Creating a Disaster Resilient America: Grand Challenges in Science and Technology: Summary of a Workshop

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THE NATIONAL ACADEMIES

CREATING A DISASTER RESILIENT AMERICA

GRAND CHALLENGES IN SCIENCE AND TECHNOLOGY

SUMMARY OF A WORKSHOP

OF THE DISASTERS ROUNDTABLE

By

Patricia Jones Kershaw, National Research Council

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Disasters Roundtable
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FOREWORD

The Disasters Roundtable (DR) seeks to facilitate and enhance communication and the exchange of ideas among scientists, practitioners, and policymakers concerned with urgent and important issues related to the understanding and mitigation of natural, technological, and other disasters. Roundtable workshops are held three times a year in Washington, D.C. Each meeting is focused on a specific topic or issue and is free and open to the public. The Disasters Roundtable Steering Committee identifies topics, creates agendas, and recruits expert speakers for Roundtable events. For information on upcoming workshops, please visit http://dels.nas.edu/dr.

The Disasters Roundtable Steering Committee is composed of eight appointed members and nine sponsoring ex-officio members. The appointed members are William H. Hooke, chair, American Meteorological Society; Ross B. Corotis, University of Colorado, Boulder; Susan K. Tubbesing, Earthquake Engineering Research Institute; Ellis M. Stanley, Sr., Emergency Preparedness Department of the City of Los Angeles; Richard T. Sylves, University of Delaware; John R. Harrald, George Washington University; David M. Simpson, University of Louisville; and Havidan Rodriguez, University of Delaware. The ex-officio members are Lloyd Cluff, Pacific Gas & Electric; Dennis E. Wenger, National Science Foundation; Timothy A. Cohn, U.S. Geological Survey; Stephen Ambrose, National Aeronautics and Space Administration; Elizabeth Lemersal, Federal Emergency Management Agency; James W. Russell, Institute for Business and Home Safety; and Helen Wood, National Oceanic and Atmospheric Administration; Frank Best, PB Alltech, Inc.; and Gerard J. Hoetmer, Public Entity Risk Institute. The DR staff includes William Anderson, director; Patricia Jones Kershaw, senior program associate; and Byron Mason, senior program assistant.

This document presents the rapporteur's summary of the workshop discussions and does not necessarily reflect the views of the Roundtable members or other participants.

For more information on the Roundtable visit our website: http://dels.nas.edu/dr or contact us at the address below.

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

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Responsibility for the final content of this summary rests entirely with the authors and the institution.

DISASTERS ROUNDTABLE

CREATING A DISASTER RESILIENT AMERICA: GRAND CHALLENGES IN SCIENCE AND TECHNOLOGY

OVERVIEW

The 12th Disasters Roundtable (DR) workshop was held at the National Academies on October 28, 2004, on the topic of grand challenges in science and technology related to society's vulnerability to disaster. A grand challenge is a fundamental problem in science and technology whose solution can be advanced by coordinated and sustained investments in research, education, communication, and the application of knowledge and technology. Strategic investments in such matters as they relate to hazards offer the promise of producing significant reductions in the loss of life and property from natural, technological and human-induced disasters. As noted by the DR chair William H. Hooke of the American Meteorology Society during his introductory remarks, this topic was chosen in collaboration with the National Science and Technology Council's Subcommittee on Disaster Reduction (SDR) as a way to aid member agencies in identifying their priorities for the next federal budget cycle. To this end, the agencies and stakeholders from the disaster research and policy community gathered to discuss research and programmatic investment priorities for the near and long-term.

THE NEED FOR STRATEGIC INVESTMENTS

It is critically important to set priorities for science and technology at the national level, noted Kathie L. Olsen, deputy director of the Office of Science and Technology Policy (OSTP). The agency is the lead advisor to the president on science and technology matters, with a major role in coordinating the science and technology investments of the various federal agencies. OSTP furthers strong partnerships among government entities, industry, and science associations. The agency coordinates cross-agency scientific activities through the National Science and Technology Council (NSTC), a cabinet level group that is comprised of committees and subcommittees. Three NSTC subcommittees relate to the disaster reduction activities of the federal government: the Subcommittee on Disaster Reduction and the Intergovernmental Working Group on Earth Observations, which fall under the Committee on Environment and Natural Resources, and the Subcommittee on Social, Behavioral and Economic Sciences under the Committee on Science. The SDR, which is one of the most active NSTC entities, has drafted a 10-year investment strategy that focuses on such challenges as hazard identification, prediction, and vulnerability reduction.

Olsen indicated that Earth observation systems, a topic of a previous Disasters Roundtable workshop held on October 22, 2003, are currently a high-priority investment for the United States because of the contributions they can make in improving societal well being, both in this country and overseas (NRC, 2004). Satellite and in situ observing systems are important in increasing our nation's disaster resilience. Satellite observations

systems that measure the height of the Earth have important ramifications for understanding earthquakes and predictions. Near-term priorities for Earth observations include data management, global land and ocean observing systems, an integrated national drought information system, and an air quality assessment and forecast system.

Olsen noted that disasters are going to happen and no amount of science and technology will stop them, but better science and technology will provide a high level of predictability and preparedness to minimize their effects. Although much needs to be done, the United States has made progress in hazard forecasting and preparedness, particularly in comparison to some other societies when it comes to reducing casualties and loss of life. For example, during the 2004 hurricane season, Hurricane Jean caused less than 100 deaths in Florida, but was responsible for over 2,000 deaths in neighboring Haiti. Olsen suggested that there is a real need for the United States to transfer its disaster-related scientific knowledge worldwide to help other countries, especially developing ones, reduce deaths and other losses from disasters of all types.

FIGURE 1. The Trans-Alaska Oil Pipeline, built in the 1970's, crosses the Denali Fault in Alaska. During the 2002 Denali Fault quake, magnitude 7.9, the ground was offset beneath the pipeline, and violent shaking damaged a few of the pipeline's supports near the fault, but the pipeline did not break. (Source: Kathy Olsen, OSTP).

Olsen indicated that sometimes success should be measured by what doesn't happen, a disaster averted, as a result of the application of extant science and technology, but this is difficult to explain to taxpayers. For example, the November 2002 Denali Fault earthquake measuring 7.9 on the Richter scale occurred in Alaska in the location of the trans-Alaska oil pipeline (Figure 1). When the pipeline was designed, seismic risks were considered and it was built to withstand large earthquakes, so even the 7.9 earthquake did not rupture the pipeline. This was a disaster averted. If the pipeline had ruptured, a major environmental disaster would

have occurred, not to mention the large economic losses the United States would have suffered as a result of the loss of oil. According to Olsen, the federal government is making investments to increase the likelihood that such disasters can be prevented.

COMMUNITY RESILIENCE

According to Stuart Nishenko, senior seismologist at Pacific Gas and Electric, creating disaster resilient communities should be part of our national agenda. Disaster resilient communities can be understood as those that have the capacity to take requisite mitigation and preparedness actions to withstand extreme natural or human induced events. Nishenko suggested that resiliency embodies four basic dimensions of society—the technical, organizational, social, and the economic—and involves what Nishenko describes as the four R's: system robustness, redundancy, rapidity, and resourcefulness. Robustness is needed to reduce system fragilities in the face of hazards. Redundancy is having back-up systems in place to reduce the consequences of extreme events. Robustness and redundancy create resourcefulness needed for rapidity in both response and recovery actions, something that Nishenko felt was apparent following the September 11, 2001, attacks on the World Trade Center and the Pentagon.

Community-based mitigation leading to a more disaster resilient community is a long-term process that not only involves science, engineering, technology, and emergency management but also touches on things like planning, development, economics, education, and critical care facilities. The 2001 magnitude 6.8 Nisqually earthquake that occurred in Washington State provides an example of how mitigation pays off, according to Nishenko, and why it is important to have the goal of creating disaster resilient communities on the national agenda. In spite of the earthquake, a disaster was avoided not only because it occurred 30 miles deep but also because after earlier seismic events in the Seattle area the community adopted building codes, started upgrading structures, and created a culture of preparedness in anticipation of future events. Of course, luck played some role in the reduced toll; for example, the historic district was closed at the time of the Nisqually earthquake. It was there that casualties could have resulted from the collapse of parapets on unreinforced masonry buildings. Nevertheless, according to Nishenko, this is a good example of how a community has taken up the charge to address the earthquake problem and slowly through continued investment receives the return in safety some stakeholders envisioned.

While it is important to place community disaster resilience on the national agenda, in the final analysis it is not achieved overnight, according to Nishenko. Community resilience results from a combination of building community-based partnerships, identifying hazards and community vulnerabilities, prioritizing hazard risk reduction activities, and maintaining momentum by sharing success stories.

Nishenko noted that there is a real need to be able to more systematically measure disaster resilience and disaster reduction if significant progress is to be made in reducing future vulnerabilities. He added that a national dialogue is required to identify the appropriate metrics to use in gauging disaster resilience on both a community and national scale. So far, in terms of what is needed, only the surface has been scratched through the application of such approaches as geographic information systems and loss estimation methodologies.

During the open discussion that followed the two presentations, two of the major points that surfaced were the need to develop more reliable metrics for determining progress in achieving community disaster resilience and cost-effective mitigation, and the need to both expand and better apply knowledge on the social and behavioral aspects of disaster reduction. Most participants felt that without advances in these areas major progress in reducing community vulnerability throughout the nation would occur at a slow pace.

THE SCORE CARD: HOW RESILIENT ARE WE AS A NATION?

What is resilience? Dennis Mileti, recently retired professor from the University of Colorado, suggested that Ben Franklin had the right notion 200 years ago when he created the widely used expression "an ounce of prevention is worth a pound of cure." Mileti noted that resilience was once perceived as coming from local communities and was not imposed by the state or federal government; it was something communities sought. It was also thought that men, women and children in our nation's communities would assume responsibility for their own futures, that is, refrain from labeling disasters as acts of God or nature.

According to Mileti, there is great variation in the nation when it comes to disaster resilience. For example, disaster resilience is high in some communities, but low in most. Resilience also varies by hazard. The disasters that we have most recently experienced are usually the ones that we focus on for awhile. Furthermore, resilience varies by how routine a disaster agent becomes, according to Mileti. Those agents that appear frequently, such as floods, tend to get more attention from government and other stakeholders.

Mileti noted that the variation in emergency preparedness and response in the United States is extraordinarily large. For example, terrorism preparedness has caused many airline passengers to completely rethink how they travel. The clothing, shoes, and carryon items that you may have once worn or toted on a plane are now things of the past. If you carry a laptop, you expect a longer delay in the security line. Yet Mileti noted that air intakes for high-rise buildings are often not secured at sidewalk-level to prevent tampering.

There is also great variance in the application of knowledge, according to Mileti. For example, there are hundreds of research publications on risk communication that have implications for improving how Americans respond to disaster warning. Although more research is needed, this is an area that is well-studied. This knowledge is used in some towns and communities but not in others. Some federal agencies use the knowledge, but others do not even know it exists.

Additionally, there is the tendency to plan mainly for immediate disaster response even though it has been known for a long time that if one wants to reconstruct a city or a community in a way that reduces future losses, pre-emergency recovery planning is also necessary. Yet such planning is something that decision makers rarely consider, according to Mileti.

Mileti also noted that we prepare for what we have already experienced, not what we might face. In other words, we get ready for the past, not for the future. And according to Mileti, we give too much preference to high-tech fixes and federal resources, while underestimating the importance of community-based solutions to hazard vulnerability.

What are some important trends relevant to the prospects for future community disaster resilience? Mileti noted that one pattern that has been emerging for a long time is increased vulnerability to larger and larger disasters. For example, we continue to have growing population concentration in the nation's most hazardous areas, such as in coastal zones and seismic prone regions, a challenge that government policy has not adequately addressed, according to Mileti.

Mileti suggested that disaster resilience emerges from the fact that there is a great need for the development of a better process to further disaster reduction and preparedness in this country. Such a process would include both the development of needed scientific knowledge about various kinds of risks and what can be done about them plus the utilization of that knowledge by relevant stakeholders. He sees activities such as this workshop as an opportunity to further the creation of a process that will lead to greater disaster resilience in the nation.

The major issue that emerged during the open discussion following Mileti's presentation centered on what can be done to facilitate the application of existing knowledge to further disaster resilience in the nation's communities. Mileti said that the vital lesson he has learned from his thirty years of experience in the field is that knowledge is more likely to be applied when knowledge producers and potential users share information and perspectives on a face-to-face basis and develop a sense of mutual trust and respect, rather than when research findings are merely published in reports and academic journals. The former involves a requisite active knowledge dissemination process, while the latter is much too passive.

EMERGING FEDERAL GRAND CHALLENGE PERSPECTIVES AND PRIORITIES

The National Science and Technology Council's Subcommittee on Disaster Reduction is identifying grand challenge priority investments related to disaster reduction in the nation. Senior level officials from the SDR agencies discussed emerging priorities and gave attention to such issues as agency successes, needed tools and technologies for disaster reduction, and where more coordination would be beneficial.

National Science Foundation

Margaret Leinin, assistant director of the Geosciences Directorate at the National Science Foundation (NSF), noted that the agency plays the role of basic research agency for disaster-related research. NSF is unique in that it has the flexibility to explore the processes that are involved in environmental disasters and to work with other agencies responsible for operational or disaster management concerns. Supporting research related to understanding and reducing disaster risks has a very high priority at NSF and many of its units are involved, including the Geosciences; Engineering; and Social, Behavioral, and Economic Sciences Directorates.

NSF collaborates with other agencies on disaster and risk reduction matters. According to Leinin, partnerships are built with other agencies primarily through jointly-funded research projects and research centers. For example, NSF participates in the funding of the Center for Analysis and Prediction of Severe Storms at the University of Oklahoma. The goal of the center is to enhance the understanding of the physics of the emergence of severe storms, primarily hurricanes and tornados, to see how this may lead to greater storm predictability. At this center fine-scale meteorology and fine-scale geography are combined and models are developed that have substantially enhanced the predictability of tornadoes and other storms. The researchers at the center have worked closely with the National Oceanic and Atmospheric Administration (NOAA) to turn information from models into operational weather forecasts. As a result of this partnership, the warning time for tornadoes in the Midwest is now double what it was 12 years ago, according to Leinin. The warning time is still in minutes, but given the intense non-linearity of the weather systems that generate this, such an outcome is phenomenal and a good example of what a strong partnership between agencies can produce.

Another example of cooperation is in the area of earthquakes. The Southern California Earthquake Center, SCEC, is supported by NSF, the US Geological Survey, and the Federal Emergency Management Agency (FEMA). This center focuses on the analysis of the physics of earthquakes and the predictability of earthquakes. NSF is interested in the basic physical processes of earth rupture now and in the past. USGS is interested in the specific issue of the Los Angeles Basin and the predictability of earthquakes. And FEMA is interested in mitigation activities.

Models developed by SCEC have resulted in contour maps depicting areas that are most prone to earthquake shaking, how that shaking propagates around the Los Angeles Basin, and which areas are prime targets for retrofitting structures. With this information, FEMA is now focusing its retrofit activities on the areas that

have the greatest potential for earthquakes. SCEC is also collaborating with researchers funded by NSF's Engineering Directorate. This includes putting model buildings and other structures on experimental shake tables to see how they perform under various earthquake loads. Such work also has important implications for advancing FEMA's mitigation efforts. In addition to SCEC, three other earthquake centers are supported by NSF, all through the Engineering Directorate: the Multidisciplinary Center for Earthquake Engineering Research, the Mid-America Earthquake Center, and the Pacific Earthquake Engineering Research Center.

NSF has also partnered with the Environmental Protection Agency (EPA) to look at decision making under uncertainty and risk management in primarily pollution-related disaster scenarios. NSF's Social, Behavioral and Economic Sciences Directorate and the EPA are co-funding projects that look at how stakeholders can improve crisis decision-making.

Leinen noted that the slowly-evolving type of disaster, for example sea level rise as a result of melting glaciers, is one area where NSF and the other agencies need to give more priority. For example, research suggests that glaciers on Greenland are melting at a more rapid rate than originally thought, giving rise to a potentially serious threat in the coming decades. She suggested that agencies need to enhance their coordination when it comes to understanding and coping with such slow onset disasters and to increase their engagement with policy makers. According to Leinen, rapid onset disasters like earthquakes, fires, and floods have forced agencies into developing good coordination mechanisms, but when there is no pressure to act very quickly, as in the case of slow onset disasters, stakeholders are not as well prepared because they believe that they have plenty of time to make decisions. The development of the previously mentioned Earth observation system is one of the keys to a more coordinated approach to coping with slowly-emerging disasters in the United States and globally. NSF's investments in sensor and other types of technologies, combined with the complementary investments of other federal agencies, should help further the development of this vital monitoring system.

National Oceanic and Atmospheric Administration

General John J. Kelly, deputy undersecretary of commerce for oceans and atmosphere at NOAA, noted that his agency does applied research to enable its operational arm to deliver products and services across a wide range of areas. Major accomplishments of NOAA involve activities related to such hazards as hurricanes, floods, droughts and tsunamis. Improved accuracy of hurricane tracking, for example, is a major accomplishment. This year NOAA's 48-hour track forecast error is less than 100 nautical miles, 30 miles better than its Government Performance and Results Act goal of 129 miles. Last year NOAA began issuing a 5-day forecast, which is as good as the 3-day forecast was 15 years ago, according to Kelly. NOAA partnered with FEMA and the U.S. Army Corps of Engineers and developed an approach to hurricane evacuation flood modeling. A total of 4600 local emergency managers are registered users of this software and communications system that is "a one-stop shop" where they can get direct output of a number of storm surge models on what will happen relative to the streams and creeks along coastal areas. NOAA has partnered with the U.S. Department of Agriculture (USDA) to put out a "drought monitor", a weekly product indicating the state of drought throughout the United States.

A part of NOAA's mission is to reduce the risks posed by tsunamis. NOAA has two tsunami warning centers, one in Alaska and one in Hawaii, to warn the West Coast of the United States and Hawaii about the threat of tsunamis. Deep ocean monitoring systems have been developed that now enable the tsunami warning centers to better determine if a tsunami has been generated by an earthquake. These types of new observational sensors make it possible to determine the most appropriate actions to take in the face of a potential threat. For example, in the summer of 2004 NOAA was able to cancel a tsunami warning and save Hawaii residents from a needless evacuation from coastal areas.

Similar to other speakers, Kelly saw the development of the Earth observation system as crucial for his and other agencies' efforts to counter the threat of disaster in the years ahead. Another important tool is the National Integrated Drought and Information System, a drought early warning system led by NOAA. Drought management is an area that requires more coordination between various stakeholders, according to Kelly. He also noted that the public should come to expect the United States to make investments in countering natural disasters that countries of the world collectively face, particularly given the disadvantages that developing countries have in acquiring needed resources to mount their own defenses against such threats.

U.S. Department of Agriculture, Forest Service

David P. Tenny, deputy under secretary for natural resources and environment for the U.S. Department of Agriculture, noted that the Forest Service manages the largest fire fighting organization in the world and that it is a truly premier wild land fire fighting operation. The Forest Service fought forest fires in Southern California in 2003 and in locations such as Arizona, Colorado and Oregon in 2002. According to Tenny, the Forest Service operates in an intergovernmental fashion in the incident management system and has the capacity to rapidly mobilize and deploy in all types of emergency situations. For example, the Forest Service responded to the September 11, 2001, attacks on the World Trade Center and the Pentagon, being one of the first organizations at the sites. Also, following the 2004 hurricanes the Fire Service dispatched 14 incident management teams and four area commands to Florida to help manage the situation—to provide everything from lodging to food and emergency essentials.

According to Tenny, the most urgent challenge that the Forest Service faces is wild land fire (Figure 2). Presently across the United States some 190 million acres of federal land are at an unacceptable level of risk from wild land fire. This is because of missed fire intervals, conditions that have accumulated on the ground that are tremendously difficult to manage and even more dangerous once a fire hits, and because more people have settled near federal lands. Tenny noted that in 2000, in addition to the fire-caused deaths of civilians and fire fighters, over 7 million acres of federal land burned, and 2300 structures and homes were lost. In the fall of 2003, 3600 homes in Southern California burned.

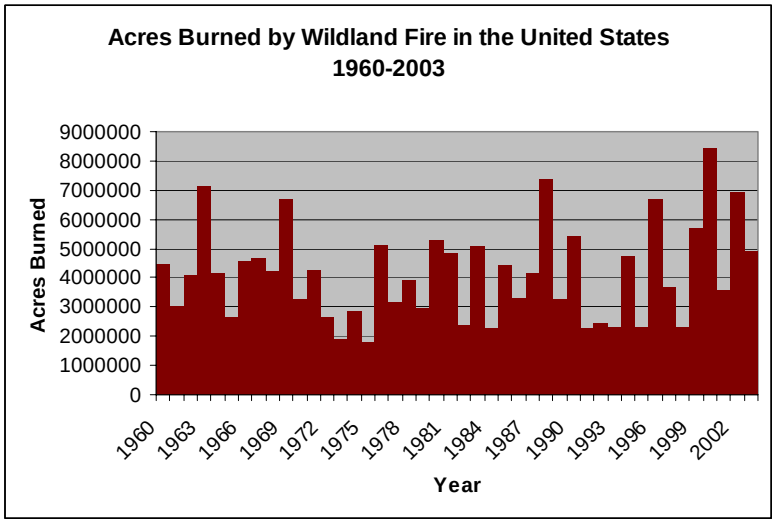

FIGURE 2. Wild land fire is an increasing challenge to the Forest Service. The annual number of acres burned is increasing. The average number of acres has been increasing since 1980, punctuated more frequently by extreme fire years (NRC, 2001).

According to Tenny, the Forest Service is taking a number of essential steps to strategically address wild land fire, including gaining a clear understanding of how natural science can shed light on fire behavior, the utilization of remote sensing technology to identify vegetation types and conditions at a 30 meter resolution, smoke modeling, and resolving practical problems such as the removal of dangerous vegetation. Tenny noted that what the Forest Service wants to accomplish in the future is to arm as quickly as possible both their own officials and their partners with this knowledge and technology so that they can use it to counter the critical wild land fire threat. This action should help further the President's Healthy Forest Initiative, according to Tenny.

Environmental Protection Agency

Paul Gilman, EPA assistant administrator for the Office of Research and Development, noted that while the agency is perhaps best known for its responses to chemical hazardous substances, they have a broader emergency response responsibility, as do many of the other federal agencies. For example, during the shuttle disaster, EPA was given a leadership role in the field recovery efforts. EPA was also deployed along with other federal partners at the World Trade Center disaster. More recently, especially with the increasing focus on homeland security, EPA has engaged in a much more substantial research effort to enhance the tools that emergency responders have in carrying out their consequence management roles in disasters. In doing this, EPA has been trying to take advantage of the fact that a number of the things they do have dual capabilities.

Gilman noted that EPA was engaged in a research effort in Midtown Manhattan at the time of the World Trade Center collapse on September 11, 2001, modeling air movement in an urban landscape. Specifically, they were looking at detailed fine-grained exposure modeling to help understand individual exposure to pollutants. EPA researchers transferred that work to Lower Manhattan to try to understand exposure to the dust from the collapse of the World Trade Center and from the combustion products and the fires that burned thereafter. In doing this EPA was trying to better understand the exposure that came from the actual collapse of the buildings.

According to Gilman, protecting the nation's water supply is part of EPA's mission. The technical challenges in fulfilling this mission include those related to detectors and systems for the detection of environmental contaminants. Computational modeling approaches to understanding the behavior of water distribution systems is key for planning prevention and response actions related to environmental hazards. Decontamination is another focus of the agency's work. EPA has a large responsibility related to such matters as understanding how to decontaminate for a particular pathogen or a particular chemical. Gilman indicated that EPA's benchmark is anthrax because of the recent exposure to it and the challenges it poses.

Prior to the World Trade Center attacks, looking at chronic exposures to pathogens through time had been the primary focus of EPA. Now, however, a big challenge for the agency is taking the risk assessment tools that have been created for more chronic, long-term exposures and improving their use by first responders dealing with rapid onset events. Gilman also noted that EPA and other agencies are increasingly recognizing the importance of the social and behavioral context of disasters for consequence management.

U.S. Geological Survey

The U.S. Geological Survey has broad responsibilities, according to Patrick Leahy, associate director for geology at the agency. Its staff includes biologists, geographers, geologists and hydrologists who focus on such hazards as earthquakes, wildlife disease, specifically those that are vector borne and affect humans; such risks as the West Nile virus and plague, and the impact of geomagnetic storms on the earth. The USGS

engages in long-term monitoring and seeks to improve its observational efforts by using advanced techniques. The agency also seeks to improve its information delivery, according to Leahy.

In terms of successes, the previously mentioned 2002 Denali Fault earthquake received no press to speak of because a disaster was averted when a major offset of the Alaska pipeline occurred without a break in the system. A disaster was avoided because of the application of good science in the construction of a resilient pipeline system, an investment in science that occurred about 20 years ago, said Leahy.

Another important seismic success story happened in 2004 with the occurrence of the Parkfield earthquake, according to Leahy. Even though the earthquake didn't occur until about 20 years after it was predicted by USGS, the resultant instrumentation of the Parkfield area in order to record the predicted earthquake enabled USGS scientists to collect valuable data as the event was happening. These data will provide important scientific insight for understanding earthquake processes.

A success in terms of earthquake information delivery is the development of Shake Map, a new product of the USGS. Within minutes after an earthquake has occurred in some parts of the country, the agency can send out information to stakeholders and the public on the intensity of its shaking.

The actions taken by USGS during the Pinatubo eruption in the Philippines in 1991, which led to the evacuation of Clark Air Force Base and other areas at risk, was another success story for the agency, said Leahy, because it resulted in the saving of many lives and property. The response to the eruption was built on lessons learned during the eruption of Mount Saint Helens in 1980.

Leahy noted that real time stream gauging is a major advancement for USGS. He said that when stream gauging technology originally became available, it was predominantly used for engineering purposes, such as to design bridges. Now emergency managers also use the real time information provided by these instruments to monitor potential floods.

Information technology has not yet reached its full potential for combining both *in situ* and remotely sensed information for disaster reduction and mitigation. According to Leahy, increased investments in this area will yield significant dividends.

Interagency partnerships, as represented by the National Earthquake Hazards Reduction Program (NEHRP), are very important for making progress in disaster reduction, according to Leahy. NEHRP agencies - USGS, NSF, FEMA and the National Institute of Standards and Technology (NIST) - have complementary roles that include basic science activities, engineering, social science and emergency management. It is important that this and other partnerships remain robust, according to Leahy. This includes forging links between such stakeholders as earth scientists, engineers, insurance officials, and emergency managers, and between levels of government. These stakeholders all have important roles to play whether the focus is on earthquakes, landslides, El Nino, or some other type of hazard.

National Aeronautics and Space Administration

The National Aeronautics and Space Administration carries out research on earth system processes using spacecraft in the venue of space, deploying over 100 instruments on approximately 18 satellites that have the capacity to make measurements, according to Ronald Birk, director of the Applied Sciences Program in the agency's Science Mission Directorate. The list of the agency's top successes over the last year have involved collaboration with NOAA to make improved forecasts possible, monitoring air quality in collaboration with EPA, partnering with the Forest Service in wildfire monitoring, and working with a group of agencies that include USGS, NOAA and the Federal Aviation Administration in monitoring volcanic ash that could pose a

threat to airline safety. NASA also carried out important work with USGS related to earthquake forecasting involving the use of geographic information systems.

Birk noted that NASA has several priority areas. One is the continuous or near continuous measurement of surface deformation to enable the prediction of both seismic and volcanic activity through the satellite capability known as Interferometric Synthetic Aperture Radar (InSAR). Other science and technology priorities include observing sea level rise and changes in ice conditions in Antarctica and other locales, better data management related to global earth observations, and improving the monitoring of weather and climate from space for more accurate predictions. According to Birk, these areas provide significant opportunity for coordination with other agencies and stakeholders for the benefit of society.

Department of Homeland Security

When the Department of Homeland Security (DHS) was formed, a significant portion of the federal government's resources for research and development was consolidated under the agency's Science and Technology Directorate, according to Nancy Suski, director of the emergency preparedness and response portfolio in the Science and Technology Directorate. This is the first time in history that there has been a federal agency dedicated to homeland security science and technology. While the initial focus of DHS has been on disasters resulting from terrorist events, particularly weapons of mass destruction, attention is also given to other disasters.

One important activity is the container security initiative, which involves the application of advance science and technology in international settings to track and secure cargo that is bound for the United States Using intrusion detection devices, the agency will have the ability to track and monitor containers during their transport to destinations in the United States, according to Suski.

In terms of urban areas, steps have been taken by DHS to provide the earliest detection possible for biohazards in the atmosphere. The agency has deployed the first area monitoring system for biotoxins called BioWatch, which samples the air on a daily basis in many of the major urban areas in the nation. In the summer of 2004, President Bush signed legislation on Project Bioshield, which is a comprehensive effort to develop and quickly move to market effective drugs and vaccines to protect against biological, chemical or radiological threats. Suski noted that DHS works with other federal agencies on these activities, including the Centers for Disease Control and Prevention, EPA, the Department of Defense, the Department of Energy, and NASA.

Suski indicated that DHS has put in place a robust scientific capability that can provide on demand expertise to federal, state and local officials during times of major disasters. The agency has a specialized on-call capability for helping to resolve radiological hazards with portal monitors that have been installed and radiation pagers that are on police officers and fire fighters. Much more is known now about radiological risks in communities than ever before, according to Suski, and interagency modeling and an atmospheric assessment center have been developed which will serve as the single source of hazards predictions for large-scale airborne events. Suski noted that these developments represent a major success story in federal agency cooperation, raising the capacity of the nation's responders and making vulnerable communities more disaster resilient.

Among the issues that emerged during the questions and discussion period was the need to be concerned with data management, educating the next generation of hazards specialists – both researchers and practitioners - so that there is the required workforce to meet future needs, and the importance of all agencies involved in disaster reduction working together to advance knowledge on hazards and disasters. In terms of

the latter, it was noted that cooperation is already occurring between some agencies and plans are emerging for increased future collaboration.

PERSPECTIVES OF OTHER STAKEHOLDERS ON GRAND CHALLENGES

Following the discussion by federal agency representatives, a panel of experts representing other sectors provided views on challenges and opportunities related to furthering the development of disaster resilient communities in the nation. These stakeholders represented the perspectives of the academic community and the private sector. And because many challenges and opportunities are also found outside the U.S., a few examples from other nations were discussed.

J. Kenneth Mitchell, professor of geography at Rutgers University, noted that we face a new day, not just because 9/11 put terrorism on the disaster management agenda, but also because there have been many other changes in society that call for new responses from physical scientists, social scientists, and technologists. One of the ways the United States can gain perspective on this is to look at how other countries around the world are responding to new imperatives, which is what Mitchell did for 18 months, visiting such countries as Canada, New Zealand, the People's Republic of China, and several European Union countries. In these countries, according to Mitchell, approaches to countering hazards and disasters go well beyond adopting new technologies and involve new policies and re-invented public institutions. In Canada, the focus is shifting from an emphasis on post-disaster relief to disaster mitigation. The bulk of the new proposals in Canada have to do with improving risk assessment procedures, expanding risk education and pioneering new institutional arrangements and partnerships between the public and private sectors, according to Mitchell.

Mitchell suggested that New Zealand has gone considerably further than Canada in terms of institutional innovations. There the government is putting into place a holistic strategy for disaster recovery, one that recognizes the need for combined attention to the recovery of ecosystems and the economy as well as infrastructure, buildings and disaster victims. This strategy makes sustainability the guiding principle for all public actions during recovery. In Mitchell's opinion, the holistic approach and emphasis upon sustainability puts disaster planning in New Zealand ahead of that in the United States

According to Mitchell, the central government in China is actively upgrading its disaster relief and mitigation apparatus so that the country can channel some of the benefits of its rapid economic development into opportunities to transition from the current pattern of high disaster death tolls to low ones. Mitchell noted that in Europe the basic task is to initiate a continent-wide integrated hazard response strategy for a vastly expanded European Union. Improved education and communication is at the heart of the new policy in Europe because leaders have embraced the notion that the first task of government is to manage various kinds of threats to human welfare.

According to Mitchell, these four examples suggest a common trend towards very broad analyses of emerging disaster problems, analyses that situate science and technology in the context of wider debates about appropriate policies for the environment and society and put the matter of institutional redesign right at the center of public investments for the new century. He suggested that this kind of broad consideration about future hazards management has yet to take place in the United States, although it is needed. This would involve such matters as how to balance investments to meet mitigation and emergency response requirements. Mitchell also noted that the United States should give attention to vulnerability as well as risk, which could have the result of directing hazard investments toward the needs of under served groups that are the most vulnerable to disasters.

Llyod Cluff, director of the geosciences department at the Pacific Gas and Electric Company (PG&E), noted that the grand challenge initiative is a very important one, especially with the involvement of OSTP, an agency with significant authority and which was crucial in the creation of the successful NEHRP. He suggested that implementation is a key to developing disaster resiliency, and it is expedited when researchers involve potential users in a process of information exchange at the earliest possible time. This can reduce the length of time it takes to apply crucial research results and thereby promote resiliency, from years to a month in some cases. Cluff noted that the Alaska pipeline case previously referred to by other speakers is an example of the effective application of earth science and earthquake engineering knowledge for the benefit of society. The fact that decision makers with the help of scientific and technical experts like him agreed to design an earthquake resilient infrastructure system saved millions of dollars and avoided untold environmental losses following the Denali earthquake. Cluff also noted that investments by public/private partnerships in California involving such organizations as PG&E and the California Department of Transportation have resulted in the application of scientific knowledge to further societal resilience.

Stephen P. Leatherman, director of the International Hurricane Research Center at Florida International University, referred to Florida's significant vulnerability to hurricanes, which was reflected in the impact that four major hurricanes had in the state in 2004. A large migration into the state of people with no previous hurricane experience and the widespread use of manufactured homes subject to high rates of wind damage contributes significantly to this vulnerability, according to Leatherman. He noted that there were some improvements in the safety of manufactured homes after Hurricane Andrew in 1992 when better standards of performance were set by the state. While hurricane property losses have been great over the years in Florida, loss of life has been remarkably low in contrast to the experience in such developing countries as Haiti.

Leatherman noted that there was significant improvement in the response to the 2004 hurricanes over the response to Hurricane Andrew. For example, according to Leatherman there was a coordinated federal and state response, with FEMA working well with the Florida Division of Emergency Management, and billions of dollars in supplemental funding provided by the federal government to help cover emergency needs. Nevertheless, Leatherman suggested that more attention needs to be given to funding research and mitigation efforts, whose value the public often fails to appreciate because the outcomes they produce tend not to be well documented. Thus disaster mitigation is a difficult investment to make and the agencies need to find a way to measure the value of mitigation in order to gain public support for it. Leatherman indicated that he is hopeful that more investments in wind research and wind hazard mitigation will be forthcoming with the passage of the National Windstorm Impact Reduction Act of 2004 to establish a National Windstorm Impact Reduction Program. He expressed hope that this activity will be as successful in developing strategies for countering wind hazards as NEHRP has been for almost 30 years in countering earthquake hazards.

Nicholas P. Jones, dean of engineering at Johns Hopkins University, also expressed enthusiasm for the recently passed wind bill. He indicated that if the new wind program leads to significant investments by government in relevant activities, it could spur sustainable solutions to wind hazards. Jones indicated that leadership from the federal agencies could make this happen, resulting in needed collaborative work that puts technical solutions in the context of such issues as risk communication, implementation and the education of the next generation of professionals, both researchers and practitioners.

Jones noted that the wind community has divided the wind hazard problem into four areas: understanding the wind hazard, reducing the impact of the hazard, enhancing community resilience, and education and outreach. Attention needs to cover all of these important areas in order to effectively deal with the problem, according to Jones. This requires a multidisciplinary approach, including input from the social sciences as well as engineering. And in wind engineering, attention should be directed at understanding the performance of a range of structures under wind loads, from the more visible and sophisticated ones such as long span bridges to non-engineered and low-rise construction like homes.

According to L. Thomas Tobin, principal of Tobin & Associates, a consulting firm that works in the hazards field, mitigation is the key grand challenge, and this requires putting to work, especially at the local level, what is already known. While the federal government has a major role in making America more disaster resilient, key decisions regarding hazards are made at the local level. Tobin said that this requires the establishment of a more effective process which will further the implementation by local authorities of vital hazard-related knowledge and technology developed under the sponsorship of the federal government. At present, there is a huge gap between available hazard reduction knowledge and tools and their utilization by responsible state and local authorities. Reducing this discrepancy requires significant financial and time investments on the part of federal agencies, according to Tobin.

Tobin also suggested that the agencies need to make investments at the international level, particularly in the more vulnerable developing countries. Since the United States is such a wealthy nation, there is a moral imperative for such actions, according to Tobin. He also noted that sharing our knowledge and science and technology related to natural hazards and working internationally is not only important from a humanitarian perspective but is also in the best interest of the United States in that it creates a better world and can serve as a basis for improving foreign relations.

Thus Tobin suggested that federal agencies and other stakeholders should think both domestically and internationally with regards to where investments to further disaster reduction should be made. And such investments should be accompanied by systematic evaluations of the projects undertaken, focusing on such issues as their value in terms of raising public awareness and achieving mitigation goals.

In the questions and discussion period following the panel presentations, the issues that emerged included the need to break down barriers between levels of government so that more effective disaster reduction actions can take place, the imperative to take population dynamics into account in disaster planning, and the importance of information dissemination and technology transfer in confronting hazards.

THE WAY FORWARD:

FEDERAL AGENCY COORDINATION AND COLLABORATION

Building on remarks made by earlier speakers on grand challenges in science and technology related to hazards, Helen Wood, NOAA's senior advisor for satellites and information services and chair of the SDR, gave an overview of the process to development the federal government's investment strategy to create a more disaster resilient nation. She noted that the SDR, under the direction of OSTP, is spearheading this effort and that the Disasters Roundtable workshop provided an important venue for the agencies to reach out and obtain the perspectives of external stakeholders, such as those in academia and the private sector.

The SDR, which is intended to further interagency interaction on hazards and disaster issues, has been in existence for 16 years and has representation from 23 federal entities. Agency representatives are appointed by high-level officials and are expected to share program information, plan cooperative activities, and help enhance agency coordination. Wood noted that the message was clear from the White House that the SDR and other entities in the National Science and Technology Council were expected to coordinate and integrate programs, avoid duplication of effort wherever possible, and provide sound advice on science and technology policy issues.

Wood made it clear that the SDR is looking at needed hazard-related investments in a holistic fashion covering a range of scientific and technical areas, including the social and behavioral sciences. The upcoming

report from the SDR titled *Grand Challenges for Disaster Reduction* will present the SDR's six grand challenges for disaster reduction and provide a framework for prioritizing the related federal investments in science and technology. It will also focus on multiple hazards, and will consider the roles of various stakeholders, from federal agencies to local authorities.

GRAND CHALLENGES AND PUBLIC/PRIVATE PARTNERSHIPS

Robert Hamilton, recently retired from the National Research Council, compared the tasks before the federal agencies relative to grand challenges to experiences in which he was involved during the United Nation's International Decade for Natural Disaster Reduction (IDNDR) activity in the 1990s. Hamilton noted that the IDNDR appointed a scientific and technical committee in the early 1990s that identified goals which each participating nation should attempt to reach: (1) a risk assessment for all the hazards that threaten it, (2) a plan to mitigate those hazards, and (3) the establishment of a warning system to get those in danger out of harms way. Such goals were largely scientific in nature, but later more attention was given to broader social and political issues relevant to implementation, which was reflected in a change in the nature of the scientific and technical committee with the addition of more non-technical stakeholders as members. Towards the end of the IDNDR in 1999, the scientific and technical committee identified five challenges to the achievement of the three goals: (1) integrated risk management and vulnerability reduction, (2) population concentrations and urban hazards, (3) environmental and resource vulnerability, (4) disaster prevention capabilities of developing countries, and (5) coordination and implementation. According to Hamilton, these five challenges are complex but reflect the realities of the linkages between the scientific and technical sectors and the social and political sectors, a perspective that many at the workshop have embraced based on earlier discussion.

Hamilton noted that if we are to be successful in disaster reduction in the United States it is clear that a process is needed to link the various sectors with a stake in it, from the experts with the specialized knowledge to the people who are impacted by disasters. He admitted having a degree of pessimism when it came to determining what this might mean with respect to public/private partnerships. However, he saw some hope in the approach used in the development of model building codes in the United States, which involves the drafting of and voting on potential code measures by stakeholders from public and private groups, including those in the building industry, government, and academia. Once developed, such model codes can be considered for adoption by communities and government authorities, with the aim of furthering disaster reduction. Hamilton saw the model code process as an exemplar of effective public/private cooperation and suggested that the approach could offer much benefit if used to solve other challenges to making the nation more disaster resilient. He noted that some of the promising candidate areas for employing a public/private process similar to that used for model building codes include developing standards for risk based insurance premiums, developing strategies for using cell phones for disaster warning, and developing model land use practices.

During the questions and discussion period, the centrality of OSTP and SDR leadership in furthering the nation's disaster reduction agenda was commented on. It was also mentioned that there has been significant public/private cooperation in the area of extreme weather warnings, for example involving the government and private media organizations.

After making announcements about future Disasters Roundtable workshops, William Hooke, chair of the DR, declared the workshop adjourned.

REFERENCES

National Research Council (NRC). 2001. To Burn or Not to Burn: Summary of the Forum on Urban and Wildland Fire, January 26, 2001. National Academies Press. Available on http://books.nap.edu/html/tbntb/report.pdf.

National Research Council (NRC). 2004. Hazards Watch: Reducing the Impact of Disasters Through Improved Earth Observations. Summary of a Workshop, October 22, 2003. National Academies Press: Washington, D.C. Available on http://books.nap.edu/html/ndr/hazards_watch.pdf.