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NATIONAL ACADEMY OF SCIENCES' REVIEW OF THE U.S. CLIMATE CHANGE SCIENCE PROGRAM STRATEGIC PLAN

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED EIGHTH CONGRESS

FIRST SESSION

MAY 7, 2003

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED EIGHTH CONGRESS

FIRST SESSION

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NATIONAL ACADEMY OF SCIENCES' REVIEW OF THE U.S. CLIMATE CHANGE SCIENCE PROGRAM STRATEGIC PLAN

WEDNESDAY, MAY 7, 2003

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Committee met, pursuant to notice, at 9:30 a.m. in room SR–253, Russell Senate Office Building, Hon. John McCain, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. JOHN MCCAIN, U.S. SENATOR FROM ARIZONA

The CHAIRMAN. It is reported that greenhouse gases are accumulating in the earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. Temperatures are, in fact, rising.

The changes observed over the last several decades are likely mostly due to human activities, but we would not rule out that some significant part of these changes is also a reflection of natural variability. Clearly, it is time for the Nation to demonstrate real leadership and make some notable progress on this critical issue.

Earlier this year Senator Lieberman and I introduced S. 139, the Climate Stewardship Act of 2003, which would establish a mandatory carbon dioxide reduction program, along with an emission trading system. A market-based approach offers the best chance for the Nation to respond to a growing global environmental threat.

We requested the Energy Information Administration to conduct an analysis of our climate change proposal. When the results are available, we will review and make appropriate changes and the latest inclusions on the emission levels and their associated costs.

Yesterday the Senate began considering the energy legislation that if enacted, is expected to have an enormous impact on the Nation's future. However, I do not believe any energy legislation can be truly meaningful unless it seeks to address climate change. Therefore, it is my intention to offer a modified version of the Climate Stewardship Act as an amendment during the Senate's deliberations on the energy legislation.

I suspect part of the amendment will be the beginning of a long congressional battle to bring about meaningful climate change policy.

Today's hearing is a continuation of the Committee's ongoing consideration of climate change issues. Earlier this year we heard

testimony from the Administration concerning its draft strategy plan for the U.S. Climate Change Science Program. Since that hearing, the National Academy of Sciences, at the request of the Administration, completed its review of the plan, which will be the main topic during this hearing.

Also, we will consider the Academy's review of abrupt climate change. Abrupt climate change has been defined as taking place so rapidly and unexpectedly that human or natural systems have difficulty adapting to it.

The Academy's review also requested by the Administration, highlights the uncertainty associated with abrupt climate change. This is an interesting area of concern, because so many have concluded that the response to the climate systems of the increased levels of carbon dioxide is linear, therefore affording the world plenty of time to respond to it.

I look forward to a frank discussion of the logic behind such assumptions. I welcome our witnesses here today and look forward to their testimony.

Our witnesses today are Dr. Richard Alley, Professor of Geosciences, Pennsylvania State University, Earth System Science Center, at University Park, Pennsylvania; Dr. Thomas E. Graedel, Professor of Industrial Ecology at Yale University; Dr. Anthony C. Janetos, Director of the H. John Heinz Center for Science, Economics, and the Environment; Dr. Diana M. Liverman, Director of Latin American Studies Program, University of Arizona; and Dr. Andrew Solow, Associate Scientist and Director of the Marine Policy Center, Woods Hole Oceanographic Institute.

Dr. Alley, we will begin with you. Thank you. I understand that maybe there is one statement for all, or does each choose to make a statement?

STATEMENT OF RICHARD ALLEY PH.D., PROFESSOR OF GEOSCIENCES, PENNSYLVANIA STATE UNIVERSITY

Dr. ALLEY. Two statements, and then additional words.

I thank you for the opportunity to testify. I was chair of the committee at the National Academy of Sciences that released the report, Abrupt Climate Change: Inevitable Surprises.

I am also teaching my elder daughter to drive right now. She spends most of her time trying to keep the car between the lines, left turns and parking, and things she must deal with every day. In addition, she is worried about issues such as, what happens if a drunk driver comes across the center line, things that are possible, things that could happen but may not happen, but would be so important that she should know about them.

In exactly the same way, Professor Graedel will be discussing issues that are highly likely, and we will have to deal with these issues. The report from our committee was looking at things that have happened, that are possible, but that may not happen in my lifetime, or in my daughter's lifetime, but that will be so important that the committee believes that it would be useful for our society to understand them.

The records of climate change are very clear. The climate acts as if it is controlled by a dial. You change the carbon dioxide a little bit, you change the sun a little bit, and the climate changes a little

in a reasonably predictable way. Occasionally at various times in history, the climate acted as if it were controlled by a switch. A small pressure does not do anything; a slightly larger pressure and the climate jumps into a new state.

These changes have been very large locally, as much as 10 to 20 degrees Fahrenheit. They have occurred very rapidly over a couple of years or fewer. They have affected regions of continents scaled to the whole world. And they have been very persistent once the climate gets into a new state, once the switch is flipped. It may remain that way for decades or centuries.

It is clear from what we see that the big changes have occurred when the climate was being forced to change by slower processes, and so that at least raises the possibility that humans are increasing the likelihood of an abrupt climate change, not because there is anything inherently wrong with humans, but simply because we are pushing the climate system to change.

The research program that is examined by the committee that I chaired in many ways overlaps that research program that Professor Graedel will be discussing. It is distinct from it in certain ways, it includes a look at natural as well as human causes of climate change. It includes focus on looking for the switches in the climate system, the ones that would affect drought and its persistence in the grain belts, and the possibility of droughts much bigger than the dust bowl, the ones that would affect the stability of the Gulf Stream and its effect on climate. There is a focus on snow and ice, their changes. And there is also a focus on the history of climate, and something which has occurred must be possible.

The committee also noted that while it is highly likely that we can say much better what is possible. What is likely, we cannot put forward from the research community something that is useful to policymakers. Predicting a switch is always difficult, when exactly will it flip, and so some uncertainty for climate change will persist.

For that reason, the committee recommended research into possible ways to increase the bendability of society. Our history shows that when challenged by climate change or other factors, some societies have bent and others have broken. And the committee believes that bendability would be a good thing.

There is more detail in my written testimony and in the report that we issued, and after the other statements I would be most happy to answer questions.

[The prepared statement of Dr. Alley follows:]

PREPARED STATEMENT OF RICHARD ALLEY, PH.D., PROFESSOR OF GEOSCIENCES, PENNSYLVANIA STATE UNIVERSITY

Good morning. Thank you very much for this opportunity to testify. I am Richard Alley, a professor of geosciences at the Pennsylvania State University, and I served as chair of a recent committee of the National Academies that produced the report, "Abrupt Climate Change: Inevitable Surprises." Most of the other testimony this morning focuses on climate change in the broad sense and how we as a nation can improve our understanding of change and our resiliency in responding to its impacts. My role is to focus on a piece of this puzzle: Abrupt climate change.

What is Abrupt Climate Change?

Just what do I mean by abrupt climate change? If you read the evidence hidden in ice cores and other records of what the climate was in the past, you will learn that the Earth has at times undergone large, abrupt, widespread and persistent changes in climate (see Figure 1, page 4). I'm talking about a change of as much

as 10 °C during just 10 years in some places, to a new climate state that persisted for centuries. For example, roughly half the north Atlantic warming since the last ice age was achieved in only a decade, and it was accompanied by significant climatic changes across most of the globe. Paleo-records show that local warmings as large as 16 °C occurred repeatedly during the slide into and climb out of the last ice age. Think about what that kind of change might mean to farmers. Or to water managers. Evidence suggests that abrupt climate changes are not only possible but may be likely in the future, and regardless of timing such changes would bring large impacts on ecosystems and societies.

Our report, which was published in 2002, was an attempt to describe what is known about abrupt climate changes and their impacts, based on paleoclimate proxies, historical observations, and modeling. The report does not focus on large, abrupt causes—nuclear wars or giant meteorite impacts—but rather on the surprising new findings that abrupt climate change can occur when gradual causes push the earth system across a threshold. Just as the slowly increasing pressure of a finger eventually flips a switch and turns on a light, the slow effects of drifting continents or wobbling orbits or changing atmospheric composition may "switch" the climate to a new state. And, just as a moving hand is more likely than a stationary one to encounter and flip a switch, faster earth-system changes—whether natural or human-caused—are likely to increase the probability of encountering a threshold that triggers a still-faster climate shift.

Can We Predict Abrupt Climate Change?

We do not yet understand abrupt climate changes well enough to predict them. The models used to project future climate changes and their impacts are not especially good at simulating the size, speed, and extent of the past changes, casting uncertainties on assessments of potential future changes. Thus, it is likely that climate surprises await us.

When orbital wiggles and rising greenhouse gases warmed the earth from the last ice age, proxy records show that smooth changes were interspersed with abrupt coolings and warmings, wettings and dryings. By analogy, the expected future warming may come smoothly, but may come with jumps, short-lived or local coolings, floods or droughts, and other unexpected changes. Societies and ecosystems have an easier time dealing with slower or better-anticipated changes, so the abruptness and unpredictability of the possible changes may be disquieting.

Abrupt climate changes were especially common when the climate system was being forced to change most rapidly. Thus, greenhouse warming and other human alterations of the earth system may increase the possibility of large, abrupt, and unwelcome regional or global climatic events.

Our committee, which was composed of 11 of the most knowledgeable experts and which benefited from input from dozens of other scientists who participated in our workshops, considered patterns, magnitudes, mechanisms, and impacts of abrupt climate changes, possible implications for the future, and critical knowledge gaps. The potentially large impacts and prediction difficulties pose special challenges—how can we increase the adaptability and resiliency of societies and ecosystems?

What Can Society do to Prepare for Abrupt Climate Change?

There is no need to be fatalistic about the threats posed by abrupt climate change. Societies have faced both gradual and abrupt climate changes for millennia and have learned to adapt through various mechanisms, such as moving indoors, developing irrigation for crops, and migrating away from inhospitable regions. Nevertheless, because climate change will likely continue in the coming decades, denying the likelihood or downplaying the relevance of past abrupt events could be costly. Societies can take steps to face the potential for abrupt climate change. The committee believes that increased knowledge is the best way to improve the effectiveness of response, and thus that research into the causes, patterns, and likelihood of abrupt climate change can help reduce vulnerabilities and increase our adaptive capabilities. The committee's report provides detailed recommendations in two broad categories:

(1) targeted research necessary to expand instrumental and paleoclimatic observations, and

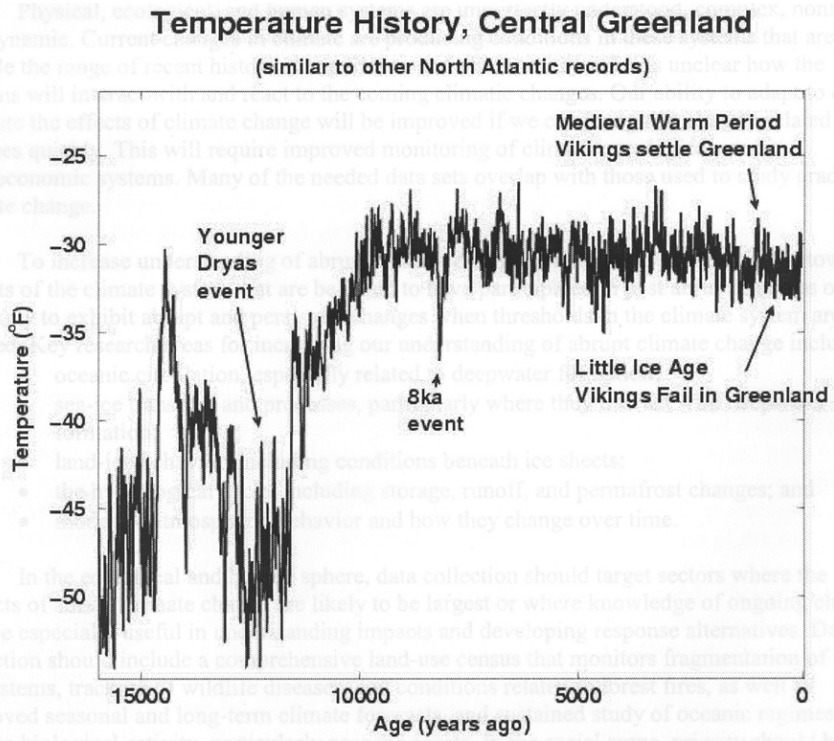
(2) modeling and associated analysis needed to understand abrupt climate change and its potential ecological, economic, and social impacts.

The charge to the committee asked us to think about what kinds of research are necessary to improve our understanding of abrupt climate change, so we give a lot of attention to research needs. A few of the most important areas are:

- Understanding abrupt climate change and its potential impacts requires that we study both human impacts on climate and also natural causes of climate change;
- Abrupt climate changes of the past especially involved shifts in ocean circulation, in land-surface processes affecting drought, in snow and ice, and in the preferred patterns of the climate system such as El Nino, so these topics are prominent in the committee's recommendations.
- Climate histories from ice and sediment cores, tree rings and more have been very important in the study of abrupt climate changes—events that actually occurred must be possible—so continued study of the history of climate remains important.

The committee emphasized the opportunity for research to identify "no regrets" measures to reduce vulnerabilities and increase adaptive capacity at little or no cost. Climate histories show that change is almost certain, and that abrupt and surprising changes are likely in at least some regions. Many current policies and practices are likely to be inadequate in a world of rapid and unforeseen climatic changes. Identifying ways to improve these policies will be beneficial even if abrupt climate change turns out to fit a best-case, rather than a worst-case, scenario. Societies will have "no regrets" about the new policies, because they will be good policies regardless of the magnitude of environmental change. For example, the phase-out of chloroflourocarbons and replacement by gases with shorter atmospheric lifetimes have reduced the U.S. contribution to global warming while at the same time reducing future health risks posed by ozone. History shows that in response to climatic challenges, some groups have "broken" while others have "bent", so the committee deemed it wise to study ways to promote "bendability".

Thank you for this opportunity to talk about abrupt climate change so you can consider this as you think about the new Climate Change Strategic Plan. More details from our report appear in my written testimony and I'd be happy to answer questions.



RECOMMENDATIONS FROM THE REPORT, "ABRUPT CLIMATE CHANGE: INEVITABLE SURPRISES"

Improve The Fundamental Knowledge Base Related To Abrupt Climate Change

Recommendation 1. Research programs should be initiated to collect data to improve understanding of thresholds and nonlinearities in geophysical, ecological, and economic systems. Geophysical efforts should focus especially on modes of coupled atmosphere-ocean behavior, oceanic deepwater processes, hydrology, and ice. Economic and ecological research should focus on understanding nonmarket and environmental issues, initiation of a comprehensive land-use census, and development of integrated economic and ecological data sets. These data will enhance understanding of abrupt climate change impacts and will aid development of adaptation strategies.

Physical, ecological, and human systems are imperfectly understood, complex, nonlinear, and dynamic. Current changes in climate are producing conditions in these systems that are outside the range of recent historical experience and observation, and it is unclear how the systems will interact with and react to the coming climatic changes. Our ability to adapt to or mitigate the effects of climate change will be improved if we can recognize climate-related changes quickly. This will require improved monitoring of climatic, ecological, and socioeconomic systems. Many of the needed data sets overlap with those used to study gradual climate change.

To increase understanding of abrupt climate change, research should be directed toward aspects of the climate system that are believed to have participated in past abrupt changes or that are likely to exhibit abrupt and persistent changes when thresholds in the climate system are crossed. Key research areas for increasing our understanding of abrupt climate change include:

- oceanic circulation, especially related to deepwater formation;
- sea-ice transport and processes, particularly where they interact with deepwater formation;
- land-ice behavior, including conditions beneath ice sheets;
- the hydrological cycle, including storage, runoff, and permafrost changes; and
- modes of atmospheric behavior and how they change over time.

In the ecological and human sphere, data collection should target sectors where the impacts of abrupt climate change are likely to be largest or where knowledge of ongoing changes will be especially useful in understanding impacts and developing response alternatives. Data collection should include a comprehensive land-use census that monitors fragmentation of ecosystems, tracking of wildlife diseases, and conditions related to forest fires, as well as improved seasonal and long-term climate forecasts, and sustained study of oceanic regimes of intense biological activity, particularly near the coasts. In the social arena, priority should be given to development of environmental and nonmarket accounts, and analyses of possible threshold crossings.

Improve Modeling Focused On Abrupt Climate Change

Recommendation 2. New modeling efforts that integrate geophysical, ecological, and social-science analyses should be developed to focus on investigating abrupt climate changes. In addition, new mechanisms that can cause abrupt climate change should be investigated, especially those operating during warm climatic intervals. Understanding of such mechanisms should be improved by developing and applying a hierarchy of models, from theory and conceptual models through models of intermediate complexity, to high-resolution models of components of the climate system, to fully coupled earth-system models. Model-data comparisons should be enhanced by improving the ability of models to simulate changes in quantities such as isotopic ratios that record past climatic conditions. Modeling should be used to generate scenarios of abrupt climate change with high spatial and temporal resolution for assessing impacts and testing possible adaptations. Enhanced, dedicated computational resources will be required for such modeling.

Developing theoretical and empirical models to understand abrupt climate changes and the interaction of such changes with ecological and economic systems is a high priority. Modeling is essential for collaborative research between physical, ecological, and social scientists, and much more effort is needed to develop accurate models that produce a useful understanding of abrupt climate processes. Model analyses help to focus research on possible causes of abrupt climate change, such as human activities; on key areas where climatic thresholds might be crossed; and on fundamental uncertainties in climate-system dynamics. To date, most analyses

have considered only gradual climate change; given the accumulating evidence of past abrupt climate change and of its capacity to affect human societies, more attention should be focused on scenarios involving abrupt change.

Climate models that are used to test leading hypotheses for abrupt climate change, such as altered deep-ocean circulation, can only partially simulate the size, speed, and extent of the large climatic changes that have occurred. The failure to explain the climate record fully suggests either that the proposed mechanisms being used to drive these models are incomplete or that the models are not as sensitive to abrupt climate change as is the natural environment. It is also of concern that existing models do not accurately simulate warm climates of the past.

A comprehensive modeling strategy designed to address abrupt climate change should include vigorous use of a hierarchy of models, from theory and conceptual models through models of intermediate complexity, to high-resolution models of components of the climate system, to fully coupled earth-system models. The simpler models are well suited for use in developing new hypotheses for abrupt climate change and should focus on warmer climate, because warming is likely. Because reorganizations of the thermohaline circulation have never been demonstrated in climate models employing high-resolution ocean components, improving the spatial resolution in climate models assumes high priority. Complex models should be used to produce geographically resolved (to about 1° of latitude by 1° of longitude), short-time (annual or seasonal) sensitivity experiments and scenarios of possible abrupt climatic changes.

Long integrations of fully coupled models under various forcings for the past, present, and future are needed to evaluate the models, assess possibilities of future abrupt changes, and provide scenarios of those future changes. The scenarios can be combined with integrated-assessment economic models to improve understanding of the costs for alternative adaptive approaches to climate change with attention to the effects of rising greenhouse-gas concentrations and nonclimatic factors, such as land use changes and urbanization. Model-data comparisons are needed to assess the quality of model predictions. It is important to note that the multiple long integrations of enhanced, fully coupled earth-system models required for this research are not possible with the computer resources available today, and thus these resources should be enhanced.

Improve Paleoclimatic Data Related To Abrupt Climate Change

Recommendation 3. The quantity of paleoclimatic data on abrupt change and ecological responses should be enhanced, with special emphasis on:

- Selected coordinated projects to produce especially robust, multi-parameter, high-resolution histories of climate change and ecological response.
- Better geographic coverage and higher temporal resolution.
- Additional proxies, including those that focus on water (e.g., droughts, floods, etc.).
- Multidisciplinary studies of selected abrupt climate changes.

The current scientific emphasis on abrupt climate change was motivated by strong evidence in proxy records that showed extreme climatic changes in the past, sometimes occurring within periods of fewer than 10 years. Paleoclimatic records provide important information related to changes in many environmental variables. However, not all proxy archives provide equally high confidence for estimating past climatic conditions, such as temperature and precipitation, and for determining when and how rapidly changes occurred.

Confidence can be improved by encouraging coordinated, multi-parameter, multi-investigator study of selected archives that have seasonal to decadal time accuracy and resolution, substantial duplication of measurements to demonstrate reproducibility, and extensive calibration of the relation between climate and sedimentary characteristics. As one example, in the ice-core projects from central Greenland, duplication of the measurements by independent, international teams provides exceptional confidence in most data and reveals which datasets do not warrant confidence. Sampling at very high time resolution to produce datasets complementary to those of other investigators gives an exceptionally clear picture of past climate. Such projects require more funding and effort than are typical of paleoclimatic research, but they provide an essential reference standard of abrupt climate change to which other records can be compared. A difficulty is that this reference standard is from one place in high northern latitudes and is inappropriate for study of much of the climate system.

Not all paleoclimatic records can be studied in the same detail as those from Greenland, but generation of at least a few similar highly resolved (preferably annu-

ally or subannually) reference standards including a North Atlantic marine record comparable with Greenland records, would be of great value. The ultimate goal is to develop a global network of records with at least decadal resolution. Terrestrial and marine records of climate change and ecological response from the regions of the western Pacific warm pool (the warmest part of the global climate system) and the Southern Ocean and Antarctic continent (the southern cold pole of the climate system) are among the most critical targets for future paleoclimate research, including generation of reference standards.

Abrupt climate change is likely to influence water availability and therefore is of great concern for economic and ecological systems. Focus on measures of precipitation, evaporation, and the quantitative difference between them is particularly important. Freshwater balance is also important in controlling water density and thus the thermohaline circulation of the oceans; reconstructions of water-mass density in polar and subpolar regions are central. New methods for investigating past changes in the hydrological cycle are important, as are additional studies of the relation between a range of climatic changes and the signals they leave in sedimentary archives.

Global maps of past climates, with high resolution in time and space and spanning long intervals, would be of great use to the climate community. However, such maps are unlikely to be available soon. The traditional alternative of reconstructing climate for selected moments, or "time-slices," fails to capture the short-lived anomalies of abrupt climate changes. Instead, mapping efforts are needed and should focus on the patterns of selected abrupt climatic changes in time and space and on their resulting effects. Additional emphasis on annually resolved records of the last 2000 years will help to place the warming and associated changes of the last 100 years in context.

Improve Statistical Approaches

Recommendation 4. Current practices in the development and use of statistics related to climate and climate-related variables generally assume a simple, unchanging distribution of outcomes. This assumption leads to serious underestimation of the likelihood of extreme events. The conceptual basis and the application of climatic statistics should be re-examined with an eye to providing realistic estimates of the likelihood of extreme events.

Many societal decisions are based on assumptions about the distribution of extreme weather-related events. Large capital projects, for instance, often have embedded safety margins that are derived from data and assumptions about the frequency distribution of extreme events. Many major decisions are based on statistical calculations that are appropriate for stationary climates, such as in the use of "30-year normals," for deriving climate data for individual locations.

On the whole, those assumptions are reasonable, if imperfect, rules of thumb to use when the variability of weather is small and climate is stationary. If climate follows normal distributions with known and constant means and standard deviations, businesses and governments can use current practices. However, in light of recent findings related to nonstationary and often highly skewed climate-related variables, current practices can be misleading and result in costly errors.

The potential for abrupt climate change and the existence of thresholds for its effects require revisions of our statistical estimates and practices.

Investigate "No-Regrets" Strategies To Reduce Vulnerability

Recommendation 5. Research should be undertaken to identify "no-regrets" measures to reduce vulnerabilities and increase adaptive capacity at little or no cost. No-regrets measures may include low-cost steps to: slow climate change; improve climate forecasting; slow biodiversity loss; improve water, land, and air quality; and develop institutions that are more robust to major disruptions. Technological changes may increase the adaptability and resiliency of market and ecological systems faced by the prospect of damaging abrupt climate change. Research is particularly needed to assist poor countries, which lack both scientific resources and economic infrastructure to reduce their vulnerabilities to potential abrupt climate changes.

Social and ecological systems have long dealt with climate variability by taking steps to reduce vulnerability to its effects. The rapidity of abrupt climate change makes adaptation more difficult. By moving research and policy in directions that will increase the adaptability of economic and ecological systems, it might be possible to reduce vulnerability and increase adaptation at little or no cost. Many current policies and practices are likely to be inadequate in a world of rapid and unforeseen climatic changes. Improving these policies will be beneficial even if abrupt climate change turns out to fit a best-case, rather than a worst-case, scenario. Soci-

eties will have "no regrets" about the new policies, because they will be good policies regardless of the magnitude of environmental change. For example, the phaseout of chloroflourocarbons and replacement by gases with shorter atmospheric lifetimes have reduced the U.S. contribution to global warming while at the same time reducing future health risks posed by ozone depletion.

In land-use and coastal planning, managers should consider the effects on ecosystem services that could result from interaction of abrupt climate changes with changes caused by people. Scientists and government organizations at various levels may be used to develop and implement regulations and policies that reduce environmental degradation of water, air, and biota. Conservation measures related to land and watersheds might be put into place to reduce the rate of biotic invasions, with management strategies used to limit the spread of invasions. The potential economic and ecological costs of disease emerging from abrupt climate change should be assessed.

A promising option is to improve institutions to allow societies to withstand the greater risks associated with abrupt changes in climate. For example, water systems are likely to be stressed by abrupt climate change; to manage scarce water, it might prove beneficial to seek more flexible ways to allocate water, such as through use of water markets. Another example of a "no-regrets" strategy is insurance against the financial impacts of fires, floods, storms, and hurricanes. Through the development of new instruments, such as weather derivatives and catastrophe bonds, markets might better accommodate extreme events such as the effects of abrupt climate change. It will be important to investigate the development of better instruments to spread large losses that result from extreme events, priced realistically to reflect the risks but not to encourage excessive risk taking.

Because of the strength of existing infrastructure and institutions, the United States and other wealthy nations are likely to cope with the effects of abrupt climate change more easily than poorer countries. That does not mean that developed countries can remain isolated from the rest of the world, however. With growing globalization, adverse impacts—although likely to vary from region to region because exposure and sensitivity will vary—are likely to spill across national boundaries, through human and biotic migration, economic shocks, and political aftershocks. Thus, even though this report focuses primarily on the United States, the issues are global and it will be important to give attention to the issues faced by poorer countries that are likely to be especially vulnerable to the social and economic impacts of abrupt climate change.

The United States is uniquely positioned to provide both scientific and financial leadership, and to work collaboratively with scientists around the world, to gain better understanding of the global impacts of abrupt climate change as well as reducing the vulnerability and increasing the adaptation in countries that are particularly vulnerable to these changes. Many of the recommendations in this report, although currently aimed at U.S. institutions, would apply throughout the world.

The CHAIRMAN. Thank you, Dr. Alley. Dr. Graedel.

STATEMENT OF THOMAS E. GRAEDEL, PH.D., PROFESSOR OF INDUSTRIAL ECOLOGY, YALE UNIVERSITY

Dr. GRAEDEL. Thank you, Mr. Chairman. As you mentioned, I am a professor of industrial ecology at Yale University, but I am here because I served as the chairman of the National Research Council Committee to Review the U.S. Climate Change Science Program strategic plan.

I appreciate the opportunity to appear before you today to discuss our recent report in which we reviewed the draft strategic plan, and to share this panel with three members of the committee who wrote the report, Doctors Janetos, Liverman and Solow.

U.S. Climate Change Science Program, or CCSP, was formed in 2002 to coordinate and direct the U.S. efforts in climate change and global change research. It builds upon the decades-old global change research program and adds a new complement, climate change research initiative, whose primary goal is to measure the improving aggregation of scientific knowledge, including measures of uncertainty, into effective decision support systems and re-

sources. Thus, the overall activity combines an existing program, the Climate Change Research Program, with a new component, the Climate Change Research Initiative.

On September 17th of last year, Assistant Secretary of Commerce for Oceans and Atmosphere James Mahoney requested that the National Academies undertake a fast-track review of the U.S. Climate Change Science Program's draft strategic plan and of its revision. Our committee's first report in which the draft plan was reviewed was released last February 25th. My remaining comments reflect the findings and recommendations presented in that report.

The committee commends the CCSP for undertaking the task of developing a strategic plan. The current draft of the plan represents a good start for the process, particularly in that it identifies exciting new directions for the program while building on the well-established foundation of the Global Change Research Program. Indeed, the draft strategic plan identifies many of the cutting-edge scientific research activities that are necessary to improve understanding of the earth system.

The Climate Change Research Initiative portion of the plan introduces an admirable emphasis on the need for science to address shorter-term national needs, including support for those in the public and private sectors whose decisions are affected by climate change and variability.

What recommendations do we make for improving the draft strategic plan? First, we recommend revisions that would clarify its vision and goals. The committee finds that the draft strategic plan lacks the kind of clear and consistent guiding framework that would enable decisionmakers, 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.

We recommend that the revised strategic plan articulate a clear, concise, ambitious vision statement, and translate this vision into a set of tangible goals and apply an explicit process to establish priorities.

Second, we recommend that the CCSP improve the treatment of program management in the draft plan. The management of a program involving 13 agencies, each with a separate mission and a long history of independent research on climate and global changes, is a challenging task. However, the creation of a cabinet level committee with the authority to shift resources among agencies to meet the goals of the program is an improvement over past approaches. Nonetheless, the interagency approach to managing the program may not be enough to ensure that the agencies cooperate toward the common goals of the program, because no individual is clearly identified in the draft plan as having the responsibility for managing the plan as a whole. The committee recommends that the revised strategic plan describe the management process to be used to foster agency cooperation toward common program goals. In particular, the responsibilities of CCSP leadership and relevant agencies should be clearly outlined.

In parallel with the CCSP, the President announced a Climate Change Technology Program created to develop and coordinate technologies for stabilizing and reducing greenhouse gas levels in

the atmosphere. The committee is concerned that the existing management and program links between the Climate Chance Science Program and the Climate Change Technology Program may not be extensive enough to take advantage of the synergies between those two programs. We thus recommend that the revised plan clearly describe the mechanisms for coordinating and linking science and technology development activities.

Third, we recommend that the revised strategic plan better support the increase in understanding the potential impacts of climate change on human society's ecosystems and related options for adaptation and mitigation. The need for research applications in these areas logically follows from the CCSP's new evidence from its issued report. The draft plan's approach to these human decision issues lacks research into consumption, institutions, and social aspects of technology, and on the costs and benefits of climate change and related response options, and its treatment of ecosystems needs a more cohesive and strategic organizational framework.

Fourth, we recommend strengthening decision support in the revised plan. Although the plan does incorporate in general language about decision support in many places, it is vague about what this will actually mean. We recommend that the revised plan identify which categories of decisionmakers the program serves and describe how the program will improve two-way communications with them. It should also better describe how decisions or capabilities will be developed.

The draft plan identifies the reduction of uncertainty as a top priority for the Climate Change Science Program. Unfortunately, it does not apply a systematic process for identifying the key scientific uncertainties and to ascertain which of those are most important in decisionmaking. And we recommend that the revised plan identify what sources and magnitudes of reduction of climate change uncertainties are especially needed to benefit decisionmaking.

Last, we recommend that revisions be made to the draft strategic plan to better set the stage for implementation. It is clear that the scope of activities that are described is greatly enlarged over what has been supported in the past. Implementing this expanded suite of activities will require significant investments in global observing systems, computing capabilities, and human resources. This will necessitate either greatly increased funding for the Climate Change Science Program or a major reprioritization and cutback in existing programs. Even if program funding increases, CCSP management will continue to be faced with many funding decisions. To assist in this process, we recommend that the Climate Change Science Program use the clear goals and program priorities that it will present in the revised plan, as well as advice from an independent advisory body to guide future funding decisions.

To conclude, the committee finds that the draft plan addresses crucial issues facing our Nation and the world in the 21st century. We wish 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 decisionmakers, who need to better understand the potential impacts of climate change, and make choices among the possible responses.

Thank you, Mr. Chairman, and we will be happy to respond to questions.

[The prepared statement of Dr. Graedel follows:]

PREPARED STATEMENT OF THOMAS E. GRAEDEL, PH.D., PROFESSOR OF INDUSTRIAL ECOLOGY, YALE UNIVERSITY

Good morning, Mr. Chairman, Senator Hollings, and Members of the Committee:

My name is Thomas Graedel. I am professor of industrial engineering at Yale University and serve as chairman of the Committee to Review the U.S. Climate Change Science Program Strategic Plan of the National Research Council. The Research Council is the operating arm of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine, chartered by Congress in 1863 to advise the government on matters of science and technology. I appreciate the opportunity to appear before the Committee today to discuss a recent report of the National Research Council entitled *Planning Climate and Global Change Research: A Review of the Draft U.S. Climate Change Science Program Strategic Plan.* I am pleased to share this panel with three members of the committee who wrote this report: Tony Janetos from the H. John Heinz III Center for Science, Economics, and the Environment; Diana Liverman from the University of Arizona; and Andrew Solow from the Woods Hole Oceanographic Institute.

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. The U.S. Climate Change Science Program, or 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. Since its inception the Global Change Research Program, or 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, or CCRI—whose primary goal is to "measurably improve the integration of scientific knowledge, including measures of uncertainty, into effective decision support systems and resources." Thus, this overall activity combines an existing program, the Global Change Research Program, with a new component, the Climate Change Research Initiative.

On September 17, 2002, Assistant Secretary of Commerce for Oceans and Atmosphere James R. Mahoney requested that the National Academies undertake a fast-track review of the U.S. Climate Change Science Program's draft strategic plan for climate and global change studies. He asked the National Academies to form a committee to review both the discussion draft of the strategic plan, which was released on November 11, 2002, and the final strategic plan after it has been revised. In response the 17-member Committee to Review the U.S. Climate Change Science Program Strategic Plan was formed. The committee's first report, in which the draft strategic plan is reviewed, was released on February 25, 2003. My remaining comments reflect the findings and recommendations presented in this report.

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 Global Change Research Program. The committee finds that the draft strategic plan identifies many of the cutting-edge scientific research activities that are necessary to improve understanding of the Earth system. The Climate Change Research Initiative 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. 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.

In general, the draft strategic plan provides a solid foundation for the Climate Change Science Program. With suitable revisions, the plan could articulate an explicit and forward-looking vision for the CCSP and clearly identifiable pathways to successful implementation. To assist the CCSP in revising the strategic plan, the

NRC review makes an extensive set of recommendations. These recommendations for revisions fall into five categories: (1) clarify the vision and goals of the CCSP and the CCRI, (2) improve the treatment of program management, (3) fill key information needs, (4) enhance efforts to support decision making, and (5) set the stage for implementation. I will comment briefly on some of the specific recommendations that address these five points. I refer you to the committee's full report for more details.

The first set of recommendations address revisions to the draft strategic plan that would clarify the vision and goals of the Climate Change Science Program and its subcomponent, the Climate Change Research Initiative. The committee finds 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. In particular, it lacks most of the common 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. The draft plan lists a multitude of proposed activities, but does not identify which of these activities are higher priorities than others, nor does it provide an explicit process for establishing such priorities. 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*. The committee recommends that the revised strategic plan 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 Climate Change Science Program. 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 Climate Change Research Initiative. The draft strategic plan states that to be included in the CCRI, a program must produce significant decision or policy-relevant deliverables within two to four years and contribute significantly to improving scientific understanding; optimizing observations, monitoring, and data management systems; or developing decision support resources. The committee considers the CCRI's emphasis on scientific support for decision makers one of the most promising and innovative features of the draft strategic plan. Further, the plan appropriately recognizes that there are some short-term products that can and should be delivered by the program. 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 CCRI activities aimed at reducing uncertainty and improving observations 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 recommends that the revised strategic plan present clear goals for the Climate Change Research Initiative and ensure that its activities are consistent with these goals while maintaining the CCRI's strong emphasis on support for near-term decisions as an ongoing component.

The revised strategic plan also needs to describe more clearly how the research activities included in the Global Change Research Program support the decision support needs of the Climate Change Research Initiative. 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. The committee believes it is essential for the Climate Change Science Program to move forward with the important new elements of CCRI while preserving crucial parts of existing GCRP programs. The committee recommends that the revised plan include an explicit mechanism to link Global Change Research Program and Climate Change Research Initiative activities.

The second overarching area for improvement in the draft plan is its treatment of 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 Global Change Research Program 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 draft plan takes positive steps towards improved interdisciplinary research opportu-

nities. The creation of a cabinet-level committee with the authority to shift resources among agencies to meet the goals of the Climate Change Science Program 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. The committee recommends that the revised strategic plan describe the management processes to be used to foster agency cooperation toward common Climate Change Science Program goals. In particular, the responsibilities of the CCSP leadership and relevant agencies should be clearly outlined.

The Climate Change Technology Program 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 Climate Change Technology Program may not be extensive enough to take advantage of the synergies between these two programs. The committee recommends that the revised Climate Change Science Program strategic plan clearly describe mechanisms for coordinating and linking its activities with the technology development activities of the Climate Change Technology.

A third overarching set of recommendations for improving the draft strategic plan addresses better filling key information needs. In this regard, the Global Change Research Program's research of the last decade, which focused on national- to global-scale phenomena, should be augmented with research to develop an understanding of regional scale variability and change. 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 will be adapted and combined with information to address regional issues and seasonal-to-interannual timeframes. The committee recommends that the revised strategic plan more fully describe how models and knowledge that support regional decision making 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 draft strategic plan's treatment of human dimensions and ecosystems, however, has several important gaps. The draft plan lacks research into consumption, institutions, and social aspects of technology as causes of climate and associated global changes. It does not propose any research into the costs and benefits of climate change and related response options. And, its treatment of 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 policy choices. The committee recommends that the revised strategic plan strengthen its approach to the human, economic, and ecological dimensions of climate and associated global changes.

The draft strategic plan's call for greatly improved observational capabilities reflects a well recognized priority for increasing understanding of climate and associated global changes. To date, the global climate observing 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 climate observing system. A critical weakness in the draft plan is that it does not adequately explain how existing observation systems will be integrated and expanded. The committee recommends that the revised strategic plan 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.

A fourth opportunity for improvement to the draft strategic plan is to strengthen its treatment of decision support. 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. Indeed, the draft plan does not recognize the full diversity of decision makers and does not describe mechanisms for two-way communication with stakeholders. The committee recommends that the revised strategic plan identify which categories of decision makers the Climate Change Science Program 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 identifies the reduction of uncertainty as a top priority for the Climate Change Science Program and its subcomponent, the Climate Change Research Initiative. The draft plan 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, 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. The committee recommends that the revised strategic plan identify what sources and magnitudes of reductions in key climate change uncertainties are especially needed to benefit decision-making.

A fifth and final overarching area for improving in the draft strategic plan is to better set the stage for implementation. The draft strategic plan calls for a multitude of research and decision support advances. In this regard, the committee believes that the Climate Change Science Program 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. In addition, 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. The committee recommends that the revised strategic plan explicitly address the major requirements in building capacity in human and computing resources necessary to achieve its goals.

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 Global Change Research Program. Implementing this expanded suite of activities will require significant investments in infrastructure and human resources. This will necessitate either greatly increased funding for the Climate Change Science Program or a major reprioritization and cutback in existing programs. 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. The committee recommends that the Climate Change Science Program use the clear goals and program priorities of the revised strategic plan and advice from an independent advisory body to guide future funding decisions.

To conclude, the committee finds that the draft plan addresses crucial issues facing our nation and the world in the twenty-first century. The committee has worked diligently to make this report as useful as possible to the Climate Change Science Program. 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. Thank you for this opportunity to address the Committee. We would be pleased to answer any questions the Committee might have.

The CHAIRMAN. Would any of the other witnesses like to make any additional comments? Dr. Janetos.

STATEMENT OF DR. ANTHONY C. JANETOS, DIRECTOR, H. JOHN HEINZ III CENTER FOR SCIENCE, ECONOMICS, AND THE ENVIRONMENT

Dr. JANETOS. Good morning, Mr. Senator, thank you for the opportunity to testify. I am the vice president of the John Heinz III Center for Science, Economics, and the Environment, where my functions include directing our center's global change program. Prior to joining the Heinz Center, I was a program scientist in NASA's Office of Earth Science and had the pleasure of serving as

co-chair of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change, and as an author of the IPCC's special report on land use change in forestry.

I would be happy to answer any questions you might have on the NRC review of the draft Climate Change Science Program, especially on topics of land use and land cover change, ecosystems, climate variability and change, the draft plan's approach to addressing key climate uncertainties, challenges associated with the financial resources available for implementation, and the extent to which the plan fosters interagency collaboration.

The CHAIRMAN. Thank you. Dr. Liverman.

STATEMENT OF DR. DIANA M. LIVERMAN, DIRECTOR, LATIN AMERICAN STUDIES PROGRAM, UNIVERSITY OF ARIZONA

Dr. LIVERMAN. Good morning. I am Diana Liverman. I am professor of geography and regional development at the University of Arizona, where I also direct the Latin American Studies Program, and I work at the Institute for the Study of Planet Earth, where we have the Southwest climate assessment that specializes in providing climate information to stakeholders in the Southwest.

My research area and the area for which I can answer questions in our report looks at the social causes and consequences of environmental change, and the international dimensions of climate change.

I am past chair of the National Research Council Committee on the Human Dimensions of Global Change, and the Scientific Advisory Committee for the Inter-American Institute for Global Change Research.

I appreciate the opportunity to discuss with the Committee the draft Climate Change Science Program after our review of that document, and the areas that I am especially willing to answer questions on are human contributions and responses to environmental change, the development of decisions to comport resources for climate change stakeholders, opportunities for enhancing linkages and communications between researchers and stakeholders, and the role of international research and cooperation on climate and associated global changes. Thank you.

The CHAIRMAN. Thank you. Dr. Solow.

STATEMENT OF DR. ANDREW SOLOW, ASSOCIATE SCIENTIST AND DIRECTOR, MARINE POLICY CENTER, WOODS HOLE OCEANOGRAPHIC INSTITUTION

Dr. SOLOW. Good morning. Thank you very much for giving me this opportunity to testify before the Committee. My name is Andrew Solow. I am a scientist and director of the Marine Policy Center at the Woods Hole Oceanographic Institution. My research interests include environmental and ecological statistics.

I would also be glad to address any questions that the Committee may have, in particular those pertaining to the plans, treatment of the global climate observing system, grand challenges in modeling, observations and information systems, the management and review of the program, and the water cycle. Thank you very much.

The CHAIRMAN. Well, thank you. I want to thank the witnesses and maybe I would like to go back a little bit to the basics here

so that we can have a framework for our discussion. I guess my first question for all the panel is, how serious do you think the issue of climate change is, is it reality, and how serious is the issue of abrupt climate change? I would like to begin with you, Dr. Alley.

Dr. ALLEY. I believe that there is a wealth of evidence that has been presented in National Academy reports and in international documents ultimately under the auspices of the United Nations, that indicates that climate change is highly likely to continue, that climate change is occurring, that it is highly likely that it is occurring at least in part because of human influences, and that this presents challenges to humans which can be addressed through appropriate responses.

The CHAIRMAN. When do we cross from highly likely to certainty?

Dr. ALLEY. I, as a scientist, always believe that there is something more to learn and if I am absolutely certain, then there is nothing more to learn, it is too late for me, so I have a faith that there is more out there. So I am never going to tell you that I am certain. But we are, our understanding of the physical processes on earth says that if you change the atmosphere in a particular way, that the world should respond by warming on average. The observations indicate that the world is warming on average and that we have changed the atmosphere in a particular way. And certainly there are many people, many National Academy panels that have drawn the conclusion that those are related to humans.

The CHAIRMAN. The reason why I ask this question, and I am not trying to make you say anything you do not want to say, and I have not been involved in this issue for several years, but I have learned about the caution of scientists. They are the only group of Americans that are more cautious than politicians in taking a specific stand on a difficult issue.

But you see, when you say what you say, Dr. Alley, the opponents of acting to try to take some policy measures will say see, the scientists are not sure, how can you advocate. Because any course of action that we take will require some form of sacrifice, in other words, the world cannot continue to do business as usual if you accept the fact that global, or that climate change is taking place. So whatever actions you have to take is going to entail some kind of sacrifice or change in the way that we live or do business. Hopefully we can minimize that.

And I am not being baitful of you when I say this, but it makes it a little more difficult for me to make my case, to ask my colleagues to vote for a cap and trade system on missions where they say well, the scientists are not sure yet, so you might as well wait before you ask us to regulate the emissions from our power plants, make more fuel efficient cars, you know, the steps that we all know that may be necessary.

So please do not take this as a criticism. I guess I am venting to you the difficulty that I have because as you know, there is significant opposition to any action. And I think that one of the reasons why you have made some of the, shall I say recommendations, it is hard to clarify the visions and goals unless you accept that climate change is taking place. Do you agree?

Dr. ALLEY. I completely agree. As a scientist who is confident that there is uncertainty, I nonetheless get up in the morning and

I do things, and I do them in the face of that uncertainty. And I do many things and I make many decisions that I personally have less confidence than I do in the solid science behind climate change. So I am acting as an uncertain human being because we have to act as uncertain human beings because we are never certain.

The CHAIRMAN. Dr. Graedel.

Dr. GRAEDEL. Thank you. Well, Dr. Alley has made many of the points that I think I would make or almost any scientist would make on this issue.

But I think it is significant that the government in presenting its plan, has indicated that it wants to go forward in a major way because of scientific near unanimity on the seriousness of this issue. And in the plan itself, the government says that uncertainty is not a reason for inaction. So, I believe that the plan itself regards decisions under uncertainty as a reasonable way to proceed, and says that the things it is doing are decision relevant but not the decisions itself, that is, those are the political issues that are not part of the science plan, but are supported by the science that can be done by such a plan.

The CHAIRMAN. In this plan, what are the specific steps that are recommended?

Dr. GRAEDEL. I think one of the most interesting and relevant that has been presented is the emphasis on decision support and decision support for people who are actually at the level of having to make decisions, and perhaps I could refer this point to Dr. Liverman.

Dr. LIVERMAN. Yes. Our report sees that the focus on decision support is one of the most important parts of the strategic plan. And one of the things that we have suggested in the revision is a little bit more development of what that might mean in terms of focusing on decision support, and there are a couple of areas where we suggested revisions.

One is to have research to identify the different source of stakeholders that may be making decisions, because there are clearly people here in Washington that are making rather different decisions or different types of decisions compared to, say, a resource manager in our State of Arizona. But the fact that this new strategic plan is focusing on science that will help those decisions, we think is a very important step for the next phase of research in this area.

We also believe that from a scientific point of view there is a wide range of tools that can help with decision support and research into those tools for decision support would be an important area. And we also know from scientific research that there are a wide range of cases that we can examine where decisions have been made in the face of uncertainty.

The CHAIRMAN. If you were in charge, Dr. Liverman, would you recommend any specific course of action?

Dr. LIVERMAN. As a scientist, I believe that we need to do research to fill some of the gaps in our knowledge and to do what we can to clarify our options and to improve our knowledge. As a scientist, I am unlikely to be put in charge of making the decisions.

The CHAIRMAN. As a scientist, I think you would be put in charge of making recommendations. I do not know who else we could refer to.

Dr. LIVERMAN. And what, you would like me to make recommendations on—our report focuses on research, not on policy, so I am happy to speak about some of the research recommendations I would make. As a citizen, I might have opinions about policy.

The CHAIRMAN. Dr. Solow, is it true that a significant percentage of the ocean reefs are dying, coral reefs are dying?

Dr. SOLOW. It is certainly true that a significant percentage of coral reefs are, the condition of them is deteriorating and some parts of them are dying, that is true.

The CHAIRMAN. And do you attribute this to any, do you have any way of accounting for this?

Dr. SOLOW. Yes. I think it is generally believed that there are multiple sources for that. One of them is warming of the sea surface temperatures of the surface of the ocean, but there are pollution issues that are also associated with the degradation of reefs, and you might well expect there to be an interaction between those and other stresses on coral reef systems.

The CHAIRMAN. Is it upsetting to you that this is happening?

Dr. SOLOW. Yes, sure.

The CHAIRMAN. Obviously you have been in this business for a long time. Have you ever seen anything like this before?

Dr. SOLOW. There are certainly periods, historical periods where coral reefs have undergone changes, bleaching, things like that. There are coral reefs now in very deep water that at one time were in shallow water and were alive and thriving. And so, there are changes in coral reef ecosystems and in the geology of coral reefs, but I guess the best available signs would suggest that what we are seeing is unprecedented.

The CHAIRMAN. And we proceed in this panel, particularly on an issue like this, that there is no such thing as a dumb question.

This is the beginning of the food chain, right, in the oceans, the reefs?

Dr. SOLOW. Well, that is not a dumb question, sir, but I do not think that it is correct. I think that there are some parts of the ocean where there are coral reef systems and other parts of the ocean where there are not. And the parts that have more temperate climates, say where I live in Massachusetts, coral reef ecosystems are not very important to the food chain in the ocean. In other places, the coral reef systems are very important.

The CHAIRMAN. Dr. Alley, the Administration's budget request for the U.S. Global Climate Research Program is about $1.6 billion, which is a decrease of $143 million. The Climate Change Research Initiative is $182 million, an increase of $142 million. Do these request levels support the resources required to perform the research as required by this strategic plan?

Dr. ALLEY. It depends on how rapidly you would like an answer, or reduced uncertainty. Very clearly in a time or reduced resources, one must prioritize and one must reduce research. So to the extent that you would like to learn a lot in a hurry, reduced resources would not get you there as efficiently as more resources would.

The CHAIRMAN. Dr. Janetos.

Dr. JANETOS. During the period that we reviewed the draft plan, the fiscal 2004 budget request had not yet been released. It obviously has been now. I think our committee's concern has been that the scope of the draft plan is significantly expanded over the scope of the program, the global change research program, its immediate predecessor. And we had felt that some of the new elements, such as the emphasis on decision support, are extraordinarily important. Our main concern is that with this increased scope, if that is not matched by resources, then the challenge is how will responsible managers, in fact, respond, what will they choose to do and what will they choose not to do.

And this is really the genesis of our concern with the lack of a clear set of priorities. Until there is a systematic approach at actually elaborating and setting out the scientific priorities, it is understandable both in the government and amongst the community of researchers who will actually do the science, it is difficult to know how the program will respond. And this is one of the weaknesses that we hope will be corrected when we see the next draft of the strategy.

The CHAIRMAN. Review also found that the current plan's description of decision support as a two- to 4-year activity, gives the false impression that decision support is needed only in the near term. What do we need, what mechanisms for long-term decision support are required? What environmental factors should be considered in the long-term research? Whoever feels most——

Dr. LIVERMAN. I will start on that. Decision support is certainly needed in the long term, precisely because of some of the uncertainties and the possibilities for abrupt climate change that Dr. Alley's report looked at. So it seems to the committee that yes, we need to invest in decision support in the long term, and research on decision support, but this is something that needs to be a long-term and very integrated part of any long-term research plan that deals with climate and global change.

One other element of decision support is that certainly some of the research areas are not likely to produce results in the short term, but we already have evidence that work on decision support, providing climate information to stakeholders can be useful even now if we focus on things like climate forecasting, the use of historical climate information, and in a sense this is stakeholders' experience in using climate information to make decisions while we are waiting for some of the improvements in other areas of science.

The CHAIRMAN. Dr. Solow, do you believe that the ice packs at the poles are melting?

Dr. SOLOW. I think there is excellent evidence that glaciers at high latitudes are melting, and I think——

The CHAIRMAN. I think that a visit to Glacier National Park would authenticate that, I do not think you need to be a scientist to know that.

Dr. SOLOW. We can be certain of that, sir.

The CHAIRMAN. Thank God. This is the first thing we are certain of.

[Laughter.]

Dr. SOLOW. If you do not mind, I was going to say that the answer to that question, while I agree that there is scientific uncer-

tainty, I would be willing to bet that human activities have changed the climate and that these activities will continue to change the climate.

To get back to your question, there is also evidence of some melting at, in polar ice, Greenland, but some of those ice caps have extremely long memories and they are still responding to changes that occurred in the distant time past, so that is a question about which there is much uncertainty, whether we are seeing the effects of global warming, say, on melting of Antarctic ice, for example.

The CHAIRMAN. If this melting continues, does that have a fairly significant effect on places like Bangladesh, the Maldives, and these islands and shores and coastlines that have very little elevation?

Dr. SOLOW. Yes, sir, that is true, if the ice continues to melt and the water in the ocean expands as a result of warming, that sea level will rise and there are places in the world like Bangladesh and some low-lying island Nations where a relatively small amount of sea level rise could pose a problem.

The melting of the ice also in the North Atlantic has a connection to the kind of abrupt climate change that Dr. Alley has been talking about, so that is also an important consideration.

The CHAIRMAN. Dr. Liverman, in the Southwest as you well know, there is severe drought conditions. Do you view this as part of a cycle that goes on in the Southwest or do you think it has more implications than that?

Dr. LIVERMAN. Well, there have certainly been periods in the history of the Southwest where we have experienced droughts of the magnitude that we are experiencing at the moment. But that is not to say that the drought that we are experiencing is inconsistent with some of the projections about what global warming might do in the Southwest. To actually separate out whether this drought is different from other droughts is a very important area of research, but we have had more severe droughts in the long-term record in the Southwest.

However, we have got more people, we have a larger economy in the Southwest today, so the question about conditions in the Southwest and how we respond to it, I think is a very important area of research and decisionmaking, and some of the research that is laid out in the strategic plan will help us make decisions about those sorts of droughts and future climate change in very useful ways.

The CHAIRMAN. Have you reached any tentative conclusions?

Dr. LIVERMAN. About whether this drought is related to global warming? I personally have not, but we have some major research activities that would be trying to answer that question.

The CHAIRMAN. Senator Nelson.

STATEMENT OF HON. BILL NELSON,
U.S. SENATOR FROM FLORIDA

Senator NELSON. Mr. Chairman, I am your soul mate when it comes to this subject, as I have been your soul mate on a number of other issues.

The CHAIRMAN. I thank you. Sometimes it is a bit lonely.

Senator NELSON. It is a privilege to be on the right side of an issue, as a matter of fact. Most of the folks in Florida understand this issue. I am not sure that they intellectualize it but when you talk to them about it they have an appreciation because of the sensitive situation that if we have global warming, the seas will rise, and our population along the coast will be in jeopardy.

We also are a peninsula that I call paradise, that happens to stick down into what is known as hurricane highway. And I will never forget in the mid-1990's seeing that satellite photo of four hurricanes like they were lined up on final approach off the coast of Africa coming west, just lined up one right after another. And global warming will cause greater intensity of storms, the greater disadvantage of pestilence, and for the life of me, I cannot understand why we get into these disagreements about what we should do.

In a former role I was the elected insurance commissioner of Florida and I tried to get insurance companies to understand what this was going to do to their bottom line, and it was me talking to that piece of granite over there.

So we have got quite an educational process to do, Mr. Chairman, and I am going to be right with you helping.

The CHAIRMAN. I thank you. And I thank the witnesses for being here today. Thank you for your very important contribution, and as Senator Nelson just said, we need to try to arrive at some consensus on this issue, and perhaps your recommendations for the strategic plan will be helpful in focusing their attention in arriving at conclusions and recommendations as rapidly as possible.

Do you have any additional comments, Dr. Alley?

Dr. ALLEY. Thank you very much.

The CHAIRMAN. Dr. Graedel?

Dr. GRAEDEL. No, sir, thank you.

The CHAIRMAN. Dr. Janetos?

Dr. JANETOS. No, sir, thank you very much.

The CHAIRMAN. Dr. Liverman?

Dr. LIVERMAN. No, thank you very much.

The CHAIRMAN. Dr. Solow?

Dr. SOLOW. No, thank you, sir.

The CHAIRMAN. I thank you all, and again I want to thank you for your significant contributions to this effort. I think it is very serious, and we rely upon you for your guidance in this very difficult challenge that we face.

Thank you. This hearing is adjourned.

[Whereupon, at 10:12 a.m, the hearing was adjourned.]

A P P E N D I X

PREPARED STATEMENT OF HON. OLYMPIA J. SNOWE, U.S. SENATOR FROM MAINE

Thank you, Mr. Chairman.

I commend you for continuing to hold hearings on climate change. I recall that your awareness of this issue as Chairman goes back to the 106th Congress when you called for hearings, realizing that global warming would be an issue that would be with us for many Congresses to come.

There is now a large amount of peer-reviewed scientific literature documenting that the burning of fossil fuels, and the subsequent release of carbon dioxide, is impacting the environment—and may literally be changing the climate through severe weather events, such as droughts, record rainfalls, and ice storms. How much of this pressing problem we put on the shoulders of future generations is clearly up to us. How we respond to these changes, how we mitigate and how we adapt to these changes are of utmost importance to our moral obligation as to how we leave the planet for the coming generations.

I congratulate NOAA's Dr. Mahoney on accepting the challenge from the President to manage the Administration's newly created Climate Change Science Program to educate, and to develop goals and strategies to address the uncertainties of climate change science. In a short timeframe, The Climate Change Research Program Office, directed by Richard Moss, has produced the draft *Strategic Plan for the Climate Change Science Program* and also put together a three day national workshop here in Washington last December that was attended by over 1,300 scientists, economists, and stakeholders from at least 47 states and 35 foreign countries to get the public's input and recommendations.

Before us today we have expert scientists from the National Academies who were asked to review the draft Strategic Plan and make recommendations for the final Plan due out this spring. Mr. Chairman, I would like to welcome Dr. Richard Alley of Penn State University, the lead author of the National Resources Council publication, "Abrupt Climate Change: Inevitable Surprises."

Abrupt climate change has become a particular interest of mine, especially through office discussions with Dr. George Denton of the University of Maine's Climate Change Institute, who was recently installed as a member of the National Academy of Sciences. The Institute is carrying out research on ice cores from Greenland, for instance, that are helping them unravel the Earth's past secrets on abrupt climate change.

The NRC Report points out that a growing body of scientific evidence suggests that the climate does not respond to change gradually, but in sudden jumps. During the last major change in climate—as the earth was coming out of the last ice age 12,000 years ago—temperatures warmed about 15 degrees Celsius in one decade, even though the increased energy from the sun occurred more gradually than the current increase in trapped energy from greenhouse gases.

I am concerned that if such a shift were to happen today, it would have immense societal consequences. According to the NRC publication, such abrupt changes *"are not only possible but likely in the future."* The publication urged that a new research program be initiated to identify the likelihood and potential impact of a sudden change in climate in response to global warming. According to the NRC publication, *"At present, there is no plan for improving our understanding of the issue, no research priorities have been identified, and no policy-making body is addressing the many concerns raised by the potential for abrupt climate change."*

Mr. Chairman, as Winston Churchill once said, *"The farther backward you can look, the farther forward you are likely to see."* It is for this reason that I have made a request to the FY 2004 appropriators to establish a National Oceanographic and Atmospheric Administration Joint Institute at the University of Maine to carry out research in abrupt climate change in collaboration with other universities renowned for their contributions to the understanding of abrupt climate change, such as Dr. Alley's Penn State, and at Columbia University's Lamont-Doherty Earth Observatory.

I look forward to working with you, Mr. Chairman, and the Administration in the very near future for a climate change plan of action as I consider this to be an issue of environmental security.

Thank you Mr. Chairman.

PREPARED STATEMENT OF HON. FRANK LAUTENBERG, U.S. SENATOR FROM NEW JERSEY

Mr. Chairman, I want to thank you for convening today's hearing on global climate change and upon the National Academy of Sciences' report that was recently released.

The impact of global warming is affecting our health, our economy and our environment. And the damage it brings to our planet will not simply go away if we try to ignore its reality.

We simply cannot ignore thirty years of accumulating science. Though some in the Administration would pretend that our world is not changing—they do so at the peril of us all.

The most recent scientific updates on the impacts of climate change are nothing short of astonishing.

In the Arctic, where powerful icebreaking ships were once needed to cut through solid ice—ice which stretched on for far as the eye could see—today after years of unprecedented melting of the polar ice cap, from nearly any point on the permafrost one can see vast openings of blue water.

I traveled to Antarctica a few years ago and saw the effects of this firsthand.

The average thickness of the arctic ice shelf has *decreased by a staggering 40 percent*, just since 1950—according to the latest consensus report by the 2000 scientists on the Intergovernmental Panel on Climate Change.

Some of the world's glaciers have lost as much as 70 percent of their ice. In a few years we're going to have to rename Glacier National Park—and sadly, that's not a joke.

All this melting ice has to go somewhere, so the sea is steadily rising.

Globally, it's risen between point-one and point-two meters. The impact is particularly noticeable along flat coastlines like Texas has where the sea level has risen over 8 inches. *And this is just a taste of what's to come.*

The message is simple—we can't continue to "study" global climate change. The time has come to act.

Our great country should be *leading* the charge against climate change: Even many *developing countries* have begun to address the unprecedented rise in carbon dioxide in our atmosphere—and so must we.

Pretending our planet is not heating up will not make it so.

We possess the capacity and the ability to confront global warming and some of the greatest minds in the world—some of which are here with us today. *Now* is the time to harness what is best in our Country to tackle the *global* problem of climate change.

We don't have any time to waste—so a strategic plan to address climate change is needed.

But to be truly strategic it must provide a clear roadmap of where we need to go, it must provide decision makers with practical suggestions for taking the next steps, and it must be *complete* in its scope and *effective* in the tactical approach it advocates.

I look forward to hearing from our witnesses today. I know they have sound advice to offer on these and other topics.

Thank you, Mr. Chairman.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO DR. THOMAS E. GRAEDEL, DR. ANTHONY C. JANETOS, DR. DIANA M. LIVERMAN, DR. ANDREW SOLOW, AND DR. RICHARD ALLEY

Question 1. What are the top two things that you would change about the strategic plan?

Answer. As you know, the National Academies released its formal review of the Climate Change Science Program's (CCSP's) draft strategic plan in February 2003. Using the recommendations from our committee's report and other input from the scientific and stakeholder communities, the CCSP extensively revised its draft plan and issued a revised strategic plan in July 2003. Our committee completed its second report examining the revised plan in February 2004. Because the questions posed here followed testimony about the draft strategic plan, these responses focus

largely on that document rather than the revised plan. Our committee's review of the draft plan found that it should be substantially revised in five main areas: (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. Our committee's first report included numerous specific recommendations for how the draft plan could be improved.

Dr. Thomas E. Graedel: In my opinion, the two top changes to be made to the draft plan are (1) the development of a management plan to clearly align the research activities with the goals of the program, and (2) the creation of a strong coordination and management strategy to link the Climate Change Science Program with the Climate Change Technology Program (see also the answer to question 9 below).

Dr. Anthony C. Janetos: Of the five areas identified by our committee, I would highlight the importance of clarifying the vision and goals of the CCSP, and setting the stage for implementation. There are many scientifically interesting topics that could be investigated under the CCSP; but the most important are those for which the research contributes the most directly to fulfilling the programs vision and goals. Without the vision and goals being very clear and specific, the program cannot fulfill its immense promise. In addition, the plan must be specific on how implementation is to proceed. Without this level of specificity, my concern is that the plan will be intellectually interesting, but it will be extremely difficult to tell if it is also being effective.

Dr. Diana M. Liverman: Among the changes identified in our committee's first report my personal priorities were to improve and define a plan for implementing the research and placing a greater emphasis on research related to mitigation and adaptation. An effective research program requires an implementation plan that includes priorities, budget allocations and measures of success. Research on mitigation and adaptation (including issues related to technology, consumption, economics, emissions, and vulnerability) is an important complement to research that focuses on reducing the biophysical uncertainties associated with climate change.

Dr. Andrew Solow: On the research side, I would strengthen the emphasis on understanding the economic impacts of both climate change and alternative measures for dealing with it. On the management side, I would strengthen overall program management and insist on external oversight.

Question 2. What has been the Administration's response to your review?

Answer. The CCSP has extensively revised its strategic plan and this revised plan was reviewed by our committee. The committee found that the CCSP had responded constructively to the National Academies review and other community input in revising the strategic plan. 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. Although there remain ways in which the plan could be improved, the committee found it to be a wholly adequate framework and recommended that the activities described in the plan be implemented with urgency.

Question 3. Other than continuing the research efforts, what other actions should the government be taking?

Answer. Our committee was asked to review the CCSP's strategic plan for *research* on climate and associated global change. We emphasize the word research because it is important to recognize that the CCSP is a research program and not a policymaking body. Therefore, our report did not provide recommendations for actions the government should be taking to address climate change beyond those needed to improve its capability to conduct and manage its research. Even so, the report does offer a number of recommendations about how the research program should be designed to best support decisions regarding actions to address climate change, including:

- The committee strongly endorsed the draft plan's new 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 committee views the development of decision support resources as the most critical short-term goal of the CCSP.
- The committee found that the draft strategic plan lacked research adaptation and mitigation, in particular the role of consumption, institutions, and social aspects of technology as causes of climate and associated global changes.

- The draft plan needed to include research into the costs and benefits of climate change and related response options.
- The research objectives for ecosystems in the draft strategic plan need 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 found that while the draft strategic plan addressed these topics to some extent, its coverage was 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.

Dr. Anthony C. Janetos: The CCSP and CCTI will have the greatest impact and utility for supporting decisions if the government can clarify what decisions are being contemplated, and which of the many possible communities of stakeholders is critical to include. What types of adaptation and mitigation decisions are being contemplated, for example? Geological sequestration of carbon emissions? Reforestation? What about other greenhouse gases? How expensive and widespread are adaptation strategies likely to be? What is the level of risk that states, landowners, and private businesses are willing to bear? Which resources and ecosystems are at the most risk? I do not pretend to be able to answer all these questions; it is the role of our committee to comment only on the science, not on the policies chosen. But without being clear about what type of decisions are being considered, in other words, what the policy context is that the science is meant to inform, it is difficult to see how the science can be focused effectively.

Question 4. Your statement refers to the strategic plan as recognizing that "uncertainty is inherent in science and decision making and therefore not in itself a basis for inaction." How would you respond to those who claim that we should not do anything about climate change because of the uncertainties about climate science?

Answer. All important decisions are made under conditions of uncertainty. Indeed, uncertainty will never be resolved fully. The draft strategic plan agrees with this point of view, stating that "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). At the same time, there are many aspects of climate change that are well-understood, and it is equally important for scientists to communicate to decision makers the degree to which they are certain about findings and predictions.

Question 5. Your statement has mentioned the need for more research on regional climate change. Should another National Assessment be conducted?

Answer. The Global Change Research Act of 1990 calls for periodic assessments, including an analysis of the "effects of global climate change on the environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity." According to the Act, such assessments are to occur "not less frequently than every 4 years." Our committee believes that regional or place-based studies, such as the first National Assessment of the Potential Consequences of Climate Variability and Change, provide important opportunities to calibrate models with specific in situ measurements, evaluate global mechanisms, address the tangible impacts of climate change of societies and ecosystems, and develop models for providing climate information to stakeholders and thus better engage them in the decision-making process. The committee did not consider whether another National Assessment should be conducted in their discussion of the draft strategic plan, but will address this issue in its review of the revised plan.

Dr. Anthony C. Janetos: Another National Assessment should be conducted as an integrated study, involving many different stakeholders, and with appropriate and extensive scientific and public comment, as occurred in the first one. I believe the main challenge to be the timing. Sufficient time should pass from the first attempt to ensure that there has been enough progress in the underlying science to justify another large, national, multi-disciplinary and multi-sectoral study. Until sufficient time has passed, and there is a consensus that another national study is needed, more focused studies on particularly important topics could be a reasonable way forward.

Dr. Diana M. Liverman: Our committee recommended research on regional climate change because regional studies provide important information that can help decision makers, resource managers and other stakeholders respond to climate change effectively. The National Assessment provided an important model for un-

dertaking research at the regional level that involves large numbers of stakeholders and identified many important issues for further study. Such regional syntheses and interactions with stakeholders should be a continuing component of the overall program and could focus on particular regions and issues, especially on more vulnerable regions and sectors such as the Arctic, critical ecosystems, or health, building the basis for periodic national and international assessments.

Question 6. You have recommended a specific link between the U.S. Global Change Research Program and the Climate Change Research Initiative. The U.S. Global Change Research Program has been around for over 10 years and is comprised of over 13 agencies, each with a separate mission and a history of independent research. How challenging a task is it to coordinate this inter-agency research effort and what actions can we take to improve the management process?

Answer. This task is very challenging. 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 committee concluded that 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. The committee recommended that the revised plan more clearly describe the responsibilities of the CCSP leadership and the management processes to be used to foster agency cooperation toward common CCSP goals.

Question 6a. What is the "value added" of the Climate Change Research Initiative?

Answer. The committee concluded that the components introduced by the CCRI portion of the draft strategic plan bring 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. In addition, the CCRI portion of the plan appropriately recognizes that there are some short-term products that can and should be delivered by the program.

Dr. Andrew Solow: It seems to me that the program's structure is not as critical to its success as the effectiveness of its overall management; in many cases, good management can trump bad structure.

Question 7. Your review found that a revised strategic plan should "articulate a clear, concise vision statement" that should be translated into "tangible goals." Based on your experience, what should be the "vision statement" for the Climate Change Science Program and what should be the specific "tangible goals" for this program?

Answer. The committee recommended that the CCSP articulate a clear, concise vision statement for the program in the context of national needs, and suggested that this vision be similar to that presented by President Bush in his February 13, 2002 speech announcing the Global Climate Initiatives The committee also recommended that the vision 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 committee concluded that the choice of the vision and the goals should be made by the program in light of scientific and stakeholder needs. The program has developed these elements and presented them in the revised strategic plan, which the committee is currently evaluating.

Question 8. Your panel recommended that the Climate Change Science Program should establish a standing advisory panel charged with independent oversight of the entire program. How should the recommended standing advisory committee be designed and what groups should be represented on it?

Answer. 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. To obtain this guidance, the committee recommended that the CCSP establish a standing advisory body charged with independent oversight of the entire program. The committee did not specify how the advisory group should be designed or what groups should be represented on it.

The revised strategic plan states that "after careful review, 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 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."

Dr. Thomas E. Graedel: I continue to think that a standing advisory committee for the entire CCSP would be valuable, especially if members from various stakeholder communities were included. Examples of those who might be particularly useful on such a committee would be a staff member from a state-level climate change office, and the manager of an urban or regional water authority.

Dr. Anthony C. Janetos: In my opinion, a standing advisory panel should have representation from the scientific community, regional stakeholders, the government itself, the private sector, and non-governmental organizations. This broad membership would ensure that the standing panel would have access to senior scientific advice, and also that its advice would reflect the needs and desires of the potential users of that information. The members of the standing panel should not be materially dependent on the CCSP for financial support of their own research or other activities, in order to ensure that they can give truly independent advice. In my own view, the advisory panel should be created under its own auspices, and should not be a committee or panel of existing bodies.

Dr. Andrew Solow: In broad terms, there are two sides of this program that would benefit from formalized external advice and oversight. First, one of the goals of the program is to produce scientific research to support decision making. It follows that it is important to the program to understand what kind of scientific information decision makers need. It therefore makes sense that decision makers be represented on the external committee. Second, there is also a clear need for advice and oversight from the external scientific community on the scientific elements of the research program. These two functions are somewhat different: one ensures that the right questions are being asked and the other ensures that these questions are being addressed correctly. This may suggest that two separate committees are needed. However, if that is the case, then communication between them (perhaps through some overlap of membership) would be important.

Question 9. What role should international research and previous reports, such as those done by the Intergovernmental Panel on Climate Change (IPCC), play in the U.S. Climate Change Science Program?

Answer. The international scientific community recognized climate and associated global changes as serious issues over a decade ago, and therefore developed a broad suite of research activities that have been effectively coordinated by several international research organizations, such as the World Climate Research Programme and the International Geosphere Biosphere Programme. The committee found that the draft plan missed an opportunity to develop a forward-looking strategy for improving international research networks and assessments. 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.

The committee also concluded that the draft strategic plan did not adequately use many prior assessments and consensus reports that have provided scientific information to decision makers. While the draft plan did refer to some of these reports with regard to scientific issues relating to the physical climate, it failed 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 committee recommended that the revised plan build on lessons learned from 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.

Question 10. Your review stated that the "existing management and program links between the Climate Change Science Program and the Climate Change Technology Program may not be extensive enough to take advantage of the synergies between these two programs." What steps should the Climate Change Science Program take to coordinate better with the Climate Change Technology Program?

Answer. 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 did not appear to be the case in the draft strategic plan. At the very least the results from each program should be used to guide the project portfolio of the other. 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. The committee recommended that the CCSP 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. In addition, 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.

Questions to Dr. Richard Alley

Question 1. Your report was completed prior to the development of the strategic plan. Do you feel the strategic plan adequately addresses abrupt climate change issues raised in your report? Are there things that you would change?

Answer. The proper balance between study of nearly-certain gradual climate change and possible, difficult-to-predict abrupt climate change may be more of a policy question than a scientific one, requiring the insights of those who are accustomed to governing in the face of uncertainty. The draft strategic plan did highlight areas of research that are relevant to abrupt climate change. However, the National Academies committee that reviewed the draft plan found that it needed a better presentation of the time scales associated with climate change, which would point to the value of paleoclimate data as descriptors of past natural variability, including past abrupt climate changes. While paleoclimate studies were noted in the draft plan, more emphasis on them would have been helpful. Just as human history helps a policymaker understand what might occur, climate history provides an essential context for present studies of forced climate change combined with natural variability.

Question 2. You have mentioned that denying the likelihood or downplaying the relevance of past abrupt changes could be costly. Can you explain this point?

Answer. Slow, anticipated changes allow adaptation, greatly decreasing costs in comparison to rapid, unanticipated changes. Past abrupt climate changes have been very large, and recurrence of such an event could have major consequences. Learning whether such recurrence is possible, and if so, how likely it is, thus could have value in preparing for the future.

Question 2a. What might be the economic effects if abrupt climate change was happening today or within the next twenty years?

Answer. A recent study on the possible impacts of climate change on U.S. agriculture suggested that an unpredicted but large shift in the strength and frequency of the El Nino/Southern Oscillation phenomenon (such a shift is one of many possible abrupt climate changes) could have annual impacts on U.S. agriculture of approximately $1 billion, but that useful forecasts could cut such damages by more than half (J. Reilly *et al.*, 2003, Climatic Change). The possible damages clearly depend on the size, speed, and extent of the assumed climate change, but the potential magnitude of the impacts and of the value of improved knowledge are clear.

Question 3. You have mentioned in your statement that the potential economic and ecological costs of disease emerging from abrupt climate change should be assessed. Can the current situation with SARS (severe acute respiratory syndrome) be used as a study case?

Answer. The National Research Council report *Abrupt Climate Change: Inevitable Surprises*, identifies disease issues associated with climate change. I know of no evidence that emergence of SARS was linked to climate change directly; however, insofar as SARS appears to be a new disease, poses large problems for public-health officials, has already had economic impacts and may have much larger impacts, I personally believe that much can be learned from the SARS incident that would be of value in addressing any new emerging diseases, whether tied to climate change or not. The NRC produced a report in 2001 titled *Under the Weather: Climate, Ecosystems, and Infectious Disease,* which provides more information on the link between climate change and infectious diseases.

Question 4. Your testimony highlights the importance of abrupt climate change on societies. What societies are most at risk today for abrupt climate change, and how might they be affected?

Answer. Comparison of archaeological, historical and paleoclimatic records shows cases in which past settlements or civilizations "failed" in association with strong climatic stress, including abandonment of sites. Thus, the worst things that can happen are bad indeed. Climatic stress is only one of many stresses to which societies are subject. "Healthy" societies—those with assets including vigorous economies and strong political institutions—are better able to deal with stresses than are

"unhealthy" societies, which may aid in assessing vulnerability to climate change. In addition, those societies that rely heavily on long-lived and relatively immobile infrastructure and ecosystems, including traditional hunter-gatherer societies, may be especially vulnerable. As noted in the NRC *Abrupt Climate Change* report, however, little research has directly addressed this important question.

Question 5. If abrupt climate change is occurring, what actions should be taken to mitigate its effects?

Answer. Better-foreseen changes are less damaging, so improvement in knowledge of what changes are possible, what changes are likely, and when changes are likely will reduce damages. Some uncertainty will always be attached to projections of abrupt climate changes, so actions that increase the resiliency and adaptability of society in the face of large, unexpected changes would be valuable. In addition, research into "no regrets" policies is needed to help inform decision makers about available options. Some ideas are listed in the *Abrupt Climate Change* report, but actual policy recommendations were beyond the charge of that NRC committee that prepared that report.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. OLYMPIA J. SNOWE TO DR. THOMAS E. GRAEDEL, DR. ANTHONY C. JANETOS, DR. DIANA M. LIVERMAN, DR. ANDREW SOLOW, AND DR. RICHARD ALLEY

Question 1. There has been an ongoing argument in Congress as to whether global climate change is actually occurring. I understand the task of the November 2002 *Strategic Plan for the Climate Change Science Program* was to map out the scientific uncertainties. But, there are many published certainties from the Intergovernmental Panel on Climate change (the IPCC), from the National Research Council, and from the President's U.S. Climate Action Report–2002, to the United Nations, which state that there is a strong degree of certainty that global warming is occurring. As renowned scientists, is it your belief that the Earth is experiencing climate change over and above that which would occur with natural variability because of anthropogenic fossil fuel emissions?

Answer. As is explained in the 2001 National Academies Report *Climate Change Science*, there is wide scientific consensus that climate is indeed changing. Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. This conclusion is based on instrumental records from land stations and ships, which indicate that global mean surface air temperature warmed about 0.4–0.8 °C (0.7–1.5 °F) during the 20th century. The ocean, which represents the largest reservoir of heat in the climate system, has warmed by about 0.05 °C (0.09 °F) averaged over the layer extending from the surface down to 10,000 feet, since the 1950s. In addition to these direct measurements, proxy records—which can be derived from ice cores, tree rings, and corals—indicate that today's levels of carbon dioxide (CO_2), a key greenhouse gas, are at their highest levels of the last 400,000 years. The proxy records indicated that recent warming is anomalous and that the observed change in temperature is consistent with our understanding of how Earth responds to greenhouse gases present in the atmosphere.

Dr. Thomas E. Graedel: Yes, I believe that the Earth is experiencing climate change over and above that which would occur with natural variability because of anthropogenic fossil fuel emissions.

Dr. Anthony C. Janetos: Yes, I believe that the Earth is experiencing climate change over and above that which would occur with natural variability because of anthropogenic fossil fuel emissions.

Dr. Diana M. Liverman: Yes, I believe that the Earth is experiencing climate change over and above that which would occur with natural variability because of anthropogenic fossil fuel emissions.

Dr. Andrew Solow: Yes, I believe that the Earth is experiencing climate change over and above that which would occur with natural variability because of anthropogenic fossil fuel emissions.

Dr. Richard Alley: Yes, I believe that the Earth is experiencing climate change over and above that which would occur with natural variability because of anthropogenic fossil fuel emissions.

Question 2. Do you believe that decision making for climate change mitigation and adaptation should occur even in the face of scientific uncertainties? Should Congress wait until these uncertainties are resolved or should Congress be acting now with

measures to decrease the emissions of carbon dioxide and other greenhouse gases? I would appreciate it if you would answer individually.

Answer. All important decisions are made under conditions of uncertainty. Indeed, uncertainty will never be resolved fully. The draft strategic plan agrees with this point of view, stating that "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). At the same time, there are many aspects of climate change that are well-understood, and it is equally important for scientists to communicate to decision makers the degree to which they are certain about findings and predictions.

Dr. Anthony C. Janetos: It is my own belief that decision making must occur, even in the face of uncertainties, and that Congress should begin to act. I have two primary reasons for this. One is that all decision making, and all decision makers must live with uncertainties, even while they attempt to have them reduced. This is true for all manner of choices that we make every day. The other is that there are some things we do know: the concentration of greenhouse gases is rising due to human influence, and is already past the realm of natural variability over the past several hundred thousand years. All the available, credible science that has been done on the sensitivities of natural resources and ecosystems to climate variability and change, and on the potential impacts due to reasonable scenarios of change in the future, suggest that there are potential consequences that one might want to avoid. The main uncertainties are the absolute magnitude of climate change and its regional basis, and therefore the absolute magnitude, regional location, and timing of potential consequences. While these are serious issues, and must be addressed, they should not be reason enough to delay beginning to reduce the emissions of greenhouse gases with sensible policies.

Dr. Diana M. Liverman: Yes I do believe that decision making should occur in the face of scientific uncertainties because we do not need to be certain to act, because effective decisions about many other important issues (e.g., economic and health policy) have been made under conditions of considerable uncertainty, and because research has developed a number of useful tools for making such decisions. My personal opinion is that it is possible to make decisions to mitigate and adapt to climate change that will reduce the risks of serious climate change and can provide side benefits (e.g., by reducing other risks such as those of air pollution and natural climate variability, by saving consumer energy costs through conservation) to many sectors of society.

Dr. Andrew Solow: I do not believe that Congress should delay acting until the scientific uncertainties are resolved. However, by the same token, I do not believe that Congress should ignore these uncertainties in its decision making.

Dr. Richard Alley: Change will occur. The existence of abrupt climate change ensures that detailed projections of climate change will always be somewhat uncertain. Just as one cannot predict exactly when a leaning person will flip a canoe on a wave-tossed lake, so it is difficult to tell exactly when a threshold will be crossed that alters the way the climate behaves. If policymakers had to wait for all scientific uncertainty to be resolved before considering appropriate policy, they would wait forever.

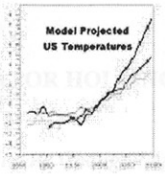
Question 3. The Global Change Research Act of 1990, Section 106, calls for an assessment to be prepared and submitted to the President that analyzes, for instance, the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity. A national assessment, *Climate Change Impacts on the United States,* of which you were one of the team members, was published in 2001, addressing the *potential* consequences of climate variability and change. Do you know why there is no mention of this 2001 National Assessment in the draft Strategic Plan, especially as was developed by a great number of regional and local stakeholders and scientific experts?

Answer.

Dr. Anthony C. Janetos: I do not know why the U.S. National Assessment of the Potential Impacts of Climate Variability and Change was not mentioned in the draft CCSP strategic plan. Our committee concluded that the draft strategic plan did not adequately use many prior assessments and consensus reports that have provided scientific information to decision makers, including the U.S. National Assessment. This is especially unfortunate in several respects. One is that the National Assessment, through its sectoral and regional studies, involved literally thousands of citizens and hundreds of scientists in its workshops and many published

products. Another is that the national reports of the Assessment were the subject of extensive scientific and public review, and contrary to some assertions, have not been discredited in the scientific community. In fact, the main conclusions from the Overview document (appended below) are quite balanced, and should continue to provide guidance for future research activities, as is also documented in the peer-reviewed literature (Parson, Edward A., Robert W. Corell, Eric J. Barron, Virginia Burkett, Dr. Anthony C. Janetos, Linda Joyce, Thomas R. Karl, Michael C. MacCracken, Jerry Melillo, M. Granger Morgan, David S. Schimel, and Thomas Wilbanks, 2003. Understanding Climatic Impacts, Vulnerabilities, and Adaptation in the United States: Building a Capacity for Assessment. Climatic Change 57: 9–42). The CCSP would also do well to learn not only the substantive lessons of the results of the National Assessment, but also the operational complexities inherent in attempting such a large-scale, national effort to engage both scientists and stakeholders in a dialogue of national importance.

KEY FINDINGS



1. Increased warming

Assuming continued growth in world greenhouse gas emissions, the primary climate models used in this Assessment project that temperatures in the US will rise 5-9°F (3-5°C) on average in the next 100 years. A wider range of outcomes is possible.

2. Differing regional impacts

Climate change will vary widely across the US. Temperature increases will vary somewhat from one region to the next. Heavy and extreme precipitation events are likely to become more frequent, yet some regions will get drier. The potential impacts of climate change will also vary widely across the nation.

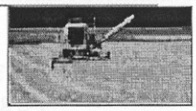
3. Vulnerable ecosystems

Many ecosystems are highly vulnerable to the projected rate and magnitude of climate change. A few, such as alpine meadows in the Rocky Mountains and some barrier islands, are likely to disappear entirely in some areas. Others, such as forests of the Southeast, are likely to experience major species shifts or break up into a mosaic of grasslands, woodlands, and forests. The goods and services lost through the disappearance or fragmentation of certain ecosystems are likely to be costly or impossible to replace.

4. Widespread water concerns

Water is an issue in every region, but the nature of the vulnerabilities varies. Drought is an important concern in every region. Floods and water quality are concerns in many regions. Snowpack changes are especially important in the West, Pacific Northwest, and Alaska.

5. Secure food supply



At the national level, the agriculture sector is likely to be able to adapt to climate change. Overall, US crop productivity is very likely to increase over the next few decades, but the gains will not be uniform across the nation. Falling prices and competitive pressures are very likely to stress some farmers, while benefiting consumers.

6. Near-term increase in forest growth

Forest productivity is likely to increase over the next several decades in some areas as trees respond to higher carbon dioxide levels. Over the longer term, changes in larger-scale processes such as fire, insects, droughts, and disease will possibly decrease forest productivity. In addition, climate change is likely to cause long-term shifts in forest species, such as sugar maples moving north out of the US.

7. Increased damage in coastal and permafrost areas

Climate change and the resulting rise in sea level are likely to exacerbate threats to buildings, roads, powerlines, and other infrastructure in climatically sensitive places. For example, infrastructure damage is related to permafrost melting in Alaska, and to sea-level rise and storm surge in low-lying coastal areas.

8. Adaptation determines health outcomes

A range of negative health impacts is possible from climate change, but adaptation is likely to help protect much of the US population. Maintaining our nation's public health and community infrastructure, from water treatment systems to emergency shelters, will be important for minimizing the impacts of water-borne diseases, heat stress, air pollution, extreme weather events, and diseases transmitted by insects, ticks, and rodents.

9. Other stresses magnified by climate change

Climate change will very likely magnify the cumulative impacts of other stresses, such as air and water pollution and habitat destruction due to human development patterns. For some systems, such as coral reefs, the combined effects of climate change and other stresses are very likely to exceed a critical threshold, bringing large, possibly irreversible impacts.

10. Uncertainties remain and surprises are expected

Significant uncertainties remain in the science underlying regional climate changes and their impacts. Further research would improve understanding and our ability to project societal and ecosystem impacts, and provide the public with additional useful information about options for adaptation. However, it is likely that some aspects and impacts of climate change will be totally unanticipated as complex systems respond to ongoing climate change in unforeseeable ways.

Question to Dr. Richard Alley

Question 1. In your book, *Abrupt Climate Change: Inevitable Surprises*, you mention that there is no federal plan for improving our understanding of abrupt climate change. I would like to know what you think of my request to establish a NOAA Joint Institute that will involve universities carrying on abrupt climate change research such as yours at Penn State and Dr. George Denton's at the University of

Maine. Should this be a priority of NOAA and the Climate Change Science Program?

Answer. The NRC report *Abrupt Climate Change: Inevitable Surprises* is clear on the need for additional research if we are to understand abrupt climate change, and provides many examples illustrating the value to society of understanding this topic. I believe that research on abrupt climate change is in the national interest. While the NRC committee did not address the policy questions of how appropriate studies should be conducted within the federal research portfolio, your proposed NOAA Joint Institute could address leading research priorities identified by the NRC committee.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. ERNEST F. HOLLINGS TO DR. THOMAS E. GRAEDEL, DR. ANTHONY C. JANETOS, DR. DIANA M. LIVERMAN, DR. ANDREW SOLOW, AND DR. RICHARD ALLEY

CCSP and GCRP Management Structure:

The National Academy of Sciences' (NAS) review of the *Draft Strategic Plan* expresses concern regarding the management of the Climate Change Science Program (CCSP) and its research programs and indicates that without centralized coordination at the level of the CCSP itself, "there will be a tendency for the individual needs and priorities of the agencies to take precedence over the needs of the entire program." Congress intended that the GCRP perform this coordination function when it passed the GCRA in 1990.

Question 1. Is another layer of management needed? What changes would be needed at the Global Change Research Program?

Answer. More important than layers of management, is that the management structure be clear and effective. 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 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). This new management structure is untested, so it is premature to evaluate its effectiveness.

The committee concluded that the creation of the cabinet-level committee with the authority to shift resources 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. To address these issues, the committee recommended that the revised strategic plan clearly describe the responsibilities of CCSP leadership and the management processes used to be used to foster agency cooperation towards common goals. The committee also recommended that the revised plan more clearly outline agency responsibilities for implementing the research.

Question 2. Would you recommend any changes to the Global Change Research Act of 1990 to ensure better prioritization and management of global change research through the GCRP?

Answer. The committee did not consider possible changes to the Global Change Research Act of 1990. Our recommendations were designed to improve the program management and prioritization of global change research within the CCSP.

Dressing up Old Initiatives as CCRI:

In your review of the strategic plan, you evaluated the budget proposals for the USGCRP and CCRI. As you are aware, NOAA's FY03 budget represented an $18 million "increase" under CCRI—not USGCRP—for aerosols research, climate modeling, carbon cycle, and observations. *All these areas were already funded at NOAA under the USGCRP in previous years*

Question 1. Of the $18 million "increase," how much is actually research that has never been done by NOAA as part of the USGCRP effort?

Question 1a. Is any of the research absolutely new?

Question 1b. Isn't this just "dressing up" old programs in new clothing?

Answer. The committee did not have enough information about the CCSP budget to address these three questions in detail. As a general proposition, providing additional resources to an existing program does not necessarily mean that no new research is done. Research is a matter of accumulating knowledge and there is more knowledge to accumulate on most of these issues. At the same time, agencies (not just NOAA) sometimes re-label programs in the way suggested by the questions. For this reason, strong central management and external program oversight are critical to the success of the program.

Climate Change Budget Request:

According to the latest budget figures within the Climate Change Science Program's (CCSP) report *Our Changing Planet,* the annual budget for climate change research has been relatively flat since the formation of the Global Change Research Program (GCRP) in 1990.

Accounting for inflation, this flat funding represents a rather substantial real decline in funding for climate change research. Meanwhile, the Administration has launched new research initiatives, such as the Climate Change Research Initiative (CCRI), and the Administrations *Draft Strategic Plan* identifies a large number of research needs, including basic research infrastructure such as climate observing systems, climate modeling centers, and data management capabilities.

Question 1. Do you think that the current funding for the Climate Change Science Program is sufficient to fulfill the research needs identified by the Administration?

Answer. 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 this question. 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.

Question 2. Does the draft plan indicate what the Administration views as priorities and does the scientific community consider these priorities appropriate?

Answer. The draft plan listed a multitude of proposed activities, but did 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 did it provide an explicit process for establishing such priorities.

Future National Assessments:

In 2000, the Global Change Research Program (GCRP) released the report *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change,* which is more commonly referred to as the *U.S. National Assessment.* This report represents the most current and comprehensive assessment of the implications of climate change for the United States, and has been an instrumental tool for communicating information on climate change to policy-makers, the media, and the general public, and was the source of much of the material within the Administration's 2002 Climate Action Report.

Strangely, in the Administration's *Draft Strategic Plan for the Climate Change Science Program* no mention is made of the *U.S. National Assessment*, nor is there any indication that a similar report will be produced in the future.

Question 1. Given the Administration's statements regarding the importance of "policy-relevant" research, does the *Draft Strategic Plan* indicate the Administration has given careful thought to the performance of outreach to policy-makers and stakeholders through tools such as the National Assessment in order to effectively communicate the products of CCSP research?

Answer.

Dr. Anthony C. Janetos: In my view, the Administration has given the topic of outreach to policy-makers and stakeholders considerable thought, but there are some surprising gaps. Our committee concluded that the draft strategic plan did not adequately use many prior assessments and consensus reports that have provided scientific information to decision makers. While the draft plan did refer to some of these reports with regard to scientific issues relating to the physical climate, it

failed 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 committee recommended that the revised plan 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. We are supportive of the efforts within the CCSP Strategic Plan to devote more effort to decision support activities, but these efforts must become both more specific and must be supported by the agencies with sufficient funding to ensure their success.

Dr. Diana M. Liverman: In my personal opinion the Draft Strategic Plan does give some thought to outreach to policy makers and stakeholders but could be considerably improved in this area. Our committee recommended that greater emphasis be placed on regional research and that the plan should build on lessons learned from the National Assessment as well as other activities such as IPCC and research programs that have demonstrated how to communicate with regional stakeholders (e.g. NOAA RISA, NASA RESAC). We also recommended that research into decision making methods and tools should be strengthened, building on the broader social science research into areas such as decision making under uncertainty and effective communication with users. The United States could also learn from other climate outreach programs around the world. In my opinion, the UK Climate Impacts Programme provides a successful model because of the wide range of stakeholders that have been engaged.

Question 2. Is the Administration likely to prepare any of the scientific assessments called for under Section 106 of the Global Climate Change Act to assist this Committee and other national policymakers by 2004?

Answer.

Dr. Anthony C. Janetos: The Global Change Research Act of 1990 calls for periodic assessments, including an analysis of the "effects of global climate change on the environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity." According to the Act, such assessments are to occur "not less frequently than every 4 years." The original draft plan did not specify how the program would fulfill this mandate. The revised strategic plan proposes 21 synthesis and assessment reports to meet the requirements of the GCRA. In my personal view, these individual reports have the potential to be well-grounded scientifically and be quite interesting and well-done. It is not as clear how they are meant to provide a more synthetic picture of the potential consequences of climate change, both negative or positive.

Dr. Diana M. Liverman: Because the revised strategic plan proposes 21 synthesis and assessment reports to meet the requirements of the GCRA, it does appear that some assessments are planned. My personal opinion is that more research and funding in certain areas may be needed to support these assessments, that they should be carefully coordinated with international efforts such as IPCC (so as to avoid unnecessary duplication, take advantage of relevant studies elsewhere) and with the priority areas of the strategic plan, and should involve a wide range of stakeholders and scientists beyond the government.

Question 3. When is the earliest assessment likely to be completed, if at all?

Answer. The revised strategic plan states that 9 of the proposed 21 synthesis and assessment products intended to meet the requirements of the Global Change Research Act of 1990 will be completed within 2 years. According to the CCSP, the other 12 synthesis and assessment products will be completed within 2 to 4 years.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN F. KERRY TO DR. RICHARD ALLEY AND DR. ANTHONY C. JANETOS

Administration Response on CO_2 and "No Regrets" Policies:

The Bush Administration sets as its climate mitigation objective an 18 percent reduction in greenhouse gas intensity over the next 10 years. However, the Chairman of CEQ testified before this Committee that this goal would actually result in a 14 percent net INCREASE in U.S. greenhouse gas emissions. This is virtually business-as-usual. In addition, the Administration's so-called "Clear Skies" plan (i.e., the President's Air Pollution Plan) does not even address carbon or greenhouse emissions from the utility sector, which is responsible for 40 percent of U.S. greenhouse gas emissions.

Last month the Congressionally chartered National Academy of Public Administration (NAPA) issued its Congressionally mandated study on the Clean Air Act New Source Review program and pollution reductions from power plants. NAPA concluded that if Congress takes up legislation on power plant pollution they should anticipate upcoming environmental challenges and provide future regulatory certainty by including emission standards for carbon dioxide. (Recommendation #7, pg. 36).

Question 1. Given the NAPA recommendation, and the fact that electricity production accounts for 40 percent of total national CO_2 emissions, does it make sense to include moderate CO_2 standards in the Administration's power plant cleanup legislation?

Answer. Setting standards for CO_2 emissions is a matter of policy that has not been addressed by the National Academies. Given that CO_2 is a greenhouse gas and is produced by electricity production, it stands to reason that controls on CO_2 emissions will be helpful in meeting emissions reduction goals.

Question 2. Wouldn't addressing carbon dioxide emissions from utilities (which in many states are already subject to state-initiated capping programs) fall into the "No Regrets" policies referred to in the *Abrupt Climate Change* Report?

Answer. The *Abrupt Climate Change* report specifically identifies energy policies, including the greenhouse-gas contributions from fossil-fuel burning, as an area in which targeted research may lead to useful policy recommendations with few or no regrets, in agreement with the suggestion in the question. However, the committee that prepared this report was not formulated to make policy recommendations and did not evaluate this policy specifically.

UNFCCC Goals and Commitments:

In 1992 the U.S. signed and ratified the UN Framework Convention on Climate Change, which set as its goal "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

And that "such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change . . ."

According to testimony before this Committee in July of last year and the U.S. Climate Action Report, U.S. greenhouse gas emission will increase by 43 percent between 2000–2020, despite improvements in greenhouse gas intensity.

Question 1. In your scientific opinion, has the U.S. met its goal?

Answer. Stabilization of greenhouse-gas concentrations in the atmosphere has not been achieved. Scientists are still trying to determine what level of greenhouse gases in the atmosphere would "prevent dangerous anthropogenic interference with the climate system." At this time, the goal is only qualitative and therefore does not lend itself well to a quantitative response. In fact, no single threshold level of greenhouse gas concentrations in the atmosphere can be defined as the beginning of dangerous interference with the climate system. The level at which concentrations pose the danger described in the Convention's language is a matter of the climatic consequences of those emissions, the sensitivities of the natural resources and economies of the affected regions of the globe, and are subject to many scientific, economic, and political uncertainties. Some impacts have already occurred, and for increasing concentrations there will be increasing impacts.

Question 2. If we continue on our current path—with emissions rising every year—*when* would we achieve this goal? Ever?

Answer. If greenhouse gas emissions rise every year, stabilizations of their atmospheric concentrations will not occur.

Question 3. Given our failure to reduce global emissions through voluntary mechanisms alone, what types of "no regrets" mandatory policies appear to be the most appropriate for Congressional consideration?

Answer. Neither the NRC Committee to Review the Draft CCSP Strategic Plan (of which Dr. Anthony C. Janetos is a member) or the NRC Committee on Abrupt Climate Change (of which Richard Alley was chair) were charged to consider the relative merits of emissions control policies.

Dr. Anthony C. Janetos: In my personal view, the limitations of voluntary mechanisms in achieving such reductions of emissions are well known in practice. Mandatory caps on emissions, with substantial flexibility in how they are to be achieved in terms of market mechanisms, use of sequestration technologies, and spread of more efficient end-uses of energy will be necessary. The main challenge will be to ensure that such activities do not present overwhelming economic burdens to citizens and businesses, and that they are undertaken cautiously, so as to allow for future research to inform their application. Also in my own view, technological

research on climate change mitigation actions in all sectors should be a high priority in order to ensure that the ingenuity of both our scientific and engineering communities is put to best use on this critical issue. Especially high priority might be given to those technologies and practices with potential payoffs that are sooner rather than later. At the same time, research on adaptation practices and the sensitivities of key sectors and regions to climate change should be sponsored, so that mitigation practices can be most efficiently applied at the least possible cost.

We should not be under any illusion that these solutions can be reached quickly. This is one of the most critical, but also one of the most difficult environmental issues of our time. We should be prepared for a period of adaptive learning and management, so that future decisions can be adequately informed by research begun today.