levels. A major weakness of the draft strategic plan is that it does not adequately identify these diverse needs or use them to target the scientific studies that it proposes. In general the description of the Climate Change Research Initiative (CCRI) in the draft plan does a better job of addressing a relatively short list of the major policy decisions that are pending at a national level. Even at this level the plan specifies that one of the objectives of the CCRI will be to identify "national-level decisions and [use] that list to develop decision support activities as well as to help prioritize climate change research" (CCSP, 2002, p. 40).

The draft strategic plan does identify at a general level four areas that will be important to meeting the needs of decision makers.[9]

- *Improve the global climate observation system.* Both the CCRI ("optimize observations, monitoring, and data management systems of 'climate quality data,'" CCSP, 2002, p. 15) and the U.S. Global Change Research Program (GCRP) ("monitor, understand, and predict global change," CCSP, 2002, p. 55) call for improved global observing and information systems.
- *Improve understanding of climate and associated global changes.* The draft plan states that "science-based information is required to inform public debate on the wide range of climate and global change issues necessary for effective public policy and stewardship of natural resources" (CCSP, 2002, p. 4). The committee considers the wide range of climate change and associated global change issues to encompass Earth system processes (physical, biological, chemical, and societal), impacts on human societies and ecological systems, and the scientific underpinnings of potential response options.
- *Reduce key uncertainties.* The CCRI seeks to "reduce significant uncertainties in climate science" (CCSP, 2002, p. 2; p. 8). Likewise, the GCRP seeks to address "key uncertainties about changes in the Earth's global environmental system, both natural and human-induced" (CCSP, 2002, p. 55).
- *Develop decision support resources.* Creating "resources to support policymaking and resource management" (CCSP, 2002, p. 2) is a major new undertaking included in the CCRI portion of the plan. This objective appears to be multifaceted, calling for developing "scenarios and comparisons; quantification of the sensitivity and uncertainty of the climate system to natural and anthropogenic forcings through the implementation and application of models; and structured information for national, regional, and local discussion about possible global change causes, impacts, benefits, and mitigation and adaptation strategies" (CCSP, 2002, p. 15).

In addition to these information needs the committee notes a related need that can be inferred from the plan, though it is not explicitly stated.

- *Build capacity to implement the strategic plan.* The ambitious objectives of the draft strategic plan require substantial investments in training new researchers, building linkages across disciplines and between researchers and stakeholders, and in computing and data storage capabilities.

This chapter assesses the extent to which the draft plan addresses these areas without commenting on whether this

[9] As discussed in Chapter 2, although these general themes are expressed repeatedly throughout the draft plan, they are not explicitly identified as overarching program goals, and therefore are not identified as such in this report.

list comprises the full set of information needs that the final CCSP plan should address. Developing that fuller list should be part of the process by which the draft plan is revised.

THE GLOBAL CLIMATE OBSERVATION SYSTEM

The draft plan correctly identifies the need for a global observing system for climate and climate-related variables. Such a system would include observations of physical, chemical, and biological parameters of the ocean, atmosphere, and land systems, and it would incorporate relevant socio-economic data needed to understand the factors that influence the causes of climate change. Its goals would be to supply the scientific basis for detecting climate and associated global changes and for testing and calibrating the climate system models, and to develop data products of use to decision makers. To provide climate-quality data, the observation strategy would need to be long-term, subject to careful calibration and validation, and be flexible enough to accommodate new understanding and evolving needs (NRC, 1999a; 2000b). The draft strategic plan could be improved by providing a structured program for establishing such a global climate observing system and a strategy for coordinating observation needs that cross disciplinary and national boundaries. The existing climate observing system is a patchwork of observation networks, which are not well coordinated. Large investments are needed in maintaining and expanding an integrated observing system that will support monitoring, diagnosis, and modeling of climate and associated global changes.

Many research needs in observations, monitoring, and data management systems are identified in Chapter 3, Chapters 5-11, and Chapter 12 of the draft plan. The observation goals are generally appropriate and reasonably complete, although they would benefit from some coarse prioritization or implementation schedule. A major weakness in the plan, however, is that it does not describe how existing observation systems will be integrated, nor does it offer a pathway to expansion of observation systems to include key climate-related ecological, biogeochemical, geophysical, and socio-economic measurements. A great need exists for systematic integrated measurements, where interagency and international cooperation could bring major advances. For example, significant changes in natural and managed ecosystems are already occurring in response to climate variability and changes, yet a clear strategy for obtaining the necessary observations is lacking. A more integrated approach to ecosystem observations would include ground-based monitoring of biogeochemical and other ecosystem processes (e.g., carbon dioxide flux at distributed reference sites and nutrients in stream, river, estuarine, and coastal systems and large-scale patterns of disturbance and fire) and monitoring of the distribution and abundance of key species in a range of regional terrestrial and marine ecosystems. The global climate observing system would provide datasets to explore the coupling of major cycles (e.g., carbon, water, nitrogen, energy). Better integrating relevant socio-economic observations—including changes in land use, location and intensity of economic activities that alter atmospheric chemistry, and social conditions that alter vulnerability to climate change—into this observation system could be of great use in understanding the importance of various drivers of climate change.

Major issues associated with creating and implementing an integrated, global climate observing system need more attention in the draft plan to make it clear how the selection of observation systems and sites would be guided by an overarching observation strategy. It is important that the revised strategic plan address the following:

- The role that the CCSP will play in implementing and maintaining national- to global-scale observing systems that require interagency and international cooperation.
- How the program will develop an appropriate range of space-based and *in situ* observing systems with an adequate overlap to allow the calibration necessary to maintain data quality.
- Efforts to observe important local and regional variability (such as due to local orography, local coastline structure, or land-sea temperature differences not otherwise resolved) that are necessary to meet the CCSP's goals of providing information to decision makers. Design of local or regional observation arrays will need to be responsive a variety of users' needs while being consistent in accuracy and practice so that they feed data into the global array.
- How climate modeling and observation activities will be coordinated, including the use of models to aid in the design of improved climate observing systems and the deployment of observation networks appropriate for testing climate models.
- The challenges associated with the transition of research observations to operational platforms and to measurements involving *in situ* and space-based instruments (NRC, 2000a). Although the plan refers to making climate observations accessible, it would be more effective if it conveyed an overall vision for climate services as discussed in various recent reports (e.g., NRC, 2001b).
- The requirements to ensure that observations for weather have value for climate studies (NRC, 1999a; 2000b; 2000c).

Chapter 3 of the plan identifies a number of observation activities that CCSP considers of higher priority for decision making, therefore warranting their inclusion in the CCRI portion of the plan. Although the

activities chosen are appropriate, the observation approach within the CCRI lacks a clear strategy for implementing the system. Chapter 3 of the plan largely sidesteps the fundamental overhaul and large national and international capacity-building required to establish the needed observation programs. It is clear that the observing system objectives listed in Chapter 3 of the plan are long-term programs with most benefits accruing well beyond two to four years. This does not necessarily mean that new initiatives to improve observations, monitoring, and data management are inappropriate for the CCRI. Rather, if they are to remain as part of the CCRI, the plan should more clearly describe what will be accomplished in two to four years, how these results will improve decision making, and how these short-term initiatives relate to longer-term progress on observations, monitoring, and data management that will be carried out under the GCRP.

Recommendation: The revised strategic plan should better describe a strategic program for achieving an integrated observing system for detecting and understanding climate variability and change and associated global changes on scales from regional to global.

IMPROVE UNDERSTANDING OF CLIMATE AND ASSOCIATED GLOBAL CHANGES

The scientific research program presented by the draft plan is of mixed quality. In general, the better developed parts of the plan build upon the substantial and largely successful research programs of the last decade. Also, those elements of the research plan that were based on the advice and reports of specialized scientific steering groups (e.g., the carbon cycle, the water cycle, climate observations, and climate modeling) benefited from a sustained and close interaction with their scientific community and the relevant federal program managers. In contrast, several of the crosscutting program elements—such as regional studies, ecosystems, the human dimensions, and the role of oceans in climate—need the greatest improvement. This is largely because these content areas are not as well developed, too narrowly constrained in the existing GCRP structure, or fall across multiple program elements.

Thus, the committee finds that, although existing GCRP activities provide a reasonably sound foundation for the CCSP strategic plan in areas of historical strength, this approach also has important shortcomings. It potentially perpetuates: the weak coordination that has existed among program elements; the adherence to agency-specific foci that, in the past, has hindered the development of comprehensive research programs in some areas; and the difficulty in supporting new crosscutting initiatives. The enhanced focus of the CCSP on decision support is likely to bring these shortcomings into sharp relief, as decision makers who need to understand impacts and develop response strategies call for new kinds of information that have historically received relatively little attention from the GCRP.

In the following pages the committee discusses several weaknesses in the research activities presented by the plan. A more detailed analysis of each chapter of the draft plan is provided in Part II of this report.

Regional Studies to Facilitate Decision Making

A need now exists to use understanding of global-scale phenomena to develop predictive information on regional and smaller scales. Such information is essential for federal, regional, and local decision makers and resource managers addressing such issues as public health and economic development, water use planning, the condition of forests and fisheries, and endangered species. The CCSP highlights the need to investigate regional problems, devoting a section in Chapter 4 of the draft plan to "Decision Support Resources for Regional Resource Management" (CCSP, 2002, p. 41-43) and identifying some regional modeling products and payoffs designed to improve interactions between producers and users of climate variability and change information (CCSP, 2002, p. 77-78). Insufficient detail, however, is provided in the draft plan about how the program anticipates scaling down its current efforts to address regional issues.

Scaling down from global to regional and local scales is an important research endeavor that the CCSP must address. Particularly important and challenging will be analyses and models of future regional climate and related effects on social, economic, and ecological issues of concern to regional decision makers. The committee believes that regional or place-based studies provide important opportunities to calibrate models with specific *in situ* measurements, evaluate global mechanisms, address the tangible impacts of climate change on societies and ecosystems, and develop models for providing climate information to stakeholders and thus better engage them in the decision-making process. Regional studies are also a critical element of the global climate observing system, providing key information for improving climate system models. Pursuing regional studies can also provide scientific understanding of scale interactions that translate local climate and associated global changes to global impacts.

Most routine resource management decisions are made on a daily, seasonal, interannual time scale (e.g., agricultural planting and risk management, water management, energy resources for heating and cooling, etc.), yet these time scales are under-represented in the CCSP. To maximize the utility of decision support activities, the nature and time frame of the relevant decisions need to be clearly identified, and appropriate tools need to be developed. This concept has been well

articulated in the western water "decision calendar" developed by NOAA's Regional Integrated Sciences and Assessments (RISA) in Boulder, Colorado. The calendar depicts the annual reservoir management decision timeframes so that climate information can be provided to managers when it is most useful to them. The preliminary success of El Niño-Southern Oscillation (ENSO) forecasts, as discussed in the draft plan (CCSP, 2002, p. 6), and the achievements of pilot regional assessments in delivering useful climate information to stakeholders demonstrate the societal and economic benefits that can accrue from such efforts. The successful prediction of long-term climate change at regional scales, however, is a significant challenge facing the CCSP.

On an international level the development of regional specific studies and networks of scientists is an opportunity to leverage the U.S. program with international contributions while building a broader community of scientists outside the United States. Regional and local networks of on-the-ground science efforts will enhance the reliability of the outputs from the program and provide key links with global satellite observations.

Recommendation: The revised strategic plan should more fully describe how models and knowledge that support regional decision making and place-based science will be developed.

Human, Economic, and Ecological Dimensions of Climate Change

While the last decade of climate change research focused on how the climate is changing, the next decade must also support an increase in understanding of the potential impacts of climate change on human societies and ecosystems and related options for adaptation and mitigation. The need for research in these areas logically follows from the CCSP's new emphasis on decision support, and is identified in the draft strategic plan.[10] Strong and strategic research programs on human dimensions and ecosystems and better integration of economic concepts would enable CCSP to meet this need. However, the committee finds that the draft plan's coverage of these topics (primarily in Chapters 10 and 11) is sufficiently weak that it raises serious questions about CCSP's ability to meet current and future needs of decision-makers at local, state, regional, and national levels or to provide adequate input into the models and analyses needed to reduce or clarify uncertainties. These flaws create critical weaknesses that translate across the draft strategic plan, because so many connections should exist between the plan's other research areas and research on human dimension and ecosystems, and because economic analysis is so integral to decision-making.

The plan's treatment of human dimensions has several important gaps. It does not include, for example, research on the role of institutions (e.g., property rights and markets) or of consumption (e.g., per capita water consumption) in driving future patterns of environmental change and resource supply and demand. Nor does it recognize the importance of deliberative interactions with stakeholders and the value of research on human preferences as input into policy decisions. Importantly, Chapter 11 fails to address the need for basic social science research into human-environment interactions or for more applied research into questions about mitigation and adaptation.

A key gap in the draft plan is research that might lead to better understanding of the costs and benefits of climate change. Measuring and monetizing the costs and benefits of climate change is a fundamental intellectual problem. A wide range of potential costs and benefits needs to be considered, including the direct and indirect costs and benefits of mitigation, the costs and benefits of public and private adaptation, and the costs and benefits of adjustment from one climate to another. Generating estimates of the impacts from climate change, which involves both market and nonmarket effects, is a continuing research challenge. Improving the economic research in the draft plan could be of great value to policymakers whose choices will hinge on the broadly construed costs and benefits of alternative actions.

The research plan for ecosystems needs a more cohesive and strategic organizing framework that places a clear priority on predicting ecosystem impacts and on providing the scientific foundation for possible actions and policies to minimize deleterious effects and optimize future outcomes. Overall, the draft plan devotes insufficient attention to understanding the interplay between climate change and the ecological patterns and processes that sustain the capacity of ecosystems to deliver goods and services desired by society (e.g., the diversity, distribution, and dynamics of species and ecological communities; large scale ecosystem processes like disturbance and hydrology; the spatial configuration and connections among ecosystems; and evolutionary processes) (NRC, 1999d). Targeted research in these areas will be essential for ensuring that managed and natural ecosystems continue to provide food, clean water, wildlife, germplasm resources, and other benefits. Insights from this research will be of use, for example, to farmers and public land agencies for designing and choosing among competing management approaches, to county agencies for developing land-use plans, and to policy makers for evaluating the full benefits and risks of adaptation and mitigation strategies.

Recommendation: The revised plan should strengthen its approach to the human, economic, and ecological

[10] For example, "How readily can adaptation take place in different natural and socio-economic systems?" (CCSP, 2002, p. 8), and "What are the projected costs and effects of different potential response strategies to manage the risks of long-term climate change?" (CCSP, 2002, p. 5).

dimensions of climate and associated global changes to ensure it supports the research necessary to project and monitor societal and ecosystem impacts, to design adaptation and mitigation strategies, and to understand the costs and benefits of climate change and related response options.

Integration of Critical Crosscutting Issues and Associated Global Changes

While the draft strategic plan does a better job of identifying links between chapters and crosscutting themes than did previous draft GCRP plans, overall, the coordination among many program components is poor. Chapter 8 of the draft plan on land use and land cover is a notable exception by presenting a problem-driven approach that integrates natural science and social science research on environmental change. This chapter frames its research strategy by identifying and analyzing the agents of change in the system in question, improving the ability to characterize and predict environmental changes and improving understanding of the links and feedbacks between the environmental systems. Chapter 6 of the plan provides an overarching discussion of climate variability and change with questions that would motivate efforts that span present elements of the GCRP, but it does not indicate how such crosscutting themes would be addressed.

There are many examples where coordination is lacking in the plan. Ecosystems and human dimensions are weakly integrated across the draft plan. The carbon cycle strategy in Chapter 9 would be greatly strengthened if it included a more comprehensive plan for research on the human dimensions of the carbon cycle and if it addressed the full range of interactions with ecological systems. The plan's treatment of water resource issues would be strengthened by greater linkages between the water cycle chapter and the addressing decision support, carbon, and land use and land cover. The apparent disconnect among the chapters on atmospheric composition, the water cycle, ecology, and land use and land cover is another manifestation of a problem with plan integration.

Certain crosscutting topics that ought to come up in multiple parts of the plan are surprisingly absent. One already mentioned is the general lack of economic approaches across the plan. Another example is the oceans. The plan provides uneven coverage of ocean-related issues and impacts, despite the well-documented role of the ocean in climate change and variability. The oceans store and transport freshwater, nutrients, heat and carbon, and as such are a critical component of the climate system; they are also an important source of livelihood, recreation, and food and directly impact the majority of the world's population.

The CCSP needs to address another kind of linkage in addition to those among existing program elements, specifically the interactions and synergies between climate and associated global changes. The committee believes that it will be particularly important for the CCSP to consider those processes (1) that interact with climate change to produce significant impacts of societal relevance and therefore must be integrated into research to understand impacts and to develop adaptation and mitigation approaches, and (2) that have large feedbacks to climate change.

The draft plan makes an important step in this direction through its inclusion of land use and land cover change as a new core program element. The committee believes that the CCSP should consider expanding its coverage of two other interacting processes of global change. First, major shifts are now occurring in global nutrient cycles, which can have important feedbacks with the climate system. Of particular concern is the widespread elevation in environmental nitrogen due to greatly increased use of nitrogen, especially in agriculture. Second, major translocations are now occurring in the world's biota. Species invasions and alterations in the structure and functioning of many ecosystems, already on the rise due to other factors, are expected to increase in response to a changing climate. In turn, these ecological shifts (such as increases in fire frequency due to invasions of fire prone plants) are likely to alter the set of feasible options for adapting to climate change.

Recommendation: The CCSP should strengthen the treatment and integration of crosscutting research areas in all substantive chapters. The revised strategic plan should address the interactions and synergies of climate change with other associated global changes.

Global and Long-Term Context for Climate Science

The global and long-time scale perspectives of climate researchers have provided a valuable context in observing, understanding, modeling, and responding to climate variability and change (e.g., NRC, 1999b). This context is not clearly conveyed in the draft plan. Further, the plan does not acknowledge how variability and change in North America is strongly affected by the global atmosphere, ocean, and cryosphere. It is the global, three-dimensional ocean circulation that introduces long-time scales (decades to centuries) into climate variability and change and it is the basin-scale patterns of coupled ocean and atmosphere variability that introduce interannual and decadal variability in North America. The plan should better reflect the role of large-scale and global variability: the global nature of the ocean and atmosphere circulation and their associated time scales; the large storage capacity and slow sequestration of heat, carbon and other constituents in important reservoirs; and the ability of remote regions to affect climate in North America.

The draft plan could be improved by establishing the setting of the Earth located in space, receiving solar radiation from the Sun, with large-scale processes in the atmosphere and ocean then governing the distribution of heat and freshwater about the globe. The influence of the large-scale setting on regional variability and change needs to be a recurring theme in all the chapters of the draft plan. To do so would motivate the need for an integrated global climate observing system and explain why climate science research in the United States must include studies of processes and variability at sites remote from North America. This would also help justify to stakeholders who seek improved local prediction why they should support long-term, global climate observations and research.

A better presentation of the time scales associated with climate change would also point to the value of paleoclimate data as a descriptor of past natural variability, including past abrupt climate changes (NRC, 2002). While paleoclimate data is noted at times in the draft plan, its value becomes more clear when one is aware of the large-scale patterns of variability of the climate system. It should be made clear that paleoclimate data provides long records of the time scales and range of variability that have been dominant in the past and an essential context for present studies of forced climate change combined with natural variability.

Recommendation: The global and long-term historical context of climate change and variability should receive greater emphasis in the revised strategic plan.

ADDRESSING KEY UNCERTAINTIES

The draft strategic plan identifies reducing uncertainty as a top priority for the CCSP, and the CCRI in particular (e.g., CCSP, 2002, p. 2). Addressing uncertainty is the subject of one of the three guiding principles for the CCSP.

CCSP analyses should specifically evaluate and report uncertainty. All of science, and all decisionmaking, involves uncertainty. Uncertainty need not be a basis for inaction; however, scientific uncertainty should be carefully described in CCSP reports as an aid to the public and decisionmakers (CCSP, 2002, p. 11).

Chapter 2 of the draft strategic plan titled "Research Focused on Key Climate Change Uncertainties," describes research areas that address "key and emerging climate change science areas that offer the prospect of significant improvement in understanding of climate change phenomena, and where accelerated development of decision support information is possible" (CCSP, 2002, p. 15; p. 17). These statements indicate that the CCSP realizes three important points about uncertainty: (1) uncertainty is inherent in science and decision making and therefore not necessarily a basis for inaction; (2) decision makers need to be well informed about uncertainty to allow more knowledgeable decisions to be made; and (3) accelerated research on uncertainties should focus on those uncertainties that are important for informing policy and decision making. However, the draft plan does not present a systematic process to identify the key scientific uncertainties and to ascertain which are most important to decision makers. The draft plan would be more useful in sequencing a set of problem-driven research activities if such a process had been applied. Further, the committee believes that the draft plan understates the level of our current understanding and overstates the level of uncertainty in some places, possibly because parts of it so closely resemble preceding GCRP plans. Thus, the resources put into the GCRP over the last decade appear to be undervalued, despite the significant advances in understanding of climate and global change achieved by the program. The connections between what the plan promises to do for the coming years and what has been accomplished over the last decade should be strengthened in the revised plan.

The CCRI goal of reducing significant uncertainties within two to four years may only be achievable incrementally for the topics identified in Chapter 2 of the draft plan (i.e., aerosols, North American carbon cycle, and cloud and polar feedback processes). Such incremental reductions in uncertainty in these areas could be realized within longer-term national and international research efforts. Thus, because addressing key uncertainties for decision makers is a high priority for the CCSP in the next two to four years, the program should set goals for near-term reporting of progress. Additionally, the CCRI could focus on better characterizing uncertainties and on uncertainties that are more amenable to a short-term solution. These include questions that can be addressed using "if, then" scenarios and improvements to climate models that can be accomplished with existing data and collaborations among current researchers.

Characterizing and Reducing Uncertainty

All important decisions are made under conditions of uncertainty. Indeed, uncertainty will never be resolved fully. This points to the importance of providing the most accurate representation of uncertainty and points of scientific disagreement. The CCSP recognizes this point in choosing a guiding principle that "CCSP analyses should specifically evaluate and report uncertainty" (CCSP, 2002, p. 11), but the draft strategic plan neither clearly describes the different types of uncertainties nor articulates the value of characterizing uncertainty to decision makers. For example, inherent uncertainty in the climate system (e.g., the chaotic motions of Earth's atmosphere and oceans) is not clearly distinguished from uncertainty due to a lack of understanding. Yet, it is important for decision makers to understand the source, magnitude, and nature of uncertainty, as well as areas of insufficient scientific understanding and of scientific disagreement. Is the

uncertainty due to a lack of knowledge about causal processes? Are causal processes known, but the parameters cannot be accurately estimated because of lack of data, imprecision in the data, or inadequate computing power? Is uncertainty traced to broken links in the separate but interacting systems that drive climatic dynamics and other global processes? The precise characterization of the bases of uncertainty can target areas of further investigation. It can also help decision makers judge whether additional knowledge might improve decisions in the near future.

Systematic Identification of Key Uncertainties for Decision Making

Chapter 2 of the strategic plan accurately identifies three research questions related to significant remaining uncertainties in the physical, chemical, and biological understanding of the Earth system. The plan does not explain how these questions were selected or how the results of these research activities will lead to improved decision making in two to four years. It is not apparent that the CCSP systematically considered the value of these activities for decision making. Instead, the draft plan states that the research areas are selected from recommendations of the NRC report *Climate Change Science: An Analysis of Some Key Questions* (NRC, 2001a). Because the recommended research areas in this report were intended to answer, "What are the specific areas of science that need to be studied further, in order of priority, to advance our understanding of climate change?", this list of research areas may be different from one optimized for providing useful information to decision makers. Relying on the recommendations for priority research from the *Climate Change Science* report is inadequate for meeting the nation's broader needs for global change information to support a wide range of decisions.

Key uncertainties should be identified more systematically, in consultation with decision makers to learn what decisions they need to make. A research agenda focused on making better decisions can then be generated by carefully considering what information is most critical for making those decisions, and then identifying the information that is most uncertain. In many ways this process is similar to the strategic planning process outlined in Chapter 2 of this report. Rigorous processes of this sort are routinely used in other areas of applied research associated with substantial uncertainty (e.g., the rate of spread of a communicable disease).

As noted above, uncertainty is an unavoidable feature of climate and global environmental policy choices. Many techniques to estimate risk, the probability of an impact in the face of uncertainty, are available. There is a sizable and rapidly growing literature in the field of risk analysis that can inform climate and global change decisions, such as how to respond to the threat of drought, flooding, or crop failures. Risk analysis addresses not only the estimation and assessment of risks but also risk perception, risk communication, and risk management—knowledge useful to a wide variety of decisions. For example, the framing of risks and the means of communicating information about risk are highly influential in how risks are perceived by laypersons and experts (NRC, 1996).

Recommendation: The revised strategic plan should identify what sources and magnitudes of reductions in key climate change uncertainties are especially needed and where an improved characterization of uncertainty would benefit decision making, and should use this information to guide the research program.

DECISION SUPPORT RESOURCES

The CCRI portion of the plan introduces an admirable emphasis on the need for science to provide decision support for those in the public and private sectors whose policy decisions are affected by climate change and variability. The CCRI's call for building decision support resources is one of the most innovative and promising features of the draft plan. Building and using this capacity means commitments to capitalize on available information and existing decision support tools, to collect new information to address gaps in understanding, to develop new tools and capacity for decision making, and to engage stakeholders. The committee views the development of decision support resources as the most critical short-term goal of the CCSP. Strong incentives exist for decision makers to use the results of CCSP research when this information is developed and communicated in an accessible and timely manner. The overall objectives identified in the draft plan are certainly amenable to significant short-term progress.

Although the draft strategic plan has incorporated the general language about decision support in many places, it is vague about what this will actually mean. In some cases the strategic plan does not reflect the current state of knowledge relative to decision support and recent science decision-making experiences. Of particular importance is that the plan needs to better identify decision makers and their individual needs, as discussed in Chapter 5 of this report.

Decision Support Research and Operational Activities

The discussion of decision support in the draft plan is weakly developed, in particular the section "Resources for Risk Analysis and Decision Making under Uncertainty" on pages 52-53 of the draft plan. The draft plan does not adequately distinguish between *research* to develop new decision support tools or understanding, on the one hand, and *operational* decision support activities, on the other. It then does not identify state-of-the-art undertakings in both.

Decision support research includes (1) natural and social science research to address gaps in information needed by decision makers (e.g., scenarios, applied modeling); (2) research on processes to improve decision making by effectively translating scientific information into policy options; and (3) research on developing public participation processes. The operational end of decision support focuses on building specific mechanisms or tools for connecting with the wide range of stakeholders, ranging from deliberative processes to identify user needs to application of decision support tools in an operational mode.

Research on processes to improve decision making should comprise activities to tailor available tools for decision support and risk analysis, the transfer of tools across context, and the development of tools customized for climate and global change decision making. The draft plan identifies a number of existing approaches for evaluating longer-term risks in multivariable systems, including game theory, preferences elicitation, and decision sequencing (CCSP, 2002, p. 53); and scenarios, comparisons, applied climate modeling, and historical data analysis (CCSP, 2002, p. 43-52). On the other hand, as described previously, the plan could call for more efforts in the areas of risk assessment and estimation, risk perception, risk communication, and risk management. In identifying research activities in decision support the plan should emphasize products that can be used at appropriate scales and in the context of all the factors influencing environmentally relevant decisions, as well as the opportunities to produce these products in cooperation with stakeholders and the private sector.

The plan does not adequately elaborate upon the processes it will employ for deliberation and adaptive learning. The effectiveness of decision-making tools and risk analyses is fully dependent upon the procedures adopted for their use, in particular how scientists, decision makers, and other stakeholders are engaged in the process. Deliberation should be devoted to determining user needs for decision-relevant scientific information, to the selection of appropriate tools, to the application of those tools in support of decisions, and to the inclusion of all stakeholders in the process. A clearly articulated program of deliberation processes, called analytic deliberation, is contained in the NRC report *Understanding Risk: Informing Decisions in a Democratic Society* (1996).

Recommendation: The revised strategic plan should better describe how decision support capabilities will be developed and how these efforts will link with and inform the program's research to improve understanding of climate and associated global changes.

Applied Climate Modeling

The "Applied Climate Modeling" section of the draft plan (CCSP, 2002, p. 47-52) articulates a much needed new direction for U.S. climate change science, reaching out beyond the business-as-usual approach of the GCRP to provide tangible decision support resources. This section is insightful, reasonably well focused, and well grounded with respect to the priorities for climate modeling research and applications over the next decade. It also shows considerable understanding of the research required to produce some of the key mandated improvements in climate modeling skill, particularly in quantifying climate sensitivity, as well as a keen awareness of the growing but embryonic multi-organization collaborative efforts in applied and theoretical climate change modeling.

The applied climate modeling discussion could be improved by strengthening its treatment of several substantial challenges to meeting the ambitious goals it sets forward.

- The rigidly stated four-year deadline to produce a substantial reduction in climate sensitivity uncertainty is optimistic and likely unrealistic, mostly because of the daunting challenges remaining in understanding and modeling the physics of cloud-radiation feedbacks.
- This section sidesteps the challenge of making connections between the applied climate modeling results and climate impacts researchers, decision makers, resource managers, and other consumers of climate change information. Serious capacity building is necessary, particularly with respect to increasing the capability and number of researchers producing and receiving the model results. In addition, this section does not adequately address how the applied climate modeling activities will be coordinated with the more theoretical model improvements called for under the GCRP.
- The draft plan is unclear about how the National Center for Atmospheric Research-Geophysical Fluid Dynamics Laboratory partnership will be directed (e.g., will its focus be on conducting Intergovernmental Panel on Climate Change (IPCC) projections; facilitating the transition of research results into operational code; refining projections so as to reduce uncertainties in climate sensitivity; preparing model projections for local, regional, and national decision makers; or some combination of these?). The current modeling community will not be able to make substantial near-term progress on all of these fronts, and prioritization will be necessary.
- The section does not adequately address the serious mismatch between existing supercomputer resources and those needed to implement the proposed applied modeling program. Neither the draft plan nor *Our Changing Planet* (GCRP, 2003) indicate that the CCSP intends to seek sufficient funding to address these limitations in the ability to produce and utilize climate projections.
- The discussion of "Testing Against the Climate Record" understates the challenges in these endeavors. Operational satellites have had difficulty in producing reliable measurements of atmospheric temperature trends (NRC, 2000d). The CCSP should strive to ensure that

future satellite systems improve upon the recognized climate monitoring deficiencies of the existing system (NRC, 2000b; 2000c). The proposal to test contemporary climate-change models against the paleoclimate record needs to be more specific to overcome ongoing data and interpretive challenges with this type of analysis.

Recommendation: The discussion of applied climate modeling should be revised to better describe how models will be incorporated into the broader suite of decision support activities and to better address the key challenges to attaining the applied climate modeling goals set forward in the plan.

Existing Decision Support Assets

The draft strategic plan does not adequately utilize many prior assessments and consensus reports that have provided scientific information to decision makers. There are numerous examples of GCRP research supporting assessments and interactions with decision makers and industry on environmental issues. While the plan refers to some of these reports with regard to natural science issues relating to the climate, these reports are not used as examples of success or failure in applied climate studies, including efforts to assess regional impacts, or in interactions with a wide range of user communities. In this respect the plan might build on lessons learned from the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (NAST, 2001), the IPCC process (e.g., IPCC, 2001a, b), and other environmental assessment undertakings. The draft plan deals with many issues that were addressed in the U.S. National Assessment, but the document is not referenced, nor is it used fully in the human dimensions and decision support sections of the draft plan (e.g., scenario development). No matter what the evaluation of the U.S. National Assessment, there were many valuable lessons learned from it in terms of regional impact studies and interactions with stakeholders. These lessons should not be ignored in the CCSP strategic plan.

The plan does not use as a model what the United Nations Environment Programme/World Meteorological Organization (UNEP/WMO) or IPCC assessments have accomplished in terms of decision support, applied science, and stakeholder participation. The UNEP/WMO ozone assessments have had fifteen years of highly successful interaction with governments as Parties to the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer. While the IPCC assessments are referenced and used to justify the CCSP, the lessons learned, among others the outstanding success in communicating with governments around the world, are overlooked. For example, the IPCC aviation assessment (IPCC, 1999) was successful in involving scientists, industries, governments, and intergovernmental regulators (i.e., International Civil Aviation Organization) in evaluating options for future aviation. In many aspects climate science has already succeeded in communicating with stakeholders and in being used in policy decisions, but the CCSP does not take advantage of these successes.

In identifying the relevant decision makers and their needs the CCSP also should build on decades of work in this area by various government agencies, such as the Energy Information Administration, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service and Office of Global Programs, the U.S. Department of Agriculture's Natural Resources Conservation Service, and the National Aeronautics and Space Administration's (NASA's) various ozone assessments. Research needs regarding vulnerability, key risk areas, and interactions with stakeholders can be gleaned from the regional and sectoral findings of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (NAST, 2001), the IPCC report from Working Group II, *Climate Change 2001: Impacts, Adaptation, and Vulnerability* (IPCC, 2001a), and the experiences of past GCRP programs that have supported research and delivery of information to stakeholders, such as NOAA's Regional Integrated Sciences and Assessments (RISA), NASA's Regional Earth Science Application Center, and NSF's Science and Technology Center programs. In particular, the RISA program has dealt with climate impacts and delivery of regional climate and environmental information on all time scales to stakeholders in various regions of the United States, while the International Research Institute for Climate Prediction (the IRI), in cooperation with U.S. Agency for International Development has encouraged similar capacity building in developing countries. These programs could form the kernel of a future "research-to-operations" system that would be focused on understanding the decision context and informing decisions at regional scales.

Recommendation: The revised strategic plan should build upon the lessons learned in applied climate studies and stakeholder interaction from prior environmental and climate assessment activities.

CAPACITY BUILDING TO IMPLEMENT THE STRATEGIC PLAN

The draft strategic plan calls for many research and decision support advances, including a greatly strengthened climate modeling infrastructure to address local, regional, national, and international needs; increased collaboration on key scientific challenges; a significantly upgraded global climate observing system, including climate-quality data management; and a suite of sophisticated informational products for decision makers who in many cases are new to climate change science. The draft plan does not evaluate the

size, scope, and training of appropriate research and stakeholder communities necessary to address these issues or approaches for taking advantage of resources that do exist. The infrastructure requirements to support the transition from research results to operational prediction are also not addressed. For example, support will be needed to bring together in one facility diverse researchers, including observers, process study scientists, modelers, computer programmers, social scientists, and those who represent end users. The committee believes that the CCSP faces a major challenge in systematically developing institutional infrastructure, growing new cross-disciplinary intellectual talent, nurturing networks of diverse perspectives and capabilities, and fostering successful transition from research to decision support applications. In general this capacity building is a long-term activity, but significant progress can be made in the short term with strategic investments.

In both the social sciences and the natural sciences there is considerable knowledge that has the potential to make major contributions to the current and long-term goals of the CCSP, however that knowledge has not yet been fully applied to these goals, nor has the broad set of interfaces between these disciplines been addressed. The necessary personnel to execute an enhanced level of research cannot be assumed to exist, particularly for research problems that cross disciplinary boundaries. In a number of fields, particularly in the social sciences, there are relatively few researchers in the position to undertake climate research. Furthermore, it takes years to increase workforce capacity. The achievement of these capacity-building goals will require systematic investments over a long period of time.

A second capacity-building challenge for the CCSP is to educate the stakeholder community so that it can effectively use the CCSP research products. This key aspect of the linkage between the scientific community and stakeholders is addressed further in Chapter 5 of this report.

Recommendation: The revised strategic plan should explicitly address the major requirements in building capacity in human resources that are implied in the plan.

Another type of capacity building is necessary to acquire and develop the computing, communication, and information management resources necessary both to conduct the extensive climate modeling called for in the draft strategic plan and to process and store the large amounts of data to be collected from a greatly expanded observation network. Applied climate modeling and especially the crucial regional-to-global scale climate change scenarios will require substantially enhanced supercomputer powers. Improvements in research models need to be tested before transition to operational models; this testing requires substantial computing resources. Further effort would be required to develop products responsive to decision makers and other users. The draft plan says nothing about what these computing requirements might be or how the CCSP might obtain them. This omission in the plan comes despite its reference to how two recent NRC reports (NRC, 1998 and 2001c) identified the hardware and software challenges facing the U.S. climate modeling capabilities (CCSP, 2002, p. 139).

Recommendation: The revised strategic plan should provide details about how the CCSP will acquire the computing resources necessary to achieve its goals.

FINANCIAL RESOURCES FOR IMPLEMENTING THE PLAN

The committee was asked to consider whether the results and deliverables identified in the draft strategic plan are realistic given available resources. Because the draft strategic plan does not include details about present and projected levels of support for each program element and because the fiscal year 2004 budget request was not available to the committee during its deliberations, it had limited information to evaluate this question. Nonetheless, it is clear that the scope of activities described in the draft strategic plan is greatly enlarged over what has been supported in the past through the GCRP. It includes a greatly strengthened climate modeling infrastructure increased collaboration; a significantly upgraded global climate observing system; and a suite of sophisticated informational products for decision makers. As discussed in the previous section, implementing this expanded suite of activities will require significant investments in infrastructure and human resources and therefore will necessitate either greatly increased funding for the CCSP or a major reprioritization and cutback in existing programs.

Shortly after this report entered National Academies' review, the President's fiscal year 2004 budget request was made publicly available. It includes $182 million for the CCRI (compared to the fiscal year 2003 budget request of $40 million) within a total CCSP budget request of $1749 million (compared to the fiscal year 2003 budget request of $1747 million). The committee has not had the opportunity to analyze the fiscal year 2004 budget request in detail. Even so, a cursory review of the proposed budget indicates that the CCSP has chosen to increase funding for CCRI at the expense of existing GCRP program elements (or simply relabeled some activities previously considered part of the GCRP as CCRI activities) and has shifted funds from one agency to another.

Even if program funding increases, CCSP management will continue to be faced with many funding decisions, such as which new programs should be initiated (and when), whether any existing programs should be scaled back or discontinued, how to balance short-term and longer-term commitments, and how to balance support for international

and U.S. programs. As discussed in Chapter 2 of this report, these resource allocation decisions must be based on the goals and priorities of the program, which should be clearly described in the revised strategic plan. The independent advisory body recommended by the committee in Chapter 4 of this report also should be used to inform such decisions. The committee believes it is essential for the CCSP to move forward with the important new elements of CCRI while preserving crucial parts of existing GCRP programs.

Recommendation: The CCSP should use the clear goals and program priorities of the revised strategic plan and advice from the independent advisory body recommended by the committee to guide future funding decisions.

4

Managing and Guiding the Program

Are mechanisms for coordinating and integrating issues that involve multiple disciplines and multiple agencies adequately described?

Chapter 15 of the draft strategic plan describes the management structures and processes that have been established to coordinate and integrate federal research and technology development in the area of global climate change. The management structure (see Figure 1.1) includes the following major components:

- A cabinet-level Committee on Climate Change Science and Technology Integration;
- An Interagency Working Group on Climate Change Science and Technology;
- An interagency Climate Change Science Program (CCSP) whose draft strategic plan is the subject of this report; and
- An interagency Climate Change Technology Program (CCTP).

Chapter 15 of the draft plan also describes several management processes that will be used to implement, evaluate, and guide the program (see CCSP, 2002, p. 162-166), and calls for the development of a new mechanism to improve the integration of program elements that are not central to the core missions of participating agencies.[11] In the sections that follow, the committee examines elements of this management framework and offers advice on how they could be improved in the revised strategic plan.

[11] "The past decade has shown that research on climate and global change often includes components that do not fall neatly into the core mission of any one of the participating agencies, are entirely new program needs, or are key to the integration of separate agency activities…One necessary approach for addressing such integrating activities is to develop a mechanism that allows functions that are not central to the core missions of the participating agencies, but that are highly relevant, to be fostered" (CCSP, 2002, p. 165).

INTERACTIONS BETWEEN CLIMATE CHANGE SCIENCE AND TECHNOLOGY

The committee is concerned that the existing management and program links between the CCSP and CCTP may not be sufficient to take advantage of the synergies between these two programs. This may be due in part to CCTP's early stage of development. Generally, a program to define a massive problem (i.e., the CCSP) and a program to develop options for solution to the problem (i.e., the CCTP) should be guided by a common strategy, and this does not appear to be the case for the CCSP and CCTP yet. At the very least the results from each program should be used to guide the project portfolio of the other. Elements of the CCTP program will need to build upon the findings of the CCSP program. Technology solution options should be pursued for the highest-risk problems and informed by the most robust knowledge of those problems. Likewise, the impacts of implementing various solutions (e.g., sequestration, hydrogen-based fuels) should be studied as an integral part of technology development. On the other hand, there are many human dimensions, economic analysis, and decision support functions in the CCSP that critically depend on a deep understanding of the technologies and options that are being developed to address climate and associated global changes. These include the rate of diffusion of new technologies, the cost and impact of new technologies or policy drivers, and the development of realistic scenarios for anything other than business-as-usual baselines for the next 5 to 10 years.

The Interagency Working Group on Climate Change Science and Technology is responsible for coordinating the CCSP with the CCTP at the highest level, and this group may be able to foster some of the synergies described above. The committee believes that more potential benefits of these types of synergies would be realized if there were also direct coordination of some individual components of the CCSP and CCTP.

Recommendation: The CCSP should assess the scientific implications of the technologies under consideration by the CCTP and develop realistic scenarios for climate and associated global changes with these technologies in mind. The program management chapter of the revised CCSP strategic plan should clearly describe mechanisms for coordinating and linking its activities with the technology development activities of the CCTP.

INTERAGENCY MANAGEMENT

The management of an interagency program involving 13 agencies, each with a separate mission and history of independent efforts on issues of climate and global change, is a challenging task. The GCRP has been criticized in the past for being unable to do much beyond encouraging multi-agency cooperation and support because it lacked the authority to redirect long standing programs and mandates of individual agencies (NRC, 2001d). The new CCSP management structure announced by President Bush in February 2002 is designed to address this problem by providing a level of accountability and direction that was missing from the GCRP. In particular, the cabinet-level Committee on Climate Change Science and Technology Integration is responsible for providing "recommendations concerning climate science and technology to the President, and if needed, recommend the movement of funding and programs across agency boundaries" (GCRP, 2003, p. 11). An Interagency Working Group on Climate Change and Technology, composed of departmental and agency representatives at the deputy secretary level, reports to the cabinet-level committee and is responsible for making recommendations about the "funding level and focus" of the CCSP and the CCTP (CCSP, 2002, p. 162-163). The CCSP itself, an interagency group composed of representatives from all agencies that have a research mission in climate and global change, reports to the deputy-secretary level working group and is responsible for "effective management of the coordinated interagency research program" (CCSP, 2002, p. 163). Interagency committees of program managers for each major research element are responsible for interagency coordination and implementation at the program element level.

Responsibility for Managing the Program

The creation of the cabinet-level committee with the authority to shift resource among agencies to meet the goals of the CCSP (if necessary) is an improvement over past approaches to managing the GCRP. However, the interagency approach to managing the program at all levels, from the cabinet-level committee to the individual program element, may not be enough to ensure that agencies cooperate toward the common goals of the CCSP because no individual is clearly identified in the draft plan as having responsibility for managing the program as a whole. Of particular importance are those crosscutting program elements that involve multiple agencies. Chapter 15 of the draft plan on "Program Management and Review" does not describe the responsibilities and authorities of the CCSP leadership adequately.

Recommendation: The revised strategic plan should describe the management processes to be used to foster agency cooperation toward common CCSP goals. The revised plan also should clearly describe the responsibilities of the CCSP leadership.

Descriptions of Agency Responsibilities

The plan does not describe the specific responsibilities and authorities of contributing agencies, such as which entity will be responsible for implementing the work. Defining responsibilities is particularly important for new areas of research that have not been supported by the GCRP in the past, such as land-use and land-cover change and decision support. This also is important for crosscutting research elements, notably water cycle and ecosystems research, which are currently carried out within multiple agencies. The plan includes no clear delineation of which agency will do what, and in particular, which agency(ies) or program(s) will lead the proposed expansion of these crosscutting research areas.

Recommendation: The revised strategic plan should more clearly outline agency responsibilities for implementing the research.

Participation of Mission Agencies

Another management challenge for the CCSP is to foster the participation of mission-oriented agencies in the strategic planning process. The committee believes that mission oriented agencies—such as the Federal Emergency Management Agency, water resources and land management agencies within Department of the Interior, the Army Corps of Engineers, and the extension and farm program agencies within U.S. Department of Agriculture—could make important contributions to identifying research needs, collaborating on research problems, and testing research and modeling results. Because these agencies apparently played little, if any, role in the creation of the current strategic plan, the plan overlooks resources that might be available to its ambitious agenda.

Recommendation: The CCSP should encourage participation of those agencies whose research or operational responsibilities would strengthen the ability of the program to deliver products that serve national needs.

EXTERNAL GUIDANCE

The draft plan describes how the CCSP intends to use scientific steering committees composed of outside experts to help guide program elements. Advisory committees already exist for most of the agency science programs and some interagency programs (e.g., the carbon cycle and the water cycle). Such committees are especially useful for new program elements. There is also a stated desire to continue to receive advice and review from appropriate NRC committees and boards. These processes are valuable for scientific guidance on program goals, research approaches, and evaluating the usefulness and credibility of products.

Notwithstanding the value of these activities, the committee believes that the most difficult of the research management challenges will occur at the level of the CCSP program itself. Thus, there will be a need for scientific and other stakeholder guidance at the level of the program to ensure that clear priorities are established and communicated, that progress toward meeting the subsequent goals can be evaluated, and that the inevitable trade-offs in resources and allocation of time can be done with an eye toward meeting the most important of the overall program goals. Otherwise there will be a tendency for the individual needs and priorities of the agencies to take precedence over the needs of the entire program.

Recommendation: The CCSP should establish a standing advisory body charged with independent oversight of the entire program.

SUMMARY

Successful coordination and integration of CCSP activities will require clearly delineated lines of authority, requisite accountability by participating agencies, and appropriate staffing and funding. As the implementing and coordinating body for this effort, the CCSP will need the ability to direct other agencies' efforts and hold them accountable for performance and coordination. The success of the CCSP will also require the support and oversight of the Committee on Climate Change Science and Technology Integration and the Interagency Working Group on Climate Change Science and Technology, as well as the continued guidance of independent advisory bodies.

5

Enhancing Linkages and Communication

Does the plan adequately describe the roles of the public, private sector, academia, state/local governments, and international communities, and linkages among these communities?

Does the written document describing the program effectively communicate with both stakeholders and the scientific community?

Is the question format for driving the research program effective?

The committee addresses these questions in the context of its analysis of the Climate Change Science Program's (CCSP's) efforts to establish linkages with and outreach to various stakeholder groups including the scientific community. The strategic plan itself does not include explicit statements articulating the program's view of the roles of the public, private sector, academia, state and local governments, and international communities, so one answer to the first part of the first question above would be "no." Based on references in the draft plan to these stakeholder groups (e.g., CCSP, 2002, p. 149ff), the committee inferred the CCSP's view of their respective roles. This chapter starts by addressing the first two questions above for each of the following major stakeholder groups: (1) decision makers, (2) the international community, (3) the public, and (4) scientists; the third question is addressed later in this chapter. The committee will provide more detailed analysis of the strategic planning process, including its analysis of the December planning workshop, in its second report.

DECISION MAKERS

As discussed in Chapter 3 of this report and as identified repeatedly at the December planning workshop, one overarching weakness of the draft strategic plan is its treatment of decision support. Whereas the plan frequently refers to decision support resources, these resources are not defined beyond "providing the needed information" to policy and other decision makers. This approach implies strongly that the role of decision makers is primarily as passive recipients of information. For example, Chapter 13 of the draft plan focuses on describing one-way communication from researchers to various end users who may or may not have previously identified these information needs. This general weakness of the plan applies to decision makers of all types and can be addressed in the revised plan by drawing on lessons learned in previous assessment activities (see Chapter 3 of this report).

The plan lacks specificity about which decision makers it serves, how the CCSP will connect with them, and what types of decisions they will need to make. There are many different stakeholders both inside and outside of the federal government whose needs may vary considerably. When decision makers are mentioned in the plan, however, only two general communities of decision makers are mentioned (e.g., see CCSP, 2002, p. 41-42): federal policy makers with responsibility for emission mitigation decisions and officials (at what government level is unclear) in charge of natural resource management decisions. These two groups have different information needs; the first group requires knowledge of the projected costs and benefits of different emissions control scenarios, while the second is more concerned with understanding climate variability so as to develop adaptation strategies and to respond to current climate conditions, such as in water resource management. The plan needs to clearly indicate how its research activities will support both of these types of decisions, as well as those for a broader suite of stakeholders.

The strategic plan does not adequately consider the participation of state and local officials. Users of climate information at the local, state, and regional levels rely primarily on local officials and experts, not on federal officials. If the CCSP's outreach endeavors are to be successful, it is important for federal agencies to work closely with regional and state climate institutions that can directly help educate and interact with state government,

the private sector, and the general public. Indeed, some mission agencies (e.g., those under the Department of the Interior) already have state and local officers addressing climate issues, but these agencies do not yet participate in the CCSP (see Chapter 4 of this report [Appendix A]).

The plan's treatment of the private sector is also limited. Many sectors of the U.S. economy stand to be affected seriously or even restructured by policies employed to respond to climate change. Others can benefit greatly from improved climate information (e.g., from seasonal to interannual forecasts) and from new opportunities in adaptation to and mitigation of climate change (e.g., through developing new climate mitigation technologies). In addition, commercial development and implementation of most of the technology to address climate change will be carried out by the business community. Yet the plan barely mentions the private sector and when it does, its role is solely as a passive recipient of information generated by the program (e.g., CCSP, 2002, p. 151). Government decisions based on information to be provided by the CCSP are likely to be more successful if the private sector is engaged throughout the research and planning process.

Although the text in places recognizes the importance of engaging stakeholders in the preparation and review of long-term strategic plans, the plan needs to state explicitly that stakeholders should be included where appropriate throughout the research planning, execution, and results review process. Furthermore, the draft plan does not capitalize on the NRC report *Making Climate Forecasts Matter* (NRC, 1999c), which includes recommendations for using the decision sciences to communicate climate issues to stakeholders and other interested parties. Without employing two-way and deliberative communication the plan presents an outmoded and unsuccessful model of stakeholder engagement and public involvement.

Recommendation: The revised strategic plan should identify which categories of decision makers the CCSP serves and describe how the program will improve two-way communication with them.

INTERNATIONAL COMMUNITY

The committee believes that the draft plan misses an opportunity to develop a forward-looking strategy for improving international research networks and assessments. These concepts are mentioned in Chapter 14 of the draft plan, but not in a strategic way. The value of multi-national research networks has been demonstrated in several ongoing agency programs and in international organizations. For example, research conducted under the GCRP during the last 10 years has demonstrated considerable science leadership in international global change programs, particularly the International Geosphere-Biosphere Programme (IGBP), the International Program on Human Dimensions of Global Environmental Change (IHDP), and the World Climate Research Programme (WCRP). The issue for the CCSP is how to leverage the many governmental and nongovernmental organizations to develop capacity and ongoing regional networks of international scientists collaborating with U.S. scientists. Without a defined strategy it is unlikely that the full benefits of such approaches will be achieved.

International collaboration is needed for building better *in situ* calibration and validation of observations, for obtaining more globally distributed measurements, and for building synergy and reducing redundancy in the deployment of observation assets. The meteorological community offers a good example of international collaboration, with assignment of responsibilities for making measurements and data-sharing protocols arranged at an intergovernmental level under the World Meteorological Organization. The climate community lacks a similar structure. The U.S. climate community has not even identified which agency serves as the central contact for international partners on climate research issues, including coordinated observing arrays, intercalibration, capacity building, and data and product sharing.

Most of the world community recognizes that the Intergovernmental Panel on Climate Change (IPCC) approach to involving governments directly in the scientific assessments has been a success. It has acted to denationalize scientific knowledge, an objective that individual national assessments cannot always meet. The value of international assessments over national assessments lies in three factors: (1) by engaging a majority of the world's experts on the relevant scientific questions, such assessments can attain higher scientific quality and are better able to withstand partisan attacks; (2) national assessments risk the perception or actuality of being subordinated to national policy priorities; and (3) by rendering competing parallel assessments scientifically superfluous, well done international assessments control the risk that minor or unintentional disparities in coverage, emphasis, or tone between parallel national assessments are exploited to exaggerate scientific disagreement in policy negotiations. The CCSP should acknowledge such successes in science-policy interactions in its revised strategic plan.

The overall sense of insularity of the plan itself may hinder efforts to improve linkages with the international community. In particular, portions of the draft plan focus so strongly on decision support in the United States, on land cover in the United States, on the carbon cycle in the United States, and so forth that it is not at all clear what the balance may be between focusing on the United States itself and sponsoring research that is relevant to the rest of the world. Of most concern is that the plan does not discuss how it intends to provide information to the IPCC. While there is no evidence of any such nationalism in the GCRP research community, the perception of insularity in the draft plan is

of concern to the committee on two fronts. Scientifically, there is a danger that the emphasis on U.S. issues and resources will result in agencies choosing not to work in geographic regions outside the United States that are significant for understanding particularly important processes. The second issue relates to participation in international climate change research. The United States has been the source of about half the global research investment historically and a leader in many activities internationally, yet there is little discussion in the draft strategic plan of how and whether the U.S. program will participate in international arenas. This insular approach could alienate international contributions to U.S. science.

Recommendation: The revised strategic plan should clearly describe how the CCSP will contribute to and benefit from international research collaborations and assessments.

PUBLIC

The draft strategic plan appropriately recognizes the importance of efforts to communicate with the public and to promote outreach for K-12 education. Chapter 13 of the draft plan accurately describes the need for improved public understanding of climate change, and lists a number of mechanisms that could be used for this purpose. Though important, the recommendations for action in Chapter 13 of the plan are so broad and without prioritization that it will be difficult to accomplish all or even many of them. The revised chapter on communications and outreach should better identify which recommendations have the highest priorities and which agency has the responsibility for ensuring that they are carried out.

The committee notes that the draft plan itself, with its dense prose, is not easily accessible to intelligent nonexperts, and certainly not to laypersons. The draft plan would communicate with the public much more effectively if it included clearly articulated vision, goals, and priorities for the program, as discussed in Chapter 2 of this report.

SCIENTISTS

The draft strategic plan makes clear that the scientific community will play important roles in carrying out research and in advising the program through scientific advisory processes. The program has established strong linkages and two-way communication with the scientific community in general. An indication of this was the strong representation of the scientific community at the December planning workshop, with the exception of some areas of science that have not traditionally received funding from the GCRP. The document itself is generally effective in communicating with the scientific community about problems and research areas. As discussed in Chapter 2 of this report, however, the plan could be more effective in conveying to the scientific community an integrated, reasoned "strategic plan" for climate change and associated global change science.

EFFECTIVENESS OF QUESTION FORMAT

The committee commends the authors for focusing each chapter on a short list of questions or problems, and believes that this should be done consistently throughout the strategic plan. The committee found the question format particularly effective in dealing with well-specified tasks related to improved understanding of physical and chemical processes. The format was less effective in dealing with issues that cross several chapters, such as those related to human dimensions and decision support tasks, which should be better integrated into relevant chapters.

CONCLUDING REMARKS

The committee commends the CCSP for undertaking the challenging task of developing a strategic plan, an important first step in enhancing how the program communicates with its wide range of stakeholders. The current draft of the plan represents a good start to the process. Further, the CCSP has made genuine overtures to researchers and the broader stakeholder community to gain feedback on the draft strategic plan and how to improve it. The planning workshop in December 2002 attracted hundreds of attendees. The workshop summaries presented by the program's leaders (see <http://www.climatescience.gov/Library/workshop2002/closingsession>) indicated that they were attentive to the issues raised by the workshop participants. In addition to the workshop, the CCSP established a mechanism for interested parties to submit written comments on the draft plan. These efforts indicate a strong interest on the part of the CCSP to develop a plan that is consistent with current scientific thinking and is responsive to the nation's needs for information on climate and associated global changes.

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Appendix B

Statement of Task

An *ad hoc* committee will conduct an independent review of the U.S. Climate Change Science Program's strategic plan for global change and climate change studies, giving attention also to the program's strategic planning process. This review will be carried out in two phases.

Phase I

In the first phase, the committee will review the discussion draft of the plan. The review will address the following questions about the draft plan as a whole:

- Is the plan responsive to the nation's needs for information on climate change and global change, their potential implications, and comparisons of the potential effects of different response options?
- Are the goals clear and appropriate?
- Is there an appropriate balance (1) between short-term (2-5 years) and longer-term goals, (2) among substantive research areas, and (3) between research and non-research activities, such as observations, modeling, and communicating results?
- Are mechanisms for coordinating and integrating issues that involve multiple disciplines and multiple agencies adequately described?
- Does the plan adequately describe the roles of the public, private sector, academia, state/local governments, and international communities, and linkages among these communities?
- Does the written document describing the program effectively communicate with both stakeholders and the scientific community? Is the question format for driving the research program effective?

The review also will address the following questions for each of the plan's major topical areas:

- Does the plan reflect current scientific and technical understanding?
- Are the specific objectives clear and appropriate?
- Are expected results and deliverables (and their timelines) realistic given the available resources?

In its review, the committee will consider the scientific and stakeholder community comments at the U.S. Climate Change Science Program's workshop and other comments received by the program during the public comment period. If time permits, the committee also will comment on any significant process issues related to the workshop that could affect how the program revises the draft plan.

The results of phase I will be provided in a report to be delivered no later than February 28, 2003.

Phase II

In the second phase, the committee will provide an overall assessment of the revised (final) plan, with an emphasis on how the plan has evolved in response to NRC and other community input. The committee also will address the following questions related to the processes used to solicit and consider input from the scientific and stakeholder communities throughout the strategic planning process:

- Were the mechanisms for input from the scientific and stakeholder communities throughout the program's strategic

planning process adequate?

- Did the format of the workshop promote the open exchange of ideas and suggestions for improvement?
- Was the process used to make decisions on potential changes to the draft plan clearly communicated to workshop participants and others who submitted comments during the public comment period?
- Was this process consistent with generally accepted practices for considering community input during public comment periods?
- What specific improvements should be reflected in future planning efforts for the program?

The results of phase II will be provided in a report to be delivered to the program within 6 months after the revised (final) plan is published.

Appendix C

Committee and Staff Biographies

Dr. Thomas E. Graedel (*Chair*) is a professor of industrial ecology at Yale University. He earned his Ph.D. in astrophysics in 1969 from the University of Michigan. His research interests include chemistry and physics of atmospheric gases and aerosols; effects of atmospheric contaminants on materials and electrical and mechanical equipment; and environmentally responsible industrial product and process design. His most recent research focuses on studies of the stocks and flows of materials in the industrialized society, especially in very large cities and in environmentally sensitive regions. This work explores aspects of resource availability, potential environmental impacts, opportunities for recycling and reuse, and resources policy initiatives. Dr. Graedel is a member of the NRC Committee on Material Flows Accounting of Natural Resources, Products, and Residuals and is a member of the National Academy of Engineering.

Dr. Linda Capuano is an independent consultant in business and technology strategy. Prior to this she was Corporate Vice President of Technology Strategy at Honeywell International, a $23 billion diversified technology and manufacturing leader, serving customers worldwide with services, building control, aerospace, automotive and specialty chemical products. Joining AlliedSignal in 1995, Dr. Capuano was the general manager of commercial air transport auxiliary power unit products, vice president of technology and innovation, vice president of strategic marketing and business development, and vice president of strategic marketing and business development. Previously, she was the vice president of operations and business development and part of the founding team of Conductus, a telecommunications superconductive electronics business in Sunnyvale, California. Dr. Capuano has also held product management positions in magnetic memory recording at IBM. She served on the Department of Energy Task Force on Alternative Futures for the DOE National Laboratories and as chair of the NRC's Board on Assessment of NIST Programs. Dr. Capuano holds a B.S. in chemistry from State University of New York at Stony Brook, a B.S. in chemical engineering and an M.S. in chemistry from the University of Colorado, and an M.S. in engineering management and Ph.D. in materials science from Stanford University.

Dr. Elizabeth Chornesky is a freelance analyst and research associate at the University of California, Santa Cruz. For more than a decade, she has worked on integrating science into policies and practices related to the conservation of biological diversity and management of biological resources. Previously, as the director of stewardship and then director of conservation research at The Nature Conservancy, Dr. Chornesky oversaw the organization's multi-million dollar research programs and led teams of extension scientists specializing in ecological management, monitoring, and restoration. Prior to that, she was a project director and analyst at the U.S. Congress Office of Technology Assessment, working on national assessments related to invasive species and pesticide alternatives. Her early career was as a research scientist in marine ecology and systematics at the Smithsonian Institution and Lehigh University. Dr. Chornesky has consulted for the National Commission on Science for Sustainable Forestry, the Union of Concerned Scientists, and the Wallace Institute for Alternative Agriculture. She also serves on several national committees, most recently a visioning initiative of the Ecological Society of America's Governing Board and the NRC Committee on Opportunities in Agriculture. Dr. Chornesky holds a B.A. from Cornell University and a Ph.D. from the University of Texas at Austin.

Ms. Mary A. Gade is a partner in the environmental practice group in the law firm of Sonnenschein, Nath, and Rosenthal in Chicago, Illinois, where her work includes litigation, regulatory affairs, and compliance counseling. Before joining the firm, Ms. Gade was the director of the Illinois Environmental Protection Agency from 1991 to 1999. She supervised a staff of approximately 1,400 that enforced the environmental laws and regulations of the state, conducted hazardous waste cleanups, responded to environmental emergencies, maintained environmental laboratories, provided financial assistance to local governments for pollution control facilities, and encouraged and supported pollution prevention programs. She received her law degree in 1977 from Washington University School of Law in St. Louis, Missouri, and her undergraduate degree in

environmental studies and Italian from the University of Wisconsin, Madison. She has been a fellow of the National Academy of Public Administration since 1996.

Ms. Katharine L. Jacobs is a member of the faculty of the University of Arizona's Soil, Water and Environmental Science Department. She is affiliated with the Water Resources Research Center, the Institute for the Study of the Planet Earth, and the NSF Center for Sustainability of Arid Region Hydrology and Riparian Areas (SAHRA). She was the director of the Tucson Active Management Area (AMA) of the Arizona Department of Water Resources from 1988 through 2001, and worked on statewide rural water resources issues and drought planning from 2002-2003. In 2001-2002 she worked at the National Oceanic and Atmospheric Administration on the use of scientific information in policy and decision making. Ms. Jacobs earned her M.L.A. in environmental planning from the University of California, Berkeley. Her expertise is in groundwater management and developing practical, appropriate solutions to difficult public policy issues. She has been involved in all aspects of implementation of the Arizona 1980 Groundwater Management Act, including establishing water rights and permits; developing mandatory conservation requirements for municipal, agricultural, and industrial water users; developing plans for artificial recharge, and writing the Assured Water Supply Rules that require new subdivisions in AMAs to prove a 100 year supply of water. She served on the Synthesis Team for the U.S. National Assessment of the Consequences of Climate Variability and Change and two other NRC panels, Valuing Groundwater (1994) and Endangered Species on the Platte River (2003).

Dr. Anthony C. Janetos has been Vice President of the H. John Heinz Center for Science, Economics, and the Environment since March 2003; he joined the Center as a Senior Fellow in June 2002. Dr. Janetos also directs the Center's Global Change program. Before coming to the Heinz Center, he served as Vice President for Science and Research at the World Resources Institute and Senior Scientist for the Land-Cover and Land-Use Change Program in NASA's Office of Earth Science. He was also Program Scientist for NASA's Landsat 7 mission. He was a co-chair of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change and an author of the IPCC Special Report on Land-Use Change and Forestry and the Global Biodiversity Assessment. Dr. Janetos has written and spoken widely to policy, business, and scientific audiences on the need for scientific input and scientific assessment in the policymaking process and about the need to understand the scientific, environmental, economic, and policy linkages among the major global environmental issues, and the importance of keeping basic human needs in the forefront of the thinking of the environmental community. Dr. Janetos graduated magna cum laude from Harvard College with a bachelor's degree in biology and earned a master's degree and a Ph.D. in biology from Princeton University.

Dr. Charles D. Kolstad is the Donald Bren Distinguished Professor of Environmental Economics and Policy at the University of California, Santa Barbara, where he is jointly appointed in the Department of Economics and the Bren School of Environmental Science and Management. For the decade prior to joining UCSB in 1993 he was on the faculty of the University of Illinois, Urbana-Champaign. He has been a visiting professor at Massachusetts Institute of Technology, Stanford, the Catholic University of Leuven (Belgium), and the New Economic School (Moscow). He received his Ph.D. from Stanford University (1982), his M.A. from the University of Rochester and his B.S. from Bates College. His research interests have been in the area of regulation, particularly environmental regulation. Recently he has also done work on environmental valuation theory in the role of information in environmental decision making and regulation, and the role of uncertainty and learning in controlling the precursors of climate change. His past work in energy markets has focused on coal and electricity markets, including the effect of air pollution regulation on these markets. Dr. Kolstad has served on several NRC committees, including the Committee on Building a Long-Term Environmental Quality Research and Development Program in the U.S. Department of Energy and the Board on Energy and Environmental Systems.

Dr. Diana M. Liverman joined the University of Oxford as the director of the Environmental Change Institute and professor of environmental science in the School of Geography and Environment in October 2003. Dr. Liverman previously served as the director of the Center for Latin American Studies, professor of geography and regional development, and a member of the Executive Committee of the Institute for the Study of Planet Earth (ISPE) at the University of Arizona. Dr. Liverman's research examines the social causes and consequences of environmental change, especially in Latin America. She is currently working on the impacts of climate variability and change on agriculture and water resources, and on the anthropogenic causes of changes in land use and land cover, both with a regional focus on Mexico. She also studies environmental policy relating to the U.S.-Mexico border, the functioning of transnational research institutions, and the human dimensions of climate change and variation including climate impacts and the communication of climate information to stakeholders. Dr. Liverman received her Ph.D. from University of California, Los Angeles.

Dr. Jerry D. Mahlman is a senior research fellow at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado. He was the director of the Geophysical Fluid Dynamics Laboratory at the National Oceanic and Atmospheric Administration in Princeton, New Jersey, for 16 years before his retirement in 2000. He was also a professor of atmospheric and oceanic sciences at Princeton University for 28 years. Much of Dr. Mahlman's research career has been directed toward understanding the behavior of the stratosphere and troposphere. This has involved extensive mathematical modeling and diagnosis of the interactive chemical, radiative, dynamical, and transport aspects of the atmosphere, as well as their implications for climate and chemical change. Over the past decade he has played a central role in the interpretation of climate change to policy makers and affected communities. Dr. Mahlman has served on numerous committees and boards, including the NASA Advisory Council and the Board on Sustainable Development of the NRC. In 1994 he received the prestigious Carl-Gustaf Rossby Research Medal from the American Meteorological Society and the Presidential Distinguished Rank Award, the highest honor awarded to a federal employee. He received his Ph.D. from Colorado State University.

Dr. Diane McKnight is professor of civil, environmental and architectural engineering at the University of Colorado. Dr. McKnight is also a fellow of the American Geophysical Union and past president of the American Society of Limnology and Oceanography. Her research focuses on interactions between hydrologic, chemical, and biological processes in controlling the dynamics in aquatic ecosystems. This research is carried out through field-scale experiments, modeling, and laboratory characterization of natural substrates. In addition, Dr. McKnight conducts research focusing on interactions between freshwater biota, trace metals, and natural organic material in diverse freshwater environments, including lakes and streams in the Colorado Rocky Mountains and in the McMurdo Dry Valleys in Antarctica. She also develops interactions with state and local groups involved in mine drainage and watershed issues in the Rocky Mountains. Dr. McKnight is a member of the NRC's Water Science and Technology Board and is a former member of the Polar Research Board. She received her Ph.D. in environmental engineering from the Massachusetts Institute of Technology.

Dr. Michael J. Prather is professor and Kavli Chair in the Earth System Science Department at the University of California, Irvine. He received his Ph.D. in astronomy from Yale University. His research interests include the simulation of the physical, chemical, and biological processes that determine atmospheric composition and the development of detailed numerical models of photochemistry and atmospheric radiation, and global chemical transport models that describe ozone and other trace gases. Dr. Prather has played a significant role in the Intergovernmental Panel on Climate Change second and third assessments and special report on aviation, and in the World Meteorological Organization's Ozone Assessments (1985-1994). He is a fellow of the American Geophysical Union and a foreign member of the Norwegian Academy of Science and Letters, and has served on several NRC committees, including the Panel on Climate Variability on Decade-to-Century Time Scales.

Dr. Eugene Rosa is professor of sociology and the Edward R. Meyer Distinguished Professor of Natural Resource and Environmental Policy in the Thomas S. Foley Institute for Public Policy and Public Service at Washington State University. Dr. Rosa received his Ph.D. in social science from the Maxwell Graduate School of Syracuse University and completed postdoctoral work at Stanford University and at the University of Michigan. His research program has focused on environmental topics—particularly energy, technology, and risk issues—with attention to theoretical, empirical, and policy issues. His current research is focused on two complementary topics: technological risk and global environmental change. The principal activities associated with the first topic are research and publications on risky technologies such as nuclear power and biotechnology. On the second topic his research and publications are devoted to specifying the anthropogenic (human) causes of greenhouse gases and ecological footprints, to the historical relationships between CO_2 loads and societal well-being, to the history of social thought on climate change, and to testing theories of environmental impacts. He has served or currently serves on several NRC committees, including the Committee on the Staging of Nuclear Repositories, the National Board on Radioactive Waste Management, and the Committee on Metrics for Global Change Research.

Dr. William H. Schlesinger is James B. Duke professor of biogeochemistry, and Dean of the Nicholas School of the Environment and Earth Sciences at Duke University. Completing his A.B. at Dartmouth (1972), and Ph.D. at Cornell (1976), he joined the faculty at Duke in 1980. He is the author or coauthor of over 160 scientific papers and the widely-adopted textbook *Biogeochemistry: An Analysis of Global Change* (Academic Press, 2nd ed. 1997). He was elected a member of the American Academy of Arts and Sciences in 1995 and The National Academy of Sciences in 2003. Currently, Dr. Schlesinger focuses his research on global change ecology. He is the co-principal investigator for the Free Air Carbon Dioxide Enrichment (FACE) Experiment in the Duke Forest—a project that aims to understand how an entire forest ecosystem (vegetation and soils) will respond to elevated CO_2. He has also worked extensively in desert ecosystems and their response to global change—often leading to the degradation of soils and regional desertification. From 1991 to 2000, he served as

Principal Investigator for the NSF-sponsored program of Long Term Ecological Research (LTER) at the Jornada Basin in southern New Mexico. His past work has taken him to diverse habitats, ranging from Okefenokee Swamp in southern Georgia to the Mojave Desert of California. His research has been featured on NOVA, CNN, NPR, and on the pages of *Discover*, *National Geographic*, *The New York Times,* and *Scientific American*. Dr. Schlesinger has testified before U.S. House and Senate Committees on a variety of environmental issues, including preservation of desert habitats and global climate change. Schlesinger has been elected President of the Ecological Society of America for 2003-2004.

Dr. David L. Skole is a professor of geography and the director of the Center for Global Change and Earth Observations at Michigan State University. He received a Ph.D. in natural resources from the University of New Hampshire. His research interests are in the role of land-use and land-cover change and its relation to global change and sustainable development. Much of his work involves remote sensing at continental scales in the tropical and temperate zones, including assessments of the rates and geographic patterns of tropical forest conversion and fragmentation. His research incorporates geographical information and geospatial information technologies in numerical models of natural and managed landscape change and its effect on biodiversity and biogeochemistry. Dr. Skole is past chair of the IGBP-IHDP Core Project on Land Use and Cover Change. He currently serves as chair of the Forest Cover Characteristics and Changes Implementation team of the United Nations Global Terrestrial Observing System program on Global Observations of Land Cover Dynamics, and has served on several advisory committees at federal agencies and the aerospace and geographic information system industries in the United States. Dr. Skole is currently the chair of the U.S. National Science Foundation Advisory Committee on Environmental Research and Education and a member of NASA's *Landsat* 7 science team.

Dr. Andrew R. Solow is a senior scientist and the director of the Marine Policy Center at Woods Hole Oceanographic Institution. His research interests include environmental and ecological statistics, time series analysis, spatial statistics, and applied Bayesian methods. His recent work has focused on population modeling with an emphasis on capturing the population effects of environmental variability. Dr. Solow is a former member of the NRC's Commission on Geosciences, Environment, and Resources and the Committee on Fifty Years of Ocean Discovery at the National Science Foundation. Dr. Solow earned his Ph.D. in geostatistics from Stanford University.

Dr. Robert A. Weller received his Ph.D. in 1978 from the Scripps Institution of Oceanography. He is the director of the Cooperative Institute for Climate and Ocean Research at Woods Hole Oceanographic Institution; he has worked at WHOI since 1979. His research is on atmospheric forcing (wind stress and buoyancy flux), surface waves on the upper ocean, prediction of upper ocean variability, and the ocean's role in climate. He serves as the Secretary of the Navy Chair in Oceanography. He has been on multiple mooring deployment cruises and has practical experience with ocean observation instruments. Dr. Weller is currently serving on the NRC Committee on Utilization of Environmental Satellite Data: A Vision for 2010 and Beyond and the NRC Committee on Implementation of a Seafloor Observatory Network for Oceanographic Research.

Dr. Steve Wittrig is director of the Clean Energy: Facing the Future Program for BP, a program to invest $10 million in Chinese universities to develop and prove clean energy technologies for China and the rest of the world. He worked on the BP/Amoco merger, considering gas-to-liquids strategy and chemical technology strategy and implementation; and on special assignments for Amoco including leading the strategy development team for a program to convert gas to liquids and oxygenates. In prior assignments with Amoco, he managed the engineering and process evaluation group for new product development in chemicals; led a team developing new reactor technology for methane conversion to syngas; and worked with Amoco Oil on coal liquefaction, refinery research, and pollution control. He has a B.S. from the University of Illinois, Urbana, and a Ph.D. in chemical engineering from the California Institute of Technology.

National Research Council Staff

Dr. Amanda Staudt is a senior program officer with the Board on Atmospheric Sciences and Climate of the National Academies. She received an A.B. in environmental engineering and sciences and a Ph.D. in atmospheric sciences from Harvard University. Her doctorate research involved developing a global three-dimensional chemical transport model to investigate how long-range transport of continental pollutants affects the chemical composition of the remote tropical Pacific troposphere. Since joining the National Academies in 2001, Dr. Staudt has worked on studies addressing weather research needs for surface transportation, climate forcings, air quality management in the United States, research priorities for airborne particulate matter, the *NARSTO Assessment of the Atmospheric Science on Particulate Matter*, carbon monoxide episodes in

meteorological and topographical problem areas, and weather forecasting for aviation traffic flow management. She also is the study director for the longstanding Climate Research Committee.

Dr. Gregory H. Symmes serves as associate executive director of the Division on Earth and Life Studies (DELS) of the National Academies, where he is responsible for managing the review of over 70 reports each year and coordinating the National Academies' global change activities, among other management duties. Prior to the formation of DELS in January 2001, he served as associate executive director of the National Academies' Commission on Geosciences, Environment, and Resources. In addition to his division-level management responsibilities, Dr. Symmes has directed National Academies studies in the following areas of science policy: peer review processes and science and technology needs for the Department of Energy's radioactive waste management efforts; regulation of hardrock mining on federal lands; and competitive research within the U.S. Department of Agriculture. Before joining the NRC in 1995, Dr. Symmes served as a research assistant professor and postdoctoral associate in the Department of Earth and Space Sciences at the State University of New York at Stony Brook. He received his Ph.D. in geology from the Johns Hopkins University and his B.A. summa cum laude in geology from Amherst College.

Appendix D

Global Change Research Act of 1990

Public Law 101-606 [S. 169]; November 16, 1990
104 Stat. 3096-3104

An Act to require the establishment of a United States Global Change Research Program aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, to promote discussions toward international protocols in global change research, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Global Change Research Act of 1990".

SECTION 2. DEFINITIONS.

As used in this Act, the term—

1. "Committee" means the Committee on Earth and Environmental Sciences established under section 102;
2. "Council" means the Federal Coordinating Council on Science, Engineering, and Technology;
3. "Global change" means changes in the global environment (including alterations in climate, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the capacity of the Earth to sustain life;
4. "Global change research" means study, monitoring, assessment, prediction, and information management activities to describe and understand—

   A. The interactive physical, chemical, and biological processes that regulate the total Earth system;
   B. The unique environment that the Earth provides for life;
   C. Changes that are occurring in the Earth system; and
   D. The manner in which such system, environment, and changes are influenced by human actions;

5. "Plan" means the National Global Change Research Plan developed under section 104, or any revision thereof; and
6. "Program" means the United States Global Change Research Program established under section 103.

TITLE I—UNITED STATES GLOBAL CHANGE RESEARCH PROGRAM

SEC. 101. FINDINGS AND PURPOSE.

(a) FINDINGS—The Congress makes the following findings:

1. Industrial, agricultural, and other human activities, coupled with an expanding world population, are contributing to processes of global change that may significantly alter the Earth habitat within a few human generations.
2. Such human-induced changes, in conjunction with natural fluctuations, may lead to significant global warming and thus alter world climate patterns and increase global sea levels. Over the next century, these consequences could

adversely affect world agricultural and marine production, coastal habitability, biological diversity, human health, and global economic and social well-being.

3. The release of chlorofluorocarbons and other stratospheric ozone-depleting substances is rapidly reducing the ability of the atmosphere to screen out harmful ultraviolet radiation, which could adversely affect human health and ecological systems.
4. Development of effective policies to abate, mitigate, and cope with global change will rely on greatly improved scientific understanding of global environmental processes and on our ability to distinguish human-induced from natural global change.
5. New developments in interdisciplinary Earth sciences, global observing systems, and computing technology make possible significant advances in the scientific understanding and prediction of these global changes and their effects.
6. Although significant Federal global change research efforts are underway, an effective Federal research program will require efficient interagency coordination, and coordination with the research activities of State, private, and international entities.

(b) PURPOSE—The purpose of this title is to provide for development and coordination of a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.

SEC. 102. COMMITTEE ON EARTH AND ENVIRONMENTAL SCIENCES.

(a) ESTABLISHMENT—The President, through the Council, shall establish a Committee on Earth and Environmental Sciences. The Committee shall carry out Council functions under section 401 of the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6651) relating to global change research, for the purpose of increasing the overall effectiveness and productivity of Federal global change research efforts.

(b) MEMBERSHIP—The Committee shall consist of at least one representative from—

1. The National Science Foundation;
2. The National Aeronautics and Space Administration;
3. The National Oceanic and Atmospheric Administration of the Department of Commerce;
4. The Environmental Protection Agency;
5. The Department of Energy;
6. The Department of State;
7. The Department of Defense;
8. The Department of the Interior;
9. The Department of Agriculture;
10. The Department of Transportation;
11. The Office of Management and Budget;
12. The Office of Science and Technology Policy;
13. The Council on Environmental Quality;
14. The National Institute of Environmental Health Sciences of the National Institutes of Health; and
15. Such other agencies and departments of the United States as the President or the Chairman of the Council considers appropriate.

Such representatives shall be high-ranking officials of their agency or department, wherever possible the head of the portion of that agency or department that is most relevant to the purpose of the title described in section 101(b).

(c) CHAIRPERSON—The Chairman of the Council, in consultation with the Committee, biennially shall select one of the Committee members to serve as Chairperson. The Chairperson shall be knowledgeable and experienced with regard to the administration of scientific research programs, and shall be a representative of an agency that contributes substantially, in terms of scientific research capability and budget, to the Program.

(d) SUPPORT PERSONNEL—An Executive Secretary shall be appointed by the Chairperson of the Committee, with the approval of the Committee. The Executive Secretary shall be a permanent employee of one of the agencies or departments represented on the Committee, and shall remain in the employ of such agency or department. The Chairman of the Council shall have the authority to make personnel decisions regarding any employees detailed to the Council for purposes of working on business of the Committee pursuant to section 401 of the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6651).

(e) FUNCTIONS RELATIVE TO GLOBAL CHANGE—The Council, through the Committee, shall be responsible for planning and coordinating the Program. In carrying out this responsibility, the Committee shall—

1. Serve as the forum for developing the Plan and for overseeing its implementation;
2. Improve cooperation among Federal agencies and departments with respect to global change research activities;
3. Provide budgetary advice as specified in section 105;
4. Work with academic, State, industry, and other groups conducting global change research, to provide for periodic public and peer review of the Program;
5. Cooperate with the Secretary of State in—

   (A) Providing representation at international meetings and conferences on global change research in which the United States participates; and
   (B) Coordinating the Federal activities of the United States with programs of other nations and with international global change research activities such as the International Geosphere-Biosphere Program.

6. Consult with actual and potential users of the results of the Program to ensure that such results are useful in developing national and international policy responses to global change; and
7. Report at least annually to the President and the Congress, through the Chairman of the Council, on Federal global change research priorities, policies, and programs.

SEC. 103. UNITED STATES GLOBAL CHANGE RESEARCH PROGRAM.

The President shall establish an interagency United States Global Change Research Program to improve understanding of global change. The Program shall be implemented by the Plan developed under section 104.

SEC. 104. NATIONAL GLOBAL CHANGE RESEARCH PLAN.

(a) IN GENERAL—The Chairman of the Council, through the Committee, shall develop a National Global Change Research Plan for implementation of the Program. The Plan shall contain recommendations for national global change research. The Chairman of the Council shall submit the Plan to the Congress within one year after the date of enactment of this title, and a revised Plan shall be submitted at least once every three years thereafter.
(b) CONTENTS OF THE PLAN—The Plan shall—

1. Establish, for the 10-year period beginning in the year the Plan is submitted, the goals and priorities for Federal global change research which most effectively advance scientific understanding of global change and provide usable information on which to base policy decisions relating to global change;
2. Describe specific activities, including research activities, data collection and data analysis requirements, predictive modeling, participation in international research efforts, and information management, required to achieve such goals and priorities;
3. Identify and address, as appropriate, relevant programs and activities of the Federal agencies and departments represented on the Committee that contribute to the Program;
4. Set forth the role of each Federal agency and department in implementing the Plan;
5. Consider and utilize, as appropriate, reports and studies conducted by Federal agencies and departments, the National Research Council, or other entities;
6. Make recommendations for the coordination of the global change research activities of the United States with such activities of other nations and international organizations, including—

   (A) A description of the extent and nature of necessary international cooperation;
   (B) The development by the Committee, in consultation when appropriate with the National Space Council, of proposals for cooperation on major capital projects;
   (C) Bilateral and multilateral proposals for improving worldwide access to scientific data and information; and
   (D) Methods for improving participation in international global change research by developing nations; and

7. Estimate, to the extent practicable, Federal funding for global change research activities to be conducted under the Plan.

(c) RESEARCH ELEMENTS—The Plan shall provide for, but not be limited to, the following research elements:

1. Global measurements, establishing worldwide observations necessary to understand the physical, chemical, and biological processes responsible for changes in the Earth system on all relevant spatial and time scales.
2. Documentation of global change, including the development of mechanisms for recording changes that will actually occur in the Earth system over the coming decades.
3. Studies of earlier changes in the Earth system, using evidence from the geological and fossil record.
4. Predictions, using quantitative models of the Earth system to identify and simulate global environmental processes and trends, and the regional implications of such processes and trends.
5. Focused research initiatives to understand the nature of and interaction among physical, chemical, biological, and social processes related to global change.

(d) INFORMATION MANAGEMENT—The Plan shall provide recommendations for collaboration within the Federal Government and among nations to—

1. Establish, develop, and maintain information bases, including necessary management systems which will promote consistent, efficient, and compatible transfer and use of data;
2. Create globally accessible formats for data collected by various international sources; and
3. Combine and interpret data from various sources to produce information readily usable by policymakers attempting to formulate effective strategies for preventing, mitigating, and adapting to the effects of global change.

(e) NATIONAL RESEARCH COUNCIL EVALUATION—The Chairman of the Council shall enter into an agreement with the National Research Council under which the National Research Council shall—

1. Evaluate the scientific content of the Plan; and
2. Provide information and advice obtained from United States and international sources, and recommended priorities for future global change research.

(f) PUBLIC PARTICIPATION—In developing the Plan, the Committee shall consult with academic, State, industry, and environmental groups and representatives. Not later than 90 days before the Chairman of the Council submits the Plan, or any revision thereof, to the Congress, a summary of the proposed Plan shall be published in the Federal Register for a public comment period of not less than 60 days.

SEC. 105. BUDGET COORDINATION.

(a) COMMITTEE GUIDANCE—The Committee shall each year provide general guidance to each Federal agency or department participating in the Program with respect to the preparation of requests for appropriations for activities related to the Program.

(b) SUBMISSION OF REPORTS WITH AGENCY APPROPRIATIONS REQUESTS—

1. Working in conjunction with the Committee, each Federal agency or department involved in global change research shall include with its annual request for appropriations submitted to the President under section 1108 of title 31, United States Code, a report which—

   (A) Identifies each element of the proposed global change research activities of the agency or department;
   (B) specifies whether each element (i) contributes directly to the Program or (ii) contributes indirectly but in important ways to the Program; and
   (C) states the portion of its request for appropriations allocated to each element of the Program.

2. Each agency or department that submits a report under paragraph (1) shall submit such report simultaneously to the Committee.

(c) CONSIDERATION IN PRESIDENT'S BUDGET—

1. The President shall, in a timely fashion, provide the Committee with an opportunity to review and comment on the budget estimate of each agency and department involved in global change research in the context of the Plan.
2. The President shall identify in each annual budget submitted to the Congress under section 1105 of title 31, United States Code, those items in each agency's or department's annual budget which are elements of the Program.

SEC. 106. SCIENTIFIC ASSESSMENT.

On a periodic basis (not less frequently than every 4 years), the Council, through the Committee, shall prepare and submit to the President and the Congress an assessment which—

1. integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings;
2. analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
3. analyzes current trends in global change, both human- induced and natural, and projects major trends for the subsequent 25 to 100 years.

SEC. 107. ANNUAL REPORT.

(a) GENERAL.—Each year at the time of submission to the Congress of the President's budget, the Chairman of the Council shall submit to the Congress a report on the activities conducted by the Committee pursuant to this title, including—

1. a summary of the achievements of the Program during the period covered by the report and of priorities for future global change research;
2. an analysis of the progress made toward achieving the goals of the Plan;
3. expenditures required by each agency or department for carrying out its portion of the Program, including—

   (A) the amounts spent during the fiscal year most recently ended;
   (B) the amounts expected to be spent during the current fiscal year; and
   (C) the amounts requested for the fiscal year for which the budget is being submitted.

(b) RECOMMENDATIONS.—The report required by subsection (b) shall include recommendations by the President concerning—

1. changes in agency or department roles needed to improve implementation of the Plan; and
2. additional legislation which may be required to achieve the purposes of this title.

SEC. 108. RELATION TO OTHER AUTHORITIES.

(a) NATIONAL CLIMATE PROGRAM RESEARCH ACTIVITIES.— The President, the Chairman of the Council, and the Secretary of Commerce shall ensure that relevant research activities of the National Climate Program, established by the National Climate Program Act (15 U.S.C. 2901 et seq.), are considered in developing national global change research efforts.
(b) AVAILABILITY OF RESEARCH FINDINGS.—The President, the Chairman of the Council, and the heads of the agencies and departments represented on the Committee, shall ensure that the research findings of the Committee, and of Federal agencies and departments, are available to—

1. the Environmental Protection Agency for use in the formulation of a coordinated national policy on global climate change pursuant to section 1103 of the Global Climate Protection Act of 1987 (15 U.S.C. 2901 note); and
2. all Federal agencies and departments for use in the formulation of coordinated national policies for responding to human-induced and natural processes of global change pursuant to other statutory responsibilities and obligations.

(c) EFFECT ON FEDERAL RESPONSE ACTIONS.—Nothing in this title shall be construed, interpreted, or applied to preclude or delay the planning or implementation of any Federal action designed, in whole or in part, to address the threats of stratospheric ozone depletion or global climate change.

TITLE II—INTERNATIONAL COOPERATION IN GLOBAL CHANGE RESEARCH

SEC. 201. SHORT TITLE.

This title may be cited as the "International Cooperation in Global Change Research Act of 1990".

SEC. 202. FINDINGS AND PURPOSES.

(a) FINDINGS—The Congress makes the following findings:

1. Pooling of international resources and scientific capabilities will be essential to a successful international global change program.
2. While international scientific planning is already underway, there is currently no comprehensive intergovernmental mechanism for planning, coordinating, or implementing research to understand global change and to mitigate possible adverse effects.
3. An international global change research program will be important in building future consensus on methods for reducing global environmental degradation.
4. The United States, as a world leader in environmental and Earth sciences, should help provide leadership in developing and implementing an international global change research program.

(b) PURPOSES—The purposes of this title are to—

1. Promote international, intergovernmental cooperation on global change research;
2. involve scientists and policymakers from developing nations in such cooperative global change research programs; and
3. promote international efforts to provide technical and other assistance to developing nations which will facilitate improvements in their domestic standard of living while minimizing damage to the global or regional environment.

SEC. 203. INTERNATIONAL DISCUSSIONS.

(a) GLOBAL CHANGE RESEARCH.—The President should direct the Secretary of State, in cooperation with the Committee, to initiate discussions with other nations leading toward international protocols and other agreements to coordinate global change research activities. Such discussions should include the following issues:

1. Allocation of costs in global change research programs, especially with respect to major capital projects.
2. Coordination of global change research plans with those developed by international organizations such as the International Council on Scientific Unions, the World Meteorological Organization, and the United Nations Environment Program.
3. Establishment of global change research centers and training programs for scientists, especially those from developing nations.
4. Development of innovative methods for management of international global change research, including—

   (A) use of new or existing intergovernmental organizations for the coordination or funding of global change research; and
   (B) creation of a limited foundation for global change research.

5. The prompt establishment of international projects to—

   (A) create globally accessible formats for data collected by various international sources; and
   (B) combine and interpret data from various sources to produce information readily usable by policymakers attempting to formulate effective strategies for preventing, mitigating, and adapting to possible adverse effects of global change.

6. Establishment of international offices to disseminate information useful in identifying, preventing, mitigating, or adapting to the possible effects of global change.

(b) ENERGY RESEARCH.—The President should direct the Secretary of State (in cooperation with the Secretary of Energy, the Secretary of Commerce, the United States Trade Representative, and other appropriate members of the Committee) to initiate discussions with other nations leading toward an international research protocol for cooperation on the development of energy technologies which have minimally adverse effects on the environment. Such discussions should include, but not be limited to, the following issues:

1. Creation of an international cooperative program to fund research related to energy efficiency, solar and other renewable energy sources, and passively safe and diversion-resistant nuclear reactors.
2. Creation of an international cooperative program to develop low cost energy technologies which are appropriate to the environmental, economic, and social needs of developing nations.
3. Exchange of information concerning environmentally safe energy technologies and practices, including those described in paragraphs (1) and (2).

SEC. 204. GLOBAL CHANGE RESEARCH INFORMATION OFFICE.

Not more than 180 days after the date of enactment of this Act, the President shall, in consultation with the Committee and all relevant Federal agencies, establish an Office of Global Change Research Information. The purpose of the Office shall be to disseminate to foreign governments, businesses, and institutions, as well as the citizens of foreign countries, scientific research information available in the United States which would be useful in preventing, mitigating, or adapting to the effects of global change.

Such information shall include, but need not be limited to, results of scientific research and development on technologies useful for—

1. Reducing energy consumption through conservation and energy efficiency;
2. Promoting the use of solar and renewable energy sources which reduce the amount of greenhouse gases released into the atmosphere;
3. Developing replacements for chlorofluorocarbons, halons, and other ozone-depleting substances which exhibit a significantly reduced potential for depleting stratospheric ozone;
4. Promoting the conservation of forest resources which help reduce the amount of carbon dioxide in the atmosphere;
5. Assisting developing countries in ecological pest management practices and in the proper use of agricultural, and industrial chemicals; and
6. Promoting recycling and source reduction of pollutants in order to reduce the volume of waste which must be disposed of, thus decreasing energy use and greenhouse gas emissions.

TITLE III—GROWTH DECISION AID

SEC. 301. STUDY AND DECISION AID.

(a) The Secretary of Commerce shall conduct a study of the implications and potential consequences of growth and development on urban, suburban, and rural communities. Based upon the findings of the study, the Secretary shall produce a decision aid to assist State and local authorities in planning and managing urban, suburban, and rural growth and development while preserving community character.

(b) The Secretary of Commerce shall consult with other appropriate Federal departments and agencies as necessary in carrying out this section.

The Secretary of Commerce shall submit to the Congress a report containing the decision aid produced under subsection (a) no later than January 30, 1992. The Secretary shall notify appropriate State and local authorities that such decision aid is available on request.

Appendix E

Letter from James R. Mahoney

September 17, 2002

Dr. Bruce Alberts
President
National Academy of Sciences
2101 Constitution Avenue, NW
Washington, DC 20418

Subject: Requested Review of the Updated U.S. Climate Change Science Program Strategic Plan by the National Academies

Dear Bruce:

I am writing in my role as Director of the U.S. Climate Change Science Program, involving the collaboration of thirteen federal agencies responsible for sponsoring research on climate change and global change issues. The Climate Change Science Program is responsible for reporting the results of the sponsored research in a manner that facilitates public debate about climate change policy issues, and that provides analyses useful for decision-making by natural resource and infrastructure managers throughout the United States. The Climate Change Science Program incorporates the work of the U.S. Global Change Research Program (USGCRP) authorized by Global Change Research Act of 1990 and the Climate Change Research Initiative (CCRI) launched by President Bush in June 2001.

Thanks very much for taking the time to discuss our plans for the formulation and public review of an updated strategic plan for the U.S. Climate Change Science Program during our recent meeting in your office. Confirming my verbal request during our meeting, the thirteen collaborating agencies in the Climate Change Science Program request that the appropriate elements of the National Academies appoint a committee to undertake a thorough review of the Program's draft strategic plan that is currently in development.

The approach to open scientific and stakeholder review of the Program's draft strategic plan is described in the *Announcement and Invitation for the U.S. Climate Change Science Program: Planning Workshop for Scientists and Stakeholders*, which is enclosed. This document describes a strategic planning process for research and reporting activities built around the following key dates:

- November 11, 2002: Discussion draft of the strategic plan available on the web.
- December 3 - 5, 2002: Open workshop held in Washington, DC.
- January 8, 2003: End of post-workshop public comment period (for written comments).
- April 1, 2003 (approximate): Publication of revised (final) plan.
- April 2003 through 2007: Various scheduled dates for publication of findings and related decision support information (as described in the strategic plan).

The U.S. Climate Science Program would like to engage the National Academies in a thorough review of the strategic planning process, with a focus on the following elements:

1. The discussion draft of the strategic plan, as posted on the www.climatescience.gov web site by November 11, 2002.
2. The comments and questions received at the workshop on December 3 - 5, 2002.

3. The comments received on the web site during the 30-day period after the workshop.
4. The process of publishing a discussion draft strategic plan for comment and discussion by the scientific and stakeholder communities at an open workshop, followed by a written comment period.

We would ask the Academy committee to prepare its comments by February 28, 2003, so that the committee comments can be used as input to the final version of the strategic plan due by April 1, 2003. Also, we note that the 1990 Global Change Research Act requires that the strategic plans of the science program be reviewed by the National Academy. Therefore we suggest that the same Academy committee remain in operation, and report its comments on the final version of the strategic plan after its publication in April 2003.

The Academy would be requested to comment on all of the topic areas listed in the section labeled "Workshop Topics" in the enclosed announcement. Noting that the topics "Scenario Development and Evaluation" and "Decision Support Tool Development" involve technology, cost, economic and energy supply questions, the coverage of the Academy review would include:

- Climate and ecosystem science questions.
- Human interactions questions.
- Control technology issues (a limited set)
- Cost and economic analyses
- Energy analyses
- Public communications and education issues

We also request that the Academy comment on additional crosscutting issues in the strategic plan as well as the individual subsections. For example, is there appropriate balance between short and long-term goals, and across substantive research areas? Does the plan adequately describe linkages with the public, private sector, state/local governments, and the international communities? Is the plan's approach to management of issues that involve multiple disciplines and multiple agencies effectively coordinated and integrated?

We look forward to continuing discussions with representatives of the Academy to review this letter, and to develop a plan for the requested Academy review.

With best regards,

/s/ *Jim Mahoney*

Enclosure