Reducing the Impacts of Natural Hazards

A Strategy for the Nation

A Report by the
Committee on Earth and Environmental Sciences
Subcommittee on Natural Disaster Reduction

May 1992

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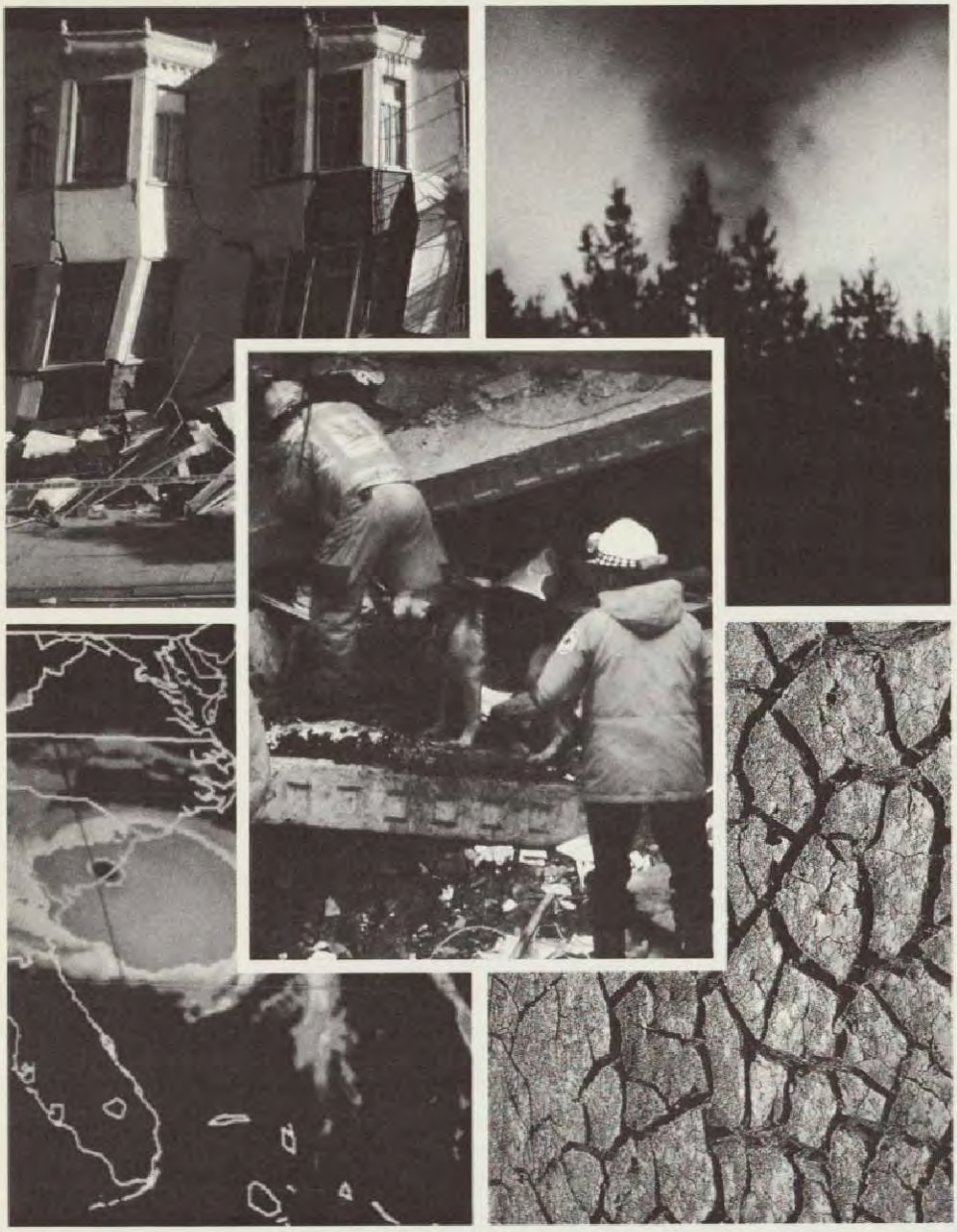

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May 1992

Office of Science and Technology Policy

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We are pleased to release "Reducing the Impacts of Natural Hazards: A Strategy for the Nation," a report by the Committee on Earth and Environmental Sciences (CEES) of the Federal Coordinating Council for Science, Engineering and Technology (FCCSET).

Natural disasters occur each year throughout the United States and the world, exacting a heavy toll in human suffering, property loss, and destruction of natural resources. The strategy we are releasing is for Federal agencies to reduce the effects of natural hazards by integrating existing programs with innovative, interagency, multidisciplinary, international approaches to disaster reduction. In this spirit, we join with others to make a safer, more productive Nation and world. The activities outlined in this report are consistent with the goal and objective of the U.N. International Decade for Natural Disaster Reduction (IDNDR) underway now. This strategy we are releasing represents the U.S. contribution and effort to participate in the IDNDR.

Unique among the CEES programs, this effort is not limited to scientific research but includes operational elements and agencies not typically part of the FCCSET process. The program recognizes that—like emergency response and recovery—prevention, preparedness, and mitigation also take place at the State and local levels and that to achieve the goal of reducing loss of life, damage to property and natural resources, and social and economic disruption, the Nation must move from a reactive mode, in which we clean up after hazards strike, to an anticipatory mode of preparing in advance in order to reduce the impact.

The report presents a balanced strategy of research and applications for reducing natural disasters first by better application of what we already know about the nature of hazards and second by identifying areas in which continued or expanded research is likely to help achieve the goal. It recommends a series of demonstration projects aimed at transferring our knowledge of integrated hazard mitigation to State and local officials while at the same time helping to increase the resilience of localities to natural hazards.

Several years of effort on the part of senior government officials, private sector individuals, and academic scientists are reflected in this comprehensive approach. The CEES Chairman, Dr. Frederick M. Bernthal, and the interagency membership of the Committee and its Subcommittee on Natural Disaster Reduction have done an excellent job and are to be commended.

Marilyn Tucker Quayle
Special High Level Council Member
IDNDR

D. Allan Bromley
Director

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Reducing the Impacts of Natural Hazards

A Strategy for the Nation

EXECUTIVE SUMMARY

Natural hazards such as earthquakes, volcanic eruptions, hurricanes, wildfire, or drought strike nearly every part of the United States and much of the world, exacting an unacceptable toll of life, property, natural resources, and economic and social well-being. In recent years, great disasters have struck in Armenia, Bangladesh, Italy, the Middle East, Central America, and elsewhere around the Pacific Rim.

The United States has not been immune. In 1989, Hurricane Hugo claimed dozens of lives and caused nearly $10 billion in damages. Since then, Hurricane Bob and other storms have ripped the Atlantic coast. The Loma Prieta earthquake of 1989 caused comparable losses; a string of California earthquakes in April 1992 serve as reminders of continued vulnerability. The Santa Barbara wildfire of 1990 was overshadowed by the Oakland wildfire of 1991. The 1991 Mount Pinatubo volcanic eruption occurred halfway around the world but cost the United States some $1 billion and combined with political forces to alter the U.S. strategic presence in the Pacific, perhaps forever.

Natural hazards, no matter how violent, need not result in natural disasters—devastating, persistent disruptions of entire communities. Much of the loss of human life and economic catastrophe can be prevented by cost-effective

governmental action. Still, we spend too much recovering from disasters and too little preventing them. The United States has many opportunities to take value-priced precautions now to prevent much greater damage in the future—to protect our citizens, lifelines, environment, industries, commerce, and national security.

This report presents a proposed Federal strategy for reducing the impacts of natural hazards. It presents a strategic framework that identifies opportunities for domestic and international cooperation and describes Federal activities and expenditures to reduce the effects of natural disasters.

Strategic Goal

The goal presented in this report is to reduce fatalities, human suffering, environmental damage, and economic losses caused by natural hazards.

Federal Strategy

The Federal strategy to reduce the occurrence and impacts of natural disasters calls for efforts in three key areas:

- **Research**: Using science and technology to understand the physical and biological nature of natural hazards, to improve engineering and managed environmental systems, and to advance knowledge from the social and health sciences to reduce the impacts of disasters on society.

- **Applications**: Accelerating the transfer of science and technology into operational practice and thereby improving our ability to take effective action before, during, and after natural hazards strike.

- **Domestic and International Cooperation**: Working together—domestically (with State and local govern-

ments and the private sector) and internationally (with other governments and nongovernmental organizations)—to gain new knowledge; to put into practice the knowledge that exists; to improve the scientific and technological basis for decisionmaking and action; to communicate hazard and risk information; and to demonstrate the power of a proactive rather than a reactive approach to disaster reduction by developing, implementing, and evaluating special cooperative projects.

The U.S. strategy will advance science and technology, hazards prevention and mitigation practice, and coordination well into the 21st century.

U.S. STRATEGIC FRAMEWORK FOR NATURAL DISASTER REDUCTION

The strategic framework emphasizes the research and applications needed to reduce the occurrence and negative impacts of natural disasters. The proposed cooperative projects identify opportunities for domestic and international cooperation and serve as models for other local, regional, national, and international activities.

The strategic framework (figs. 1, 2, 3) is described in terms of:

- Strategic Priorities
- Integrating Priorities
- Research and Applications Elements

The Strategic Priorities, related to the goal, define the overall philosophy and approach and serve as yardsticks against which proposed activities can be evaluated. The priorities are to:

- **Anticipate Hazards Rather Than React to Disasters.** Anticipation must be emphasized over reaction, and avoidance and mitigation strategies must be adopted to reduce the impacts of natural hazards and to prevent unnecessary costs and losses during and after a disaster.

- **Advance Scientific Knowledge and Application of Research Results.** The occurrence and impacts of natural hazards can be lessened through advances in scientific and technological knowledge and applications of that knowledge to natural disaster reduction.

- **Build On and Increase Efficiency and Coordination of Federal Hazard Programs.** The critical importance of collaboration and coordination among Federal agencies must be recognized to achieve the strategic goal.

- **Increase Sharing and Coordination Domestically and Internationally.** Information must be shared and activities coordinated with State and local governments, public institutions, nongovernmental entities, international organizations, and the governments of other nations.

The Integrating Priorities define a generic set of steps needed to prevent or mitigate any natural hazard. These priorities are to:

- **Observe, Characterize, and Predict Natural Hazards.** Studies of natural hazard occurrence and character, severity-frequency relations and causal linkages, precursors, and triggering mechanisms are needed to reduce the serious uncertainties in current predictions. Increasingly, interactions between hazards must also be considered.

- **Assess Actual and Acceptable Risk.** Risk is the product of hazard, value (for example, of the population, property, natural resources), and vulnerability to injury or damage. When risk is higher than what is acceptable to citizens and policymakers, measures are needed to reduce that risk.

- **Develop Options for Risk Reduction.** Risk can be reduced by a variety of social, engineering, and natural resource management measures, including warnings, evacuation, strengthening of buildings and lifelines, and adoption of special forest or agricultural practices.

- **Implement Risk-Reducing Measures.** Measures that achieve the greatest reduction of risk for the lowest social and economic cost need to be chosen and implemented.

- **Learn from Disasters.** Disaster reduction is an iterative process in which observations of each major occurrence of a hazard and the success of the human response to it are fed back into the data base from which predictions, risk assessments, and choices of risk reduction are made.

The Research and Applications Elements are the implementation-level elements in the U.S. strategy for natural disaster reduction.

Research Elements

The Research Elements (figs. 1, 2) are divided into three different groups:

- Physical and Biological Nature of Hazards
- Managed Systems
- Human Interactions

Physical and Biological Nature of Hazards research addresses the need to improve predictions of the time, place, severity, and intensity of natural hazards by understanding the underlying physical and biological processes. The elements are:

- Climate, Weather, and Hydrologic Systems
- Solid Earth Processes
- Ecosystem Processes

Managed Systems research will develop the knowledge and technological capability to manage the impacts of natural hazards. The elements are:

- Engineering Systems
- Managed Environmental Systems

Human Interactions research will enhance our knowledge of the social, health, institutional, and economic processes affecting the impacts of natural disasters on society. The elements are:

- Behavior, Health, and Communication
- Institutional Opportunities and Constraints
- Economics

Applications Elements

The Applications Elements (fig. 3) place a major emphasis on the application and dissemination of research results—translating what we know of hazards and their mitigation into operational practice. There is a logical order of applications in time:

- Before a Natural Hazard
- During a Natural Hazard
- After a Natural Hazard

Before a natural hazard strikes, important preventive and mitigative measures must be taken to reduce losses and enhance recovery. In addition, accurate, reliable, and timely prediction and warning systems are necessary to protect communities. The elements are:

- Preparation
- Prediction and Warning

During a natural hazard event, actions can be taken to reduce its impact through coordinated Federal, State, and local suppression and control efforts. The element is:

- Intervention

After a natural hazard strikes, both immediate and long-term measures can be taken to revitalize the damaged community and maximize its resistance to future disasters. The elements are:

- Emergency Assistance
- Recovery

Although each Applications Element is needed in time, it is almost always better to anticipate and thereby avoid natural disasters rather than to react to them after they have stricken a community. The adage "An ounce of prevention is worth a pound of cure" applies to natural disasters in force, and the greatest savings of life and property during the 1990's are likely to be the result of giving greater emphasis to preparation, prediction and warning, and intervention and thereby reducing the costs of emergency assistance and recovery.

Special Cooperative Projects: U.S. Strategy for Natural Disaster Reduction

A strong U.S. strategy needs major, integrating projects, built on existing activities, that reduce losses from the occurrence of natural hazards. We recommend four categories of special cooperative projects:

- **Natural Hazard Prediction Experiments:** Research in selected natural laboratories to improve the scientific basis of and methods for predicting natural hazards.

- **Disaster Prevention Resource Networks:** Sharing information, people, and equipment, regionally and nationwide, to prevent and mitigate disasters.

- **Hazard-Resistant Communities:** Intensive application of disaster mitigation techniques to demonstrate how communities can increase their resistance to disasters.

- **Natural Hazards Round Tables:** Thought-provoking forums to ensure that various parts of the hazards community learn from one another.

Projects in the first category are predominantly research. Projects in the second and third categories are mainly applications of knowledge with research, as needed, in engineering and in both the natural and social sciences. The fourth category emphasizes the sharing of ideas and information.

Each project provides opportunities for integrating the progress made in individual Research and Applications Elements and for testing and evaluating, before full-scale implementation, proposed changes in disaster prevention and mitigation practices.

The Subcommittee on Natural Disaster Reduction (SNDR) developed this strategy under the auspices of the Committee on Earth and Environmental Sciences (CEES). CEES is a Committee of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), under the direction of the President's Science Advisor.

The U.S. strategy takes into account related Federal activities coordinated by other CEES subcommittees and working groups. The strategy will yield benefits far in excess of the costs, leading to significant reductions in unbudgeted Federal outlays for disaster relief and recovery, costly replacement of damaged buildings and other structures, disruption of daily commerce, and threats of insurance industry collapse.

Conservative estimates of the average annual costs and losses from natural disasters in the United States exceed $6 billion. In 1989, they exceeded $15 billion. These figures by

no means capture the costs of environmental degradation, short- and long-term recovery and rehabilitation, impacts on local and regional economies, and the intangible costs to human health and well-being caused by natural disasters. In comparison, Federal expenditures for natural disaster activities in FY 1990 exceeded $2.5 billion. In FY 1990, 4 percent of the focused dollars are devoted to research and 96 percent to applications.

The Fundamental Challenge

Natural disasters occur each year throughout the United States and the world, exacting a heavy toll in human suffering, property loss, and destruction of natural resources. The 1990's are a challenge to advance our understanding of hazard processes and predictability, to reduce mismatches between risk and preparation, and to control losses through engineering, natural resource management, and other socially responsible and cost-effective measures. It is a challenge to prevent natural hazard events from becoming natural disasters.

The basic strategy is for Federal agencies to integrate existing programs with innovative, interagency, multidisciplinary, international approaches to disaster reduction. In this spirit, we join with others to create a safer, more productive Nation and world. These U.S. activities are consistent with the objective and goal of the U.N. International Decade for Natural Disaster Reduction (IDNDR) now underway.

INTRODUCTION

The Challenge: A World at Unnecessary Risk

We live on a changing, violent planet. The continents themselves "drift," signaling their motion through cataclysmic earthquakes and volcanic eruptions. Climate variability reflects the unending competition between hurricanes and other severe storms on one hand and scorching, blistering episodes of heat and drought on the other. These swings trigger outbreaks of wildfires and pestilence, which in turn produce dramatic shifts in the ecological balance. Lasting no more than a few tragic moments, tsunamis can redefine the coastlines of the world.

In the face of these and other natural hazards, individuals and nations struggle to achieve two very simple goals—to live free and to live well. But all too often, natural hazards take advantage of human exposure and frailty to produce natural disasters—devastating, lingering disruptions of entire communities. They inflict death and human suffering, property damage and economic loss, and destruction of natural (particularly renewable) resources, not just on a few individuals but on entire cities, regions, or nations.

In the United States, urbanization, the migration from the heartland to the coasts, a global strategic role, economic development, and technological advances sometimes combine to increase exposure to disaster. In 1989, Hurricane Hugo and the Loma Prieta earthquake together caused at least $15 billion in damages. In that same year, an eruption of the Mount Redoubt Volcano threatened Alaska's historically important role in transpolar air travel. In 1990, a single hailstorm in Denver caused $1 billion in property damage, and the drought-induced Santa Barbara wildfire caused a quarter of a billion dollars in property damage,

damaging or destroying 4,900 acres of wildland and 535 housing units and businesses (table 1). Interlocking, technology-dependent systems of communication, transportation, banking, and defense, among others, are increasingly vulnerable to natural hazards. Losses rise still higher when we include the costs of environmental damage, indirect losses to local and regional economies, and intangible social and human costs. For example, the 1991 Mount Pinatubo eruption, although not within U.S. political or geographic boundaries, may significantly impact U.S. global strategic interests in years to come and in ways that exceed mere dollar figures.

Developing nations, which are the least able to recover from disasters, are also the least prepared and protected and, as a result, suffer the greatest devastating impacts. In the past 40 years, nearly 20 events have killed over 10,000 people each. Two—a flood in Bangladesh and an earthquake in China—each claimed more than a quarter of a million lives. More recently, in a well-publicized event, Bangladesh lost more than 140,000 lives through floods. What is not so widely recognized is that, on the average, Bangladesh loses more than 100,000 people to natural disasters every year. In fact, many developing countries like Bangladesh find such events so frequent and so devastating that their economic development is constrained, their social stability is undermined, and their hopes and aspirations are diminished. Although natural hazards are inevitable, natural disasters need not be. An earthquake or storm or drought of brief duration and limited geographic extent need not result in devastating, widespread, persistent human impact. Example after example has demonstrated that, through effective action, it is possible to reduce the impact of natural hazards on everyday human experience. Indeed, expenditures for disaster prevention are repaid several times over in savings of unbudgeted disaster relief and recovery expenses. Despite considerable effort, the science and practice of natural disaster reduction still vary from region to region and nation to nation. Even though the 1988 Armenian and

Table 1. Recent natural disasters in the United States

Hazard	Human suffering	Damages/economic losses
HURRICANES		
Hurricane Hugo (1989)	• 49 fatalities • 300,000 families affected	• $9 billion in damages • 8,800 mi^2 of downed timber (7 times the size of Rhode Island)
WILDFIRES		
Santa Barbara, Calif. (1990)	• 1 fatality • 40 injuries	• 535 housing units and businesses lost • $235 million in damages • 4,900 acres of wildland burned
EARTHQUAKES		
Loma Prieta, Calif. (1990)	• 13 fatalities • 3,757 injured • 12,000 displaced • 6 million affected	• $6 billion in damages
FLOODS		
South-Central United States (1990)	• 13 fatalities	• Excess of $1 billion in damages
VOLCANOES		
Redoubt Volcano, Alaska (1989–90)	• 244 persons on jumbo jet that nearly crashed	• $80 million damage to aircraft • Over $20 million in other losses, including oil production
LANDSLIDES		
Annual estimate	• 25 fatalities	• $1.5 to 2.5 billion in damages • Unaccounted losses to forests and fisheries
TORNADOES		
Chicago, Ill., area (1990)	• 27 fatalities • 350 injuries	• Over $165 million in damages • 364 homes destroyed
DROUGHT[1]		
Central United States (1988)	• Numerous fatalities from heat effects	• $40 billion in losses

[1]The estimated impacts of drought are disproportionately larger than those of other disasters listed, demonstrating the pervasive and widespread nature of drought.

1989 Loma Prieta earthquakes were of comparable physical violence, the former killed 20,000 people, whereas the latter killed fewer than 100. Although preparation exceeding risk may waste community resources, risk exceeding preparation leads to disaster.

These facts—natural hazards facing the United States and the world, mounting losses of life and property, an imperfect but advancing understanding of hazard processes and predictability, mismatches between risk and preparation, and great potential for controlling losses through mitigation, engineering, and natural resource management—are the challenge to all who are at risk or who work to minimize losses from natural hazards.

The Response: International Decade for Natural Disaster Reduction

In 1984, Frank Press, President of the National Academy of Sciences, proposed an International Decade for Natural Hazard Reduction. In 1989, the United Nations (U.N.) General Assembly declared 1990 through 2000 A.D. as the International Decade for Natural Disaster Reduction (IDNDR), a period of concerted international action to reduce loss of life and property and to reduce social and economic disruption caused by natural disasters, especially in developing countries. The goals of such action, as stated by the U.N., are to:

- Improve the capacity of each country to mitigate the effects of natural disasters.
- Apply existing scientific and technological knowledge.
- Foster advances in science and engineering.

- Disseminate new and existing technical information.

- Develop measures for the assessment, prediction, prevention, and mitigation of natural disasters through technical assistance and technology transfer, demonstration projects, education and training, and evaluation of program effectiveness.

Each member nation was urged to develop a national program for the IDNDR that, together with others, would constitute the core of the IDNDR effort.

The U.S. Congress passed resolutions calling for U.S. participation in the Decade. Within the Executive Branch of the Federal Government, the President's Science Advisor requested that the Committee on Earth and Environmental Sciences (CEES), of the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET), recommend appropriate U.S. action. This proposed strategy, which builds on existing Federal programs and activities, is aimed mainly at reducing the domestic impact of natural hazards but will also contribute to the IDNDR.

THE PURPOSE OF THIS REPORT

This report, prepared by the CEES Subcommittee on Natural Disaster Reduction (SNDR), outlines the proposed U.S. (Federal) strategy for reducing the impacts of natural hazards and also for contributing to the International Decade for Natural Disaster Reduction. It presents the strategy in a framework that identifies opportunities for domestic and international cooperation and describes Federal activities and expenditures (FY 1990) to reduce the effects of natural hazards.

The strategy takes into account related Federal activities coordinated by other CEES subcommittees and working groups, including the Subcommittee for Atmospheric Research, the Subcommittee for Water Resources, the Subcommittee on Global Change Research, and the Subcommittee on Environmental and Natural Resource Economics. The strategy will yield benefits far in excess of its costs. In particular, it will lead to significant reductions in unbudgeted Federal outlays for disaster relief and recovery, costly replacement of damaged buildings and other structures, disruption of daily commerce, and threats of insurance industry collapse. Additional benefits will also accrue directly to communities across the Nation.

SCOPE OF THE U.S. STRATEGY FOR NATURAL DISASTER REDUCTION

The task of reducing losses from natural hazards is broad and pervasive, touching every aspect of American life. To overcome the limitations of existing hazards programs and to realize the opportunities of the 21st century while working within realistic fiscal constraints require that we define the scope of the proposed strategy for the Nation.

Programmatic Scope

The Federal strategy to reduce the occurrence and impacts of natural disasters calls for efforts in three key areas:

- **Research**: Using science and technology to understand the physical and biological nature of natural hazards, to improve engineering and managed environmental systems, and to advance the social and health sciences needed for disaster reduction.

- **Applications**: Accelerating the transfer of science and technology into operational practice and thereby improving our ability to take effective action before, during, and after natural hazards strike.

- **Domestic and International Cooperation**: Working together—domestically (with State and local governments and the private sector) and internationally (with other governments)—to put into practice the knowledge that exists; to improve the scientific and technological basis for decisionmaking and action; to communicate hazard and risk information; and to demonstrate the power of a proactive rather than a reactive approach to disaster reduction by the development, implementation, and evaluation of special cooperative projects.

Although disaster reduction includes some elements of direct Federal assistance to citizens (for example, warnings of approaching hazards), much of the work is done by State and local government leaders and by the private sector. The Federal effort will provide knowledge and tools for hazards mitigation and disaster prevention that can be used by States, local communities, and individual citizens.

Topical Scope

The strategy will address the following hazards, most of which are targeted in the U.N. program for the IDNDR: earthquakes, floods, volcanic eruptions, wildfires, drought, hurricanes and other severe windstorms, landslides, tsunamis, and insects and diseases (pestilence).

Geographic Scope

Most of the science and applications activities and the special projects, done in cooperation with States, local governments, and the private sector, apply to the United States but have significant international components. To improve and share the lessons of the cooperative projects, we will encourage exchanges between U.S. projects and those of other countries.

Duration

The IDNDR began in 1990 and will end in 2000 A.D. The U.S. strategy will operate during the same period but will aim for advances in science, technology, disaster prevention and mitigation practice, and coordination that will extend well into the 21st century.

THE U.S. STRATEGY FOR NATURAL DISASTER REDUCTION

Strategic Goal

The impacts of natural hazards will continue to increase unless the United States and other nations in the world community take concerted action. The reasons are clear. Our physical, economic, and social well-being is increasingly at risk as the population grows and concentrates in hazard-prone areas; as capital development expands and technological advances create new and unexpected impacts; as the large number of buildings, critical facilities, and lifelines remain vulnerable to natural hazards; and as the interdependence of individuals, communities, and nations continues to grow (Advisory Committee on the International Decade for Natural Hazard Reduction, 1987).

The U.S. strategic goal is to reduce fatalities, human suffering, environmental damage, and economic losses caused by natural hazards. To reduce the occurrence and impacts of natural disasters requires efforts in three areas: research, applications of new and existing knowledge, and domestic and international cooperation. These three areas were identified by the 1987 National Research Council's Advisory Committee on the International Decade, the 1989 U.N. Declaration, and the U.S. National Committee for the Decade as being critical to the success of the Decade and beyond into the 21st century.

The framework for the U.S. strategy emphasizes the research and applications needed to reduce the occurrence and impacts of natural disasters. Drawing together research and applications to reduce vulnerability to natural disasters, the proposed demonstration projects identify opportunities for domestic and international cooperation and serve as models for other local, regional, national, and international activities.

Framework

The framework provided here generally follows a form initially developed by CEES to focus and integrate multidisciplinary and multiagency efforts. It includes:

Strategic Priorities related to the strategic goal (fig. 1), which define the overall philosophy and approach and serve as yardsticks against which proposed projects can be evaluated.

Integrating Priorities (fig. 1), which define a generic set of steps needed to prevent or mitigate any natural hazard.

Research and Applications Elements (figs. 2, 3), the implementation-level, highest-priority elements in the U.S. strategy.

Although each of the elements displayed requires increased attention, natural disaster reduction can be achieved only if all these efforts are advanced in a balanced, coordinated manner.

This framework differs, however, from other FCCSET frameworks in some important respects. The latter were developed to deal with challenges unprecedented in human experience, caused by human alteration of natural global variability. For this reason, few preexisting Federal or international mechanisms were available or needed to be taken into account. The programs could focus on research alone, establishing the scientific basis for policy formulation. Moreover, it was natural for Federal and international agencies to take the lead.

However, because natural disasters have always been a part of the human experience, numerous Federal and international mechanisms already exist for coping with them, organized for the most part along hazard-specific lines. These mechanisms include both research and operational

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- Learn From Disasters

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Figure 1

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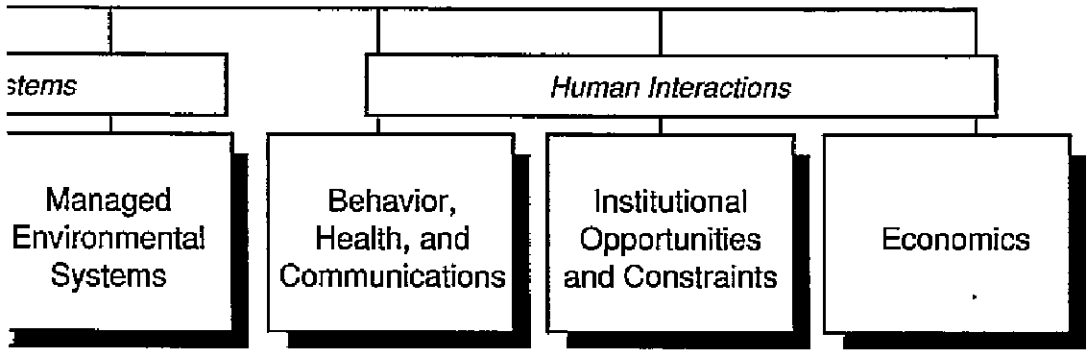

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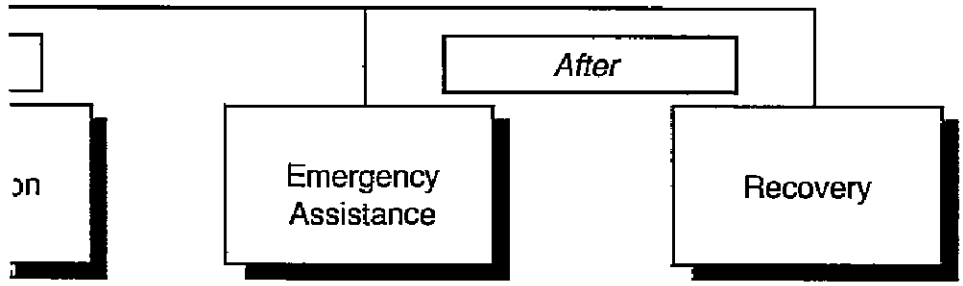

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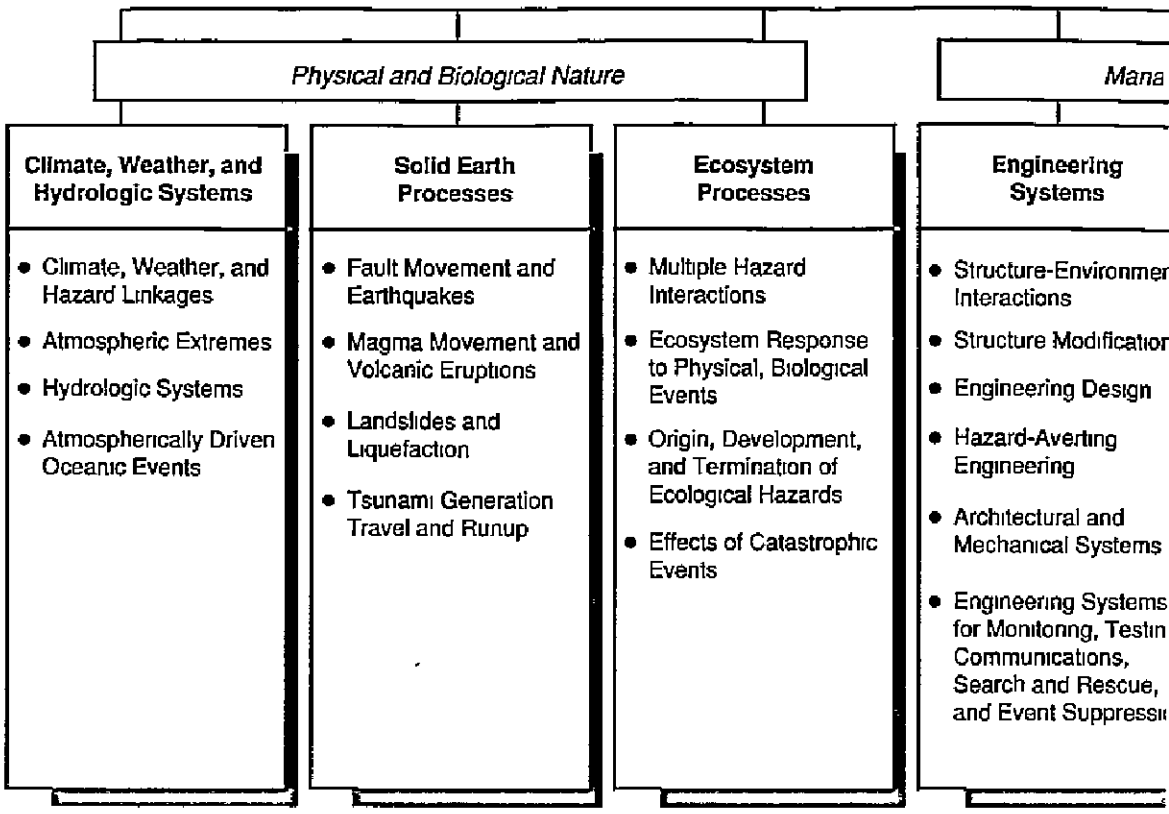

Figure 2

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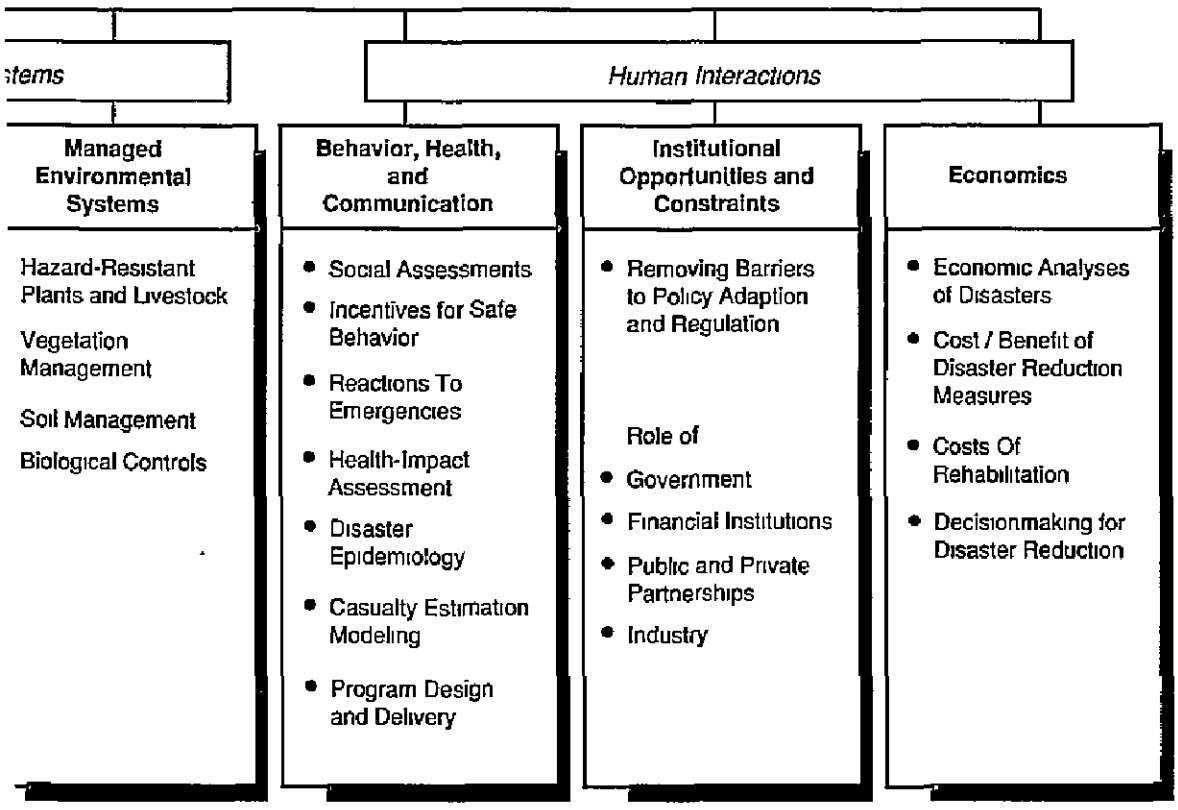
stems
Human Interactions
Managed Environmental Systems
Hazard-Resistant Plants and Livestock
Vegetation Management
Soil Management
Biological Controls
Behavior, Health, and Communication
Social Assessments
Incentives for Safe Behavior
Reactions To Emergencies
Health-Impact Assessment
Disaster Epidemiology
Casualty Estimation Modeling
Program Design and Delivery
Institutional Opportunities and Constraints
Removing Barriers to Policy Adaption and Regulation
Role of
Government
Financial Institutions
Public and Private Partnerships
Industry
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Economic Analyses of Disasters
Cost / Benefit of Disaster Reduction Measures
Costs Of Rehabilitation
Decisionmaking for Disaster Reduction

Applicatio

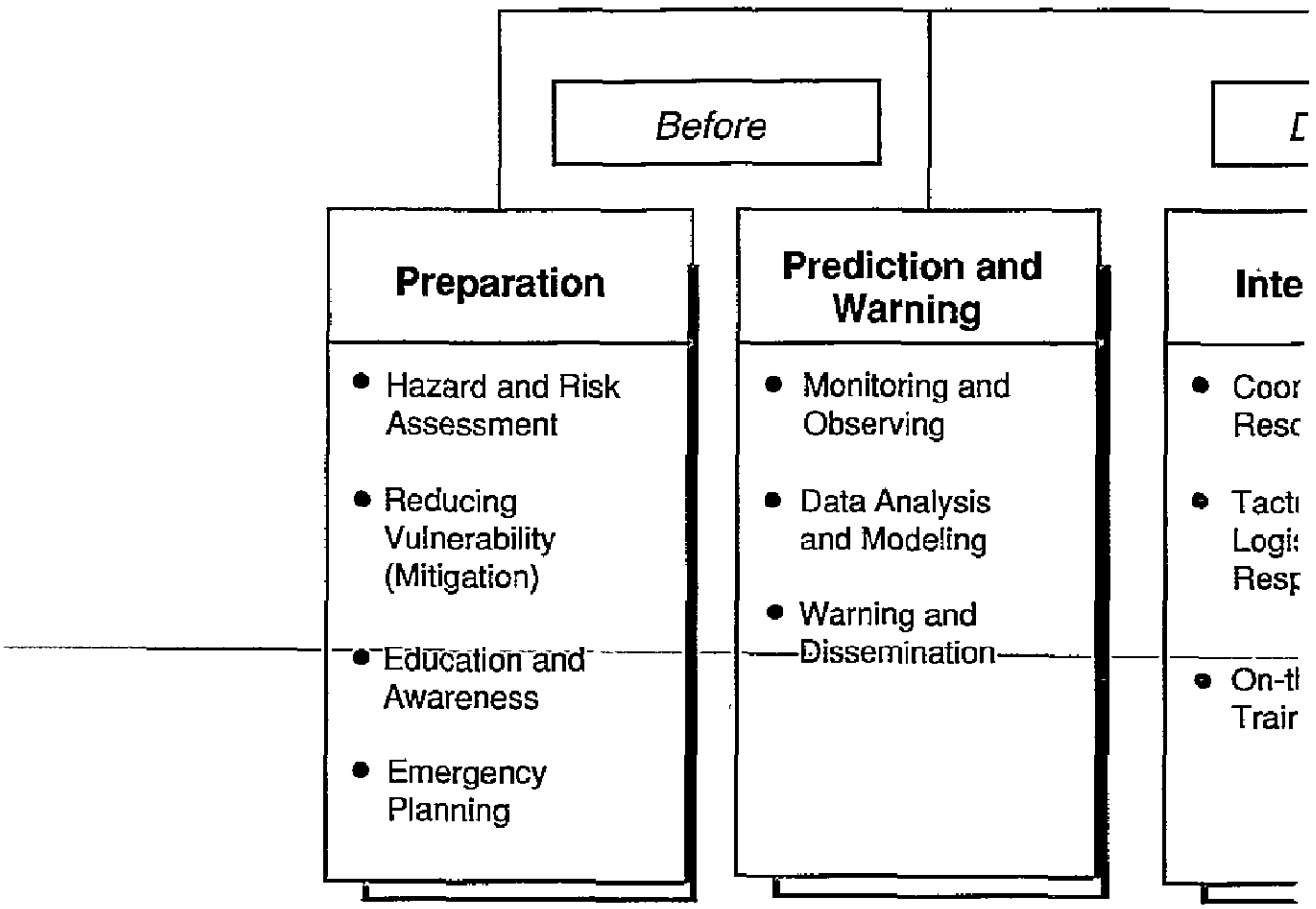
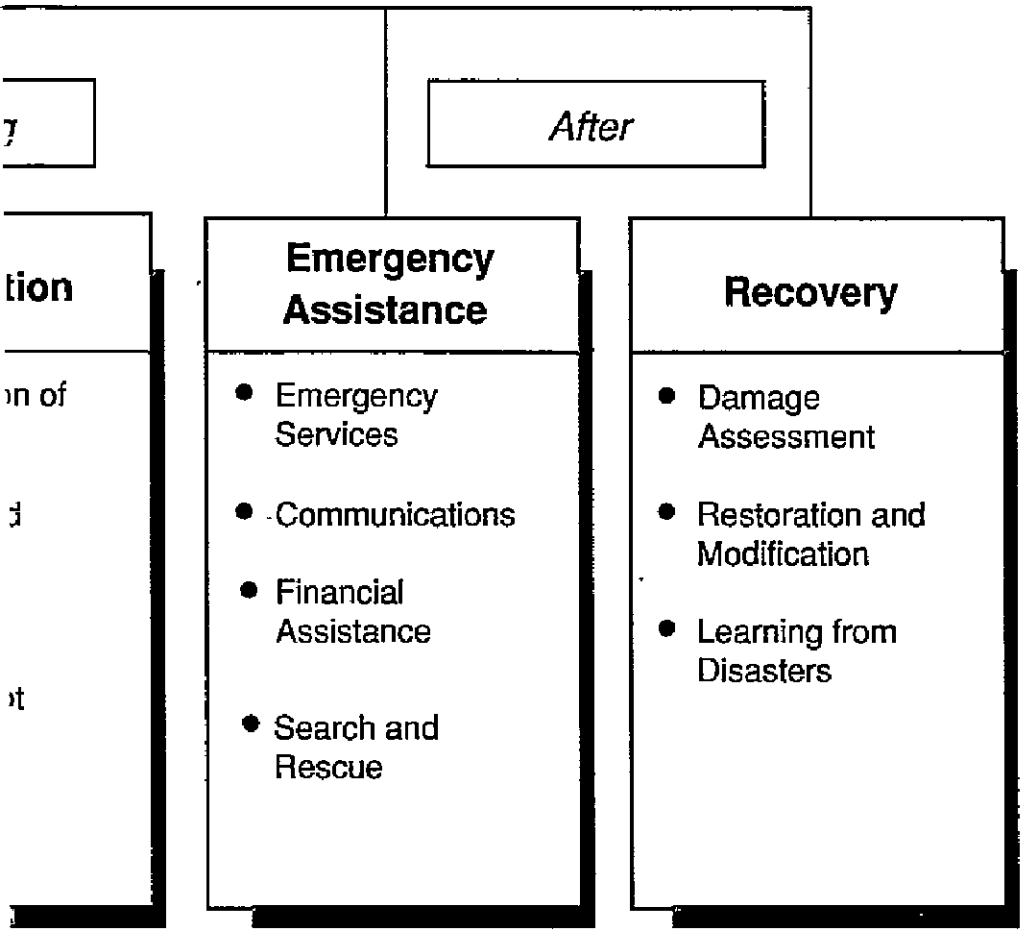


Figure 3

Elements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Financial Assistance
Search and Rescue
Recovery
Damage Assessment
Restoration and Modification
Learning from Disasters

activities. In a few cases, such as the National Earthquake Hazard Reduction Program (NEHRP) and the U.S. Weather Research Program (USWRP), significant Federal coordination already exists that merits continued support and enhancement. The framework reflects this strong emphasis on coordination.

Furthermore, because many individual natural disasters hit highly localized regions, the Federal Government is not necessarily the primary instrument for recovery and mitigation; State and local agencies and the private sector play a considerable role. Accordingly, the framework deals not only with research and technological advances but also with operational applications and practice. The SNDR finds that natural disaster reduction requires a balance between these two highly disparate activities. Any attempt at a relative ranking of the two would be artificial and counterproductive.

The Research Elements begin from the same axiom underlying the Global Change Research Program—namely, that uncertainty regarding the frequency and intensity of natural hazards (that is, the risk over a human lifetime and over the lifetime of engineered systems) remains the biggest impediment to effective action. Accordingly, reducing that uncertainty and, where possible, establishing and improving a predictive capability are the starting points. The second task, then, is appropriate engineering of the societal infrastructure and improving the management of the environment to withstand threats. Finally, improved understanding of the societal and sociological aspects of natural disaster reduction is required. The SNDR notes that, as with global change, this latter work has received the least attention to date, despite the fact that human factors such as perceptions of risk, fatalism, and competition for time and resources are critical determinants of whether disaster-preventing actions will be taken.

In Applications Elements, the primary goal is to anticipate and avoid or gird against hazards rather than to respond to disasters. Existing practice often emphasizes the latter but stems historically from a time when little was known about the recurrence frequency and intensity of hazardous events, their physical and (or) biological character, and their specific prediction. With improved capabilities in each of these respects and still further significant improvements on the horizon, the time has come for this shift in emphasis.

The following section presents a more detailed description of the framework developed by the SNDR. The exact nature of specific proposals and plans to address each of the elements will be developed by Federal agencies in close collaboration with the Nation's scientific and user communities and international partners.

Strategic Priorities

Strategic Priorities provide the overall philosophy and approach for both current and future hazards activities. They will (1) determine the key elements of the U.S. strategy, (2) keep the focus on the central goal of the strategy, and (3) be a guide to budget decisions for the strategy. The four Strategic Priorities of the U.S. strategy are to:

- **Anticipate Hazards Rather Than React to Disasters.** Anticipation must be emphasized over reaction, and avoidance and mitigation strategies must be adopted to reduce the impacts of natural hazards and to prevent unnecessary costs and losses during and after a hazard event.

- **Advance Scientific Knowledge and Application of Research Results.** The occurrence and impacts of natural disasters can be lessened through advances in scientific and technological knowledge and applications of that knowledge to natural disaster reduction.

- **Build On and Increase Efficiency and Coordination of Federal Hazard Programs.** The critical importance of collaboration and coordination among Federal agencies must be recognized to achieve this strategic goal.

- **Increase Sharing and Coordination Domestically and Internationally.** Information must be shared and activities coordinated with State and local governments, public institutions, nongovernmental entities, international organizations, and the governments of other nations.

Integrating Priorities

A generic set of steps is needed to mitigate any natural hazard. These priorities are to:

- **Observe, Characterize, and Predict Natural Hazards.** Studies of natural hazard occurrence and character, severity-frequency relations, precursors, and triggering mechanisms are needed to reduce the serious uncertainties in current predictions. Increasingly, interactions or linkages between hazards must also be considered.

- **Assess Actual and Acceptable Risk.** Risk is the product of hazard, value (for example, of the population, property, natural resources), and vulnerability of those things to injury or damage. When risk is higher than what is acceptable to citizens and policymakers, measures are needed to reduce that risk.

- **Develop Options for Risk Reduction.** Risk can be reduced by a variety of social, engineering, and natural resource management measures, including warnings, evacuation, strengthening of buildings and lifelines, and adoption of special forest or agricultural practices.

- **Implement Risk-Reducing Measures.** Measures that achieve the greatest reduction of risk for the lowest social and economic cost need to be chosen and implemented.

- **Learn from Disasters.** Disaster reduction is an iterative process in which observations of each major occurrence of a hazard and the success of the human response to it are fed back into the data base from which predictions, risk assessments, and choices of risk-reduction strategies are made.

Effective disaster reduction requires each of these steps, carefully integrated with the others. Research into the physical and biological processes and prediction of a hazard does little good unless it is linked with mechanisms for risk reduction such as alternative management practices, warning systems, building codes for hazard-resistant structures, and evacuation plans. Conversely, engineering and management practices designed to reduce the impacts of natural hazards require an understanding of the hazard itself. Even the most elegant scientific and technical solutions to the problems presented by hazards are practically worthless unless those measures are founded in an understanding of the needs, wishes, and commitment of local citizens and community leaders. History is replete with tragic examples of short memory, in which lessons learned from one disaster are forgotten shortly before the next disaster strikes. Integration across each of these steps is essential for effective disaster reduction.

Research Elements

Eight research elements, grouped into three different headings, are listed in figures 1 and 2. Within each element, the primary interdisciplinary activities are identified. These elements address the Nation's need to:

- Improve predictions of the time, place, severity, and intensity of natural hazard occurrences by understanding their underlying physical and biological processes (Physical and Biological Nature of Natural Hazards).

- Develop the knowledge and technological capability to manage the impacts of natural disasters (Managed Systems).

- Enhance our knowledge of the social, health, institutional, and economic processes affecting the impacts of natural disasters on society (Human Interactions).

PHYSICAL AND BIOLOGICAL NATURE OF NATURAL HAZARDS

Climate, Weather, and Hydrologic Systems

In the United States, weather is responsible for 85 percent of all Presidentially declared disasters. Research is needed on (1) the linkages between climate, weather, and natural hazards, (2) weather extremes related to precipitation and wind, (3) linked atmospheric and hydrologic models to improve our ability to predict floods and better manage water resources, and (4) improved prediction of atmospherically driven oceanic events such as storm surges and waves in nearshore regions.

Climate, Weather, and Hazard Linkages. The causal linkages between climate, weather, and resulting natural hazards are of special interest. This activity will examine and test a variety of hypotheses linking climate with (1) increases in the frequency and intensity of hurricanes and severe weather events, (2) increases in the impacts of atmospherically driven oceanic events such as storm surges, and (3) drought and flooding. Research is also needed to link synoptic and mesoscale weather processes to (1) wildfire disasters, (2) volcanic eruptions, large wildfires, and other short-lived events that temporarily lower global temperatures, and (3) African drought and hurricane frequency, intensity, and potential landfall areas.

Atmospheric Extremes. This element supports research to improve prediction of extreme atmospheric events. These

events range from precipitation extremes associated with drought and flood as well as high wind events associated with severe storms—thunderstorms, tornadoes, gust fronts, and downbursts to tropical and extratropical storms. Of particular interest is research on warm process rain (resulting in small basin flooding).

Hydrologic Systems. Special focus on linkages between atmospheric and hydrologic models will improve our ability to predict floods and better manage our water resources. Objective data network analysis and optimal network design will be undertaken. Studies to integrate remotely sensed data and ground observations will be used to improve forecasts of stream and river conditions, particularly in data-sparse regions, and to improve drought-prediction capabilities. Research and development activities will support a better understanding of small- and macroscale processes and the effective integration of climatic information and weather extremes into water resources management forecasting services. The increased demand for automated local flood-warning systems reflects their effectiveness as a nonstructural approach to flood mitigation. Where needed, the design, maintenance, and standards for automated local flood-warning systems need to be developed.

Atmospherically Driven Oceanic Events. This element supports research that improves predictions of atmospherically driven oceanic events such as storm surges and waves. Storm surges and waves in the nearshore oceanic environment frequently pose great risks to coastal residents. Various numerical forecast models have been developed to predict storm surges and waves for both tropical (hurricanes) and extratropical (winter) storm systems. Improved physical understanding of the driving atmospheric forces and the oceanic response in nearshore regions will lead to better predictive capabilities. Better and more numerous observations of water levels and atmospheric

variables (wind and pressure) are required to validate existing models and parameterizations.

Solid Earth Processes

Public overreaction to unfounded earthquake predictions highlights the need for improved monitoring, long-range risk assessment, and short-range predictions of earthquakes and other geologic hazards. Much needs to be learned about the fundamental causes and triggers of geologic hazards, how each hazard propagates or travels, how each hazard dissipates or ends, and how past recurrence of these hazards can be recognized and quantified in geologic and other records. Specifically, studies are needed to understand (1) fault movement and earthquakes, (2) magma movement and volcanic eruptions, (3) landslides and liquefaction, and (4) tsunami generation, travel, and runup.

Fault Movement and Earthquakes. This element examines how crustal stress accumulates and is released suddenly to generate earthquakes. Earthquakes need to be related to the scale, geometry, orientation, and rupture mechanisms of faults and to the temporal pattern, dimensions, depth, and character of fault movements. Total energy (magnitude), peak acceleration, duration, and waveform need to be related to earthquake source motions and to wave paths between the source and the point of observation.

Magma Movement and Volcanic Eruptions. This element examines how the release of dissolved gases from magma controls the timing, explosivity, and magnitude of most eruptions. The interaction of rising magma with ground water will also be studied, because this interaction is frequently explosive and opens conduits for magmatic eruptions. Studies of how erupted products are distributed during and after an eruption are needed to predict probable impacts on people and the environment.

Landslides and Liquefaction. Prediction of landslides requires research into (1) the relative influences of factors such as rock strength, slope, water saturation, and preexisting slip planes or other zones of weakness, (2) threshold values of rainfall, earthquake intensity, and external disturbances above which a slope will fail, and (3) local site conditions. Prediction of liquefaction requires research into the response of granular material and intergranular water to earthquake ground shaking and compaction.

Tsunami Generation, Travel, and Runup. Tsunamis are generated by submarine fault movements, submarine volcanic explosions, and submarine landslides. To minimize false tsunami alarms and to give accurate estimates of magnitude, research is needed on the details of each generation process, including relations between the rate and magnitude of each stimulus and the character of the resulting tsunami, and on factors that influence the travel and runup of tsunamis.

Ecosystem Processes

Understanding the nature of natural hazards such as wildfires and pestilence (insects and disease) requires understanding the fundamental relationships between ecosystem dynamics and these events. Such understanding includes learning what ecosystem changes—triggered by drought, hurricanes, or other environmental events—precede and contribute to natural hazard events, how these events "behave" in relation to the environment, and how natural hazards, in turn, affect the structure and function of ecosystems and the probability of subsequent natural hazards. Research is needed to (1) investigate the linkages among and between successional, interrelated natural hazards, (2) understand ecosystem responses to environmental events, (3) explain the origin, behavior, and termination of catastrophic wildfires and pestilence outbreaks, and (4) determine the effects of catastrophic events on the environment.

Multiple Hazard Interactions. Natural hazards frequently occur in series—that is, following an initial onset, each subsequent hazard derives from or acts upon the effects of the preceding event. Hurricane Hugo, for instance, downed 2 billion board feet of standing timber, an event that can result in explosive outbreaks of insect populations. Likewise, any fire ignited in the enormous volume of forest fuels on the ground could reach catastrophic proportions. During long periods of drought, wildfires burning in standing or downed fuels can denude slopes of vegetation and thereby trigger soil erosion, flooding, and landslides. Research will focus on understanding the numerous and critical linkages among and between successional, interrelated physical and biological hazards.

Ecosystem Response to Physical and Biological Events. Understanding how ecosystems respond to events such as floods and drought is critical to forecasting the probability that a natural hazard event will occur. Wetlands capable of absorbing floodwater, for instance, play a vital role in flood mitigation. Yet research is needed to better understand the role of these ecosystems in floodwater mitigation and to assess the impacts of the cumulative loss of wetlands on the frequency and severity of floods. Likewise, forest ecosystems stressed by drought are vulnerable to attack by insects and disease. Dead trees resulting from such attacks become highly flammable fuels for catastrophic wildfires. Research is also needed to determine the relations between long-term ecosystem health and natural hazard occurrence. Extensive monitoring is required to detect and explain changes in natural ecosystems over time and to predict the occurrence, magnitude, and severity of natural hazards in natural ecosystems.

Origin, Development, and Termination of Ecological Hazards. Natural hazards such as wildfires and pestilence, frequently the result of human activity, in many cases can be not only prevented but also contained or controlled through effective intervention and suppression measures.

To do so requires an understanding of the causal mechanisms and abatement processes related to both short-term and longer term, larger scale phenomena and factors affecting the spatial and temporal distribution, intensity, and behavior of such events.

Effects of Catastrophic Events. Natural hazards impact the environment either by causing changes in ecosystem structure and function or by creating direct, offsite impacts such as air pollution, sedimentation, or flooding. Some impacts are entirely natural; others are compounded by naturally induced damage to chemical or oil facilities, nuclear reactors, and other industrial facilities. These hazards can affect both terrestrial and aquatic ecosystems, altering, for example, barrier island/dune systems, river deltas, and ocean resources as well as affecting populations of threatened and endangered plant and animal species. Research is needed to determine the effects of natural hazards on the environment, including ecosystem productivity, environmental quality and health, and biodiversity.

MANAGED SYSTEMS

Engineering Systems

Engineering systems offer ways to increase the resistance of structures and lifelines to damage and thereby provide people who live and work in hazard-prone areas with opportunities to reduce their losses from natural hazards. To improve these engineering systems, research is required to improve knowledge of (1) structure-environment interactions in extreme events, (2) engineered and nonengineered structure modification (retrofitting), (3) engineering design, (4) hazard-averting engineering, (5) architectural and mechanical systems, and (6) engineering systems for monitoring, testing, communications, search-and-rescue efforts, and event suppression.

Structure-Environment Interactions. Research will address the effects that the interactions of a structure with

the environment (for example, fire, soil, water, wind) have on overall structural performance, especially in extreme events. These studies will advance, for example, understanding of the response of buildings, dams, bridges, and other structures to strong ground motion and extreme wind loads, taking into account interactions between soil and structure, fluid and structure, and wind and structure.

Structure Modification. This activity will address the repair and strengthening of buildings and lifelines to lengthen their service life and to improve their performance when subjected to the effects of natural hazards. Materials engineering and construction techniques for retrofitting need special attention.

Engineering Design. Research is needed to advance our understanding and use of expert and knowledge-based systems to model and forecast the performance of all types of structures exposed to natural hazards. These studies will focus on the development and use of hazard-resistant materials and construction techniques that will not only increase the service life of structural components but also enhance the structure's survivability and safety.

Hazard-Averting Engineering. This research element addresses the need for instrumentation, technologies, models, and advanced methodologies for risk assessment and risk management, all of which can be used to avert the consequences of each natural hazard. Particular emphasis will be placed on the development of decision-support systems and physical and mathematical models to predict the consequences of a natural hazard. Emphasis will also be placed on the development of active/passive isolation systems and structures that reduce or dissipate energy input from phenomena generated during a hazard.

Architectural and Mechanical Systems. Research is needed to deepen our understanding of ways to improve the performance of the architectural and mechanical systems of

buildings. These systems, which represent a large part of the overall value of the building, frequently sustain considerable damage during natural hazards owing to improper placement in the building; inadequate connections, anchorages, and joints; or incompatible material properties.

Engineering Systems for Monitoring, Testing, Communications, Search and Rescue, and Event Suppression. Research on advanced engineering systems is needed to meet a variety of special needs. These needs include (1) monitoring of physical phenomena generated by each type of natural hazard, (2) full- and partial-scale testing of structures, (3) development of new and improved communication systems that can survive a natural disaster, (4) equipment and technologies for urban search-and-rescue operations, including victim detection and extraction, including an electromagnetic location device, and (5) materials and methods for suppressing the physical effects of a hazardous event (for example, fire growth and spread, floodwater encroachment).

Managed Environmental Systems

Humans have attempted to manage their natural environments and thereby reduce the impacts of natural hazards by developing technological controls, modifying the landscape, and improving cultural practices to sustain and enhance plant and animal productivity in spite of naturally occurring events such as drought, wildfires, floods, and pestilence. To enhance our ability to manage the environment and mitigate natural hazards, research is needed to (1) develop and improve the resistance of important plant and domestic livestock species to diseases, insect pests, and environmental stresses induced by drought, (2) improve methods for managing forest and agricultural vegetation to reduce the intensity, frequency, and (or) magnitude of the impacts of natural hazards, (3) improve soil management to enhance drought and flood resistance before and during droughts or floods, and (4) develop natural controls of insect and disease outbreaks.

Hazard-Resistant Plants and Livestock. Research has shown that one of the most efficient, long-lasting solutions to pests and abiotic stressors is resistant varieties of plants and domestic animals. Relying on breeding and selection programs, biotechnology, and genetic engineering, research will focus on developing new and improved hazard-resistant trees, crops, and grazing livestock able to withstand the impacts of drought, floods, and pestilence.

Vegetation Management. Vegetation management includes silvicultural procedures that minimize the risk of insect and disease outbreaks—for example, thinning forest stands to reduce the size and density of trees and consequently the spread of pine beetles; interrupting large expanses of natural vegetation by creating fuelbreaks to slow the spread of wildfires; and controlling the selection, placement, and rotation of crops to retard the impacts of drought. Research is needed to evaluate and improve agricultural and forest vegetative management techniques that mitigate the effects of natural hazards yet maintain or enhance commodity production and biodiversity and to develop interactive models that predict the environmental and social effects of natural hazards under different vegetative management scenarios.

Soil Management. Initial priority must be on developing new soil-moisture enhancement and retention measures; increasing the control and management of water yields and runoff; and improving drought, soil moisture, and flood modeling programs.

Biological Controls. Environmentally safe and effective natural controls of insects and disease outbreaks thwart the onset of such hazards and mitigate their impacts on forest and agricultural systems. These controls include (1) introduced parasites, predators, and pathogens, (2) vegetation management that enhances populations of beneficial organisms, and (3) biochemical signals such as pheremones and allemones used to attract and trap insect pests. Laboratory

and field studies are needed to understand more fully the basic biology and ecology of pestilence; to develop a better understanding of management practices such as crop rotations that take advantage of and encourage biological control of pests and disease; to obtain the basic genetic and physiological information on insect pests and diseases; and to develop genetically engineered biological control agents such as bacteria, fungi, protozoa, and viruses that reduce insect and disease outbreaks.

HUMAN INTERACTIONS

Behavior, Health, and Communication

"To be successful, methods for reducing losses from natural hazards must be carefully adjusted to the communities they serve. Science and technology can help avert natural disasters, but only when applied with a community's social, cultural, political, and economic context in mind" (Advisory Committee on the International Decade for Natural Hazard Reduction, 1987). Research is needed to (1) assess societal changes, demographic trends, and risk perceptions in order to anticipate disaster-related problems and respond before a disaster strikes, (2) determine incentives for safe behavior and the adoption of disaster-safe community standards, (3) determine how people deal with conflicting forecasts and respond to emergencies to improve their safety and evacuation, (4) improve assessments of affected populations and the need for emergency medical services immediately after disasters, (5) determine the differential health impacts of natural disasters on populations by epidemiological methods, (6) develop better estimates of casualties to aid predisaster planning and preparation, and (7) establish program design and implementation guidelines to reach people at risk from natural hazards.

Social Assessments. As the risk stemming from natural disasters continues to rise, assessments of societal changes, demographic trends, public perceptions, and other social

indicators are a necessary foundation for changes in policy, shifts from reactive to proactive disaster reduction strategies and activities, and improvements in public safety based on better information. At a minimum, research is needed to clearly understand (1) how the public is coming to view environmental issues as interlinked (for example, hazards, global change, local air pollution, ozone depletion) and what this means for policy, (2) how development trends in the United States (for example, population movement to the Southwest, shift of businesses to rural sites) affect the potential for catastrophic losses, and (3) how various sectors of the public and "influentials" in the public and private sector perceive and deal with risks from natural hazards.

Incentives for Safe Behavior. Disaster reduction measures are designed with the future in mind and may lack immediate benefits unless they are coupled with direct and indirect incentives for individuals and organizations. Historically, taxes and tax breaks, insurance surcharges, lending rules, permits, licenses, and zoning regulations have been used to encourage hazard-safe behavior. Research is needed to (1) determine how both economic and noneconomic incentive and disincentive measures from the public and private sector affect the behavior of people living in hazardous areas and the consequent economic costs and potential losses resulting from natural disasters and (2) identify barriers to and methods for promoting implementation of "disaster-safe" standards by homeowners, businesses, land managers, and local governments.

Reactions To Emergencies. During emergencies stemming from natural disasters, the behavior of citizens and response personnel can make a significant difference in losses suffered. Research on how people react during natural disasters can provide an important foundation for preparing emergency response plans. Research is needed to determine (1) how people and governments should deal with conflicting and competitive forecasts of impending natural disasters, (2) how people and emergency response agencies

react during natural disasters as a basis for enhancing their safety, and (3) how social, economic, and cultural contexts (for example, poverty, ethnicity) affect people's responses.

Health-Impact Assessment. Immediately after a disaster, the characteristics of the affected population and the need for emergency medical services have to be assessed quickly. It is unfortunate that the quality and methodology for the assessment of disaster needs lack consistency. The data on damages collected in actual disasters are usually crude estimates based on superficial observations that are of limited technical and statistical validity. There are few standardized methods or indicators for rapidly determining the needs of disaster victims and communities. Research is needed to improve health-impact assessments. This research should include developing data collection methods that are simple and quick to use and operationally feasible.

Disaster Epidemiology. Disaster epidemiology was born from the growing realization that the effects of disasters on the health of populations can be studied by epidemiological methods. Research is needed to (1) describe the public health impacts of different types of natural disasters, (2) describe the natural history of acute health effects, (3) analyze risk factors for adverse health effects, (4) clinically investigate the impact of diagnostic and treatment approaches, (5) understand the long-term health effects and psychosocial impacts of disasters, (6) evaluate the effectiveness of various types of assistance and the long-term effects of aid on the restoration of predisaster conditions, and (7) improve surveillance and accurate reporting of disease outbreaks following a disaster so that proper followup action can be taken. Results of these studies can be used in the design of appropriate warning systems and can provide guidelines for preparedness training.

Casualty Estimation Modeling. Considerable attention has been devoted to natural disaster loss estimation, but little effort has been given to more specific estimates of

disaster-related casualties. Yet casualties are a prime concern to those who commission loss estimation studies—public and private sector organizations that are responsible for life safety. Research is needed to develop and improve casualty estimation models. Predictions from these models could be used to improve natural hazard mapping, risk assessment and management strategies, and early warning systems. In addition to improving estimates of casualties from future disasters, this research can also be used to develop more realistic scenarios for training simulations and exercises, improve design guidelines for building safety, help planners predict the impacts of hazards on vulnerable subpopulations and allocate medical resources, and lead to more effective medical training for response personnel.

Program Design and Delivery. Program design and implementation guidelines that will effectively influence behavior consistent with the risk are needed. Programs may be designed around legislation (enactment of new laws), enforcement, incentives, education, or any combination thereof. Delivery systems may include mass media, group meetings, individual mailings, or group and individual contacts as well as neighborhood organizations and existing service organizations. Studies are needed to evaluate the effects of current disaster prevention and mitigation programs and to establish program design and implementation guidelines to effectively reach and influence different target groups at risk from natural hazards.

Institutional Opportunities and Constraints

Research is needed to determine which are the most effective, appropriate, economic, and timely procedures that organizations—including governments, large businesses, and civic organizations—can use to minimize the impact of natural hazards. Studies are needed on (1) barriers to policy adoption and implementation, (2) the role of governmental laws and regulations, (3) the role of financial institutions in fostering mitigation policies, (4) the role of public and

private partnerships in marshaling human resources and information, and (5) the role of industry in disaster mitigation.

Removing Barriers to Policy Adoption and Regulation. Research involving all sectors concerned with the formulation of natural disaster mitigation policies is needed to devise creative ways to remove economic, social, and political barriers to policy adoption and regulation.

Government. Studies are needed to better define the role of government in disaster reduction. We need to know (1) how emerging new relationships and cooperation between Federal, State, and local governments will affect hazard reduction (for example, through new taxing authorities) and (2) how existing laws and regulations affect natural disaster mitigation.

Financial Institutions. Research is needed to define the financial interests of banks, insurance companies, and real estate firms in hazards mitigation and how these institutions can foster hazard-safe building standards and other mitigation measures.

Public and Private Partnerships. Research will focus on the best ways to form public-private partnerships that are able to marshal extraordinary human resources and information for hazards mitigation.

Industry. Research is needed to define how U.S. industry could assume a leadership role and a strong international research and development position in natural disaster mitigation.

Economics

The economic consequences of natural disasters vary with the type of hazard, the intensity and duration of an event, the physical and social characteristics of the impacted area,

the kinds of natural and built environments affected, and the predisaster economic conditions of the area and their relationships with other economic systems. To date, precise figures on losses and methods of determining these losses are not always available, nor is their accuracy dependable. Data on damages are usually not consistently collected, nor are analytical methods systematically updated. Research is needed to (1) improve economic analyses of disasters and enhance methods for determining losses to urban developments, (2) develop better cost-benefit assessments of disaster reduction measures, (3) assess the costs of rehabilitating an area after a natural disaster, and (4) improve disaster-related decisionmaking.

Economic Analyses of Disasters. A major effort is needed to validate and improve the available methods and models for accurately assessing economic impacts both before and following disasters on all scales—local, regional, national, and international. Research will address the quality of available techniques and models for determining short- and long-term losses to urban development in all disaster-prone regions of the Nation and selected international locations. Also, methods for assessing ecosystem damage as opposed to change should be developed. Environmental disturbances are a natural part of an evolving ecological system. Whether such disturbances result in environmental damage depends upon how society values the immediate and long-term effects. Environmental assessments should go beyond the mere counting of organisms affected to address questions of valuation and whether ensuing damages are preventable. Research is needed to develop a simple set of guidelines that isolate and weigh preventable ecological impacts. Research on the assessment of damage to cultural and social environments is needed as well. The preservation of historical monuments and cultural assets has become an increasingly important aspect of urban planning. Cultural assets clearly contribute to the integrity and continuity of social identity, qualities which yield traditional value. Yet little has been done to assess what society is willing to pay to protect these

assets from the effects of natural hazards. A simple set of guidelines is needed to ensure that the potential loss of these assets is reflected in any overall assessment of disaster impacts.

Cost-Benefit of Disaster Reduction Measures. Research is needed to develop improved and innovative cost-benefit models and methods for assessing past, present, and proposed mitigation, prediction, response, and recovery policies. These models and methods, developed with input from the public and private sectors, need to be cost effective and easily understood to ensure consistent use at the Federal, State, and local levels. Transnational economic repercussions should be investigated. The international financial and monetary system has evolved to a point where the effects of catastrophic events are no longer confined to the nation in which they occur. The rapid liquidation of financial assets in conjunction with the destruction of key production and communications facilities could produce transnational economic shock. Very little is known about the vulnerability of these key economic institutions, nor have we seriously considered how they could be modified to limit postdisaster economic repercussions.

Costs of Rehabilitation. Research is needed to develop and improve methods for accurately assessing the costs of rehabilitating both natural and built environments following natural disasters. The economics of multiple objectives must be studied, because the 1990's not only will see an increase in hazard awareness but also will be a decade of extreme fiscal conservatism. Tight Federal, State, and local budgets will make it increasingly difficult to institute single-purpose measures. The promotion of hazard insurance or the retrofitting of hazardous buildings and infrastructure will have to reflect more than a single goal. Research is needed to develop innovative linkages between the reduction of natural disasters and other pressing social needs.

Decisionmaking for Disaster Reduction. Research should address all factors entering into the decisionmaking process, including (1) the short- and long-term economic incentives and disincentives of present coping mechanisms and policies and (2) the benefits of new and improved mitigation, prediction, response, and recovery measures as a function of time. Research is needed to identify and evaluate current decisionmaking processes and, on the basis of those evaluations, to determine how the processes can be improved.

Applications Elements

All the research in the world is of no use if it remains on the shelf. Therefore, a major emphasis of the U.S. strategy is the application and dissemination of research results—that is, translating what we know of hazards and their mitigation into operational practice.

There is a logical order of applications in time (fig. 3). Before a hazard strikes, important preparation measures must be taken. The hazard must be identified and the vulnerability assessed. Mitigation measures designed to lessen the impact of the hazard on lives and property must be put in place. Furthermore, the public must be made aware of the hazard and the impact that it could have on their community and their lives. Finally, every disaster-prone community needs to have a response plan in place that is practiced on a regular basis. State and Federal governments must have their response plans, as must those in the corporate world.

In addition to preparation, accurate, reliable, and timely prediction and warning systems are necessary to protect communities before a hazard strikes. Monitoring and observing natural hazards and analyzing hazard data can translate improved predictions of hazardous events into timely warnings that are disseminated rapidly to the public.

While a natural hazard is striking, intervention by the Federal, State, and local sectors is sometimes necessary to mitigate the effects of that hazard. Such intervention requires coordination of people and equipment, organized tactical and logistical activities, and on-the-spot training of supplemental suppression forces.

After a hazard strikes, both immediate and long-term emergency assistance and recovery measures must be taken. Recovery measures such as reconstruction should not only revitalize the damaged community but also maximize its resistance to future disasters.

Although each Applications Element is needed in time, it is almost always better to anticipate and therefore to avoid natural disasters rather than to react to them after they have occurred. The adage "An ounce of prevention is worth a pound of cure" applies to natural disasters in force, and the greatest savings of life and property during the 1990's are likely to be the result of placing greater emphasis on preparation, prediction and warning, and intervention and thus saving costs of emergency assistance and recovery.

BEFORE THE NATURAL HAZARD STRIKES

Preparation

Time and again, when hazards strike, areas where proper preparedness plans and effective prevention and mitigation programs are in place suffer fewer losses and recover more quickly than those that do not have preparedness programs. During Hurricane Hugo, for instance, the Governor of South Carolina ordered the evacuation of over 250,000 inhabitants in coastal areas. Because of hurricane preparedness evacuation plans developed by Federal agencies in cooperation with South Carolina, fewer than 10 people were killed by the hurricane itself. In addition, those structures that had been built according to flood-plain management and wind code standards suffered less damage than those not built according to standards. In order to provide ade-

quate preparation for hazards and to reduce their impacts, Federal agencies, in cooperation with State and local governments, need to (1) improve hazard and risk assessments, (2) reduce vulnerability to natural hazards, (3) educate the public and increase their awareness of natural hazards, and (4) improve emergency planning, so that response can be immediate and effective.

Hazard and Risk Assessments. Hazard assessments tell us about the nature of hazards and the probability of hazards occurring in a given area. Hazard assessments must (1) quantify the recurrence of each hazard, (2) increase the amount of detail available about the location, frequency, and severity of physical and biological effects on hazard maps, and (3) ensure that assessments consider possible interrelations between hazards (for example, the triggering of floods by hurricane rains or an increase in wildfires during drought). Risk assessments tell us the loss expected from each hazard, what is at risk (population, property, natural resources), and how easily various elements at risk can be damaged by each hazard. Risk assessments should include estimates of the interlocking vulnerability of new technologies and the extent to which human actions may influence risk. They should also include estimated deaths and injuries expected from different types of natural hazards, given that natural hazards are characterized by very different morbidity and mortality patterns and, thus, health care requirements. This U.S. strategy encourages Federal agencies to complete hazard and risk assessments for key areas in the United States and its territories and make such information available to other Federal agencies and to State and local governments.

Reducing Vulnerability (Mitigation). Once the risk for each hazard is known, several engineering, social, resource management, and policy actions can be taken to reduce vulnerability. These actions include strengthening buildings, modifying forest or agricultural management practices, ensuring low-density use of high-hazard areas, modi-

fying transportation and energy distribution systems, constructing protective works in highly developed areas where no other suitable alternative exists, enforcing flood-plain regulations, and employing fire-safe construction and landscaping in and around housing developments. Although both structural and nonstructural mitigation measures may cost money in the short run, these investments prevent losses in the long run and provide savings to building and homeowners, landowners and managers, communities, and governments. Major challenges include demonstrations of practical methods and the immediate economic benefits of, for example, hazard-resistant design, construction, and retrofitting. An added challenge is assuring compliance with building codes and standards that include mitigation measures. The U.S. strategy encourages Federal agencies to increase their efforts to work with State and local governments and to provide them with information that can be used to mitigate the effects of natural disasters. This information can be transmitted by publishing manuals, sponsoring workshops, and working with building code organizations, national professional organizations, and local land-use planning commissions.

Education and Awareness. People who live and work in hazard-prone areas need to know the nature and probable impact of natural hazards and what they can do to protect themselves before, during, and after a natural disaster. This information can be conveyed through schools, special television programs, popular publications, workshops, and other channels. One important challenge of this element is presenting accurate information in ways that lead to preventive and precautionary actions. Another challenge is to reach the broadest possible audience by using a wide variety of educational media. Federal agencies, working with State and local governments, should promote the importance of disaster prevention and mitigation programs through the media, especially in specific high-risk areas. They should also provide hazard information to the media for local programming and continue to work with organiza-

tions such as the Children's Television Workshop to educate the public and bring pressure to bear on recalcitrant local officials who do not adopt natural hazard reduction measures.

Emergency Planning. Emergency plans must be prepared and tested many times before a natural hazard strikes. Even the most comprehensive and well-constructed contingency plans need to be tested and evaluated through tabletop and field exercises. These activities can identify planning voids that need to be filled. Exercises are particularly valuable for hazardous events that are not commonplace, such as catastrophic earthquakes. Low-probability, high-consequence events must be simulated realistically and with participation from local, State, and Federal agencies. These simulations encourage interagency and intergovernmental coordination and sharing of information, techniques, and procedures. Finally, although planning for frequent, small natural hazards may seem challenging enough, planning for infrequent disasters, though much more difficult, is equally important. Federal, State, and local emergency plans for response and recovery need to be updated periodically even if no hazard occurs. They also need to be evaluated and improved after each hazardous event, including those that do not actually culminate in disasters, and include mechanisms for allocating appropriate medical supplies and resources in the immediate postdisaster environment.

Prediction and Warning

Predicting the time, place, and severity of a hazardous event saves lives and reduces losses when it is followed by timely and effective dissemination of warnings to the public. Even with only a few minutes notice, individuals can act to save their lives. Given longer lead times, actions can be taken to reduce other losses. Our capability to predict natural hazards has grown considerably as a result of scientific and technological advances in recent decades,

even though variability still exists from hazard to hazard. To close the gap even further, we must (1) monitor and observe the hazards and their precursors, (2) analyze and model the data acquired, and (3) translate predictions into easily understood warnings and disseminate them expeditiously to the public.

Monitoring and Observing. The need to observe potential hazard precursors should drive the rapid development and adoption of technological advances in sensors, data telemetry, and data reduction. Instruments that can detect multiple hazards deserve special attention—for example, weather radar and lighting detectors to detect severe storms, potential wildfire ignitions, and volcanic ash clouds. For both scientific value and economy of operation and telecommunication, sensors for various hazards should be co-located and linked as much as possible. The U.S. strategy encourages Federal agencies to accelerate their capabilities to monitor and observe natural hazards and pass their data on to State and local governments for action. Although Federal budget curtailments may limit some of these efforts, every effort must be made to continue, if not increase, them, because these efforts have had positive effects in saving lives.

Data Analysis and Modeling. Although monitoring can suggest that a hazard is imminent, the chances for error are usually too high for us to rely on observations alone. Data must be analyzed and modeled in order to compare them with previous patterns of precursors, to seek a physical explanation for the observed changes, and to project them into a quantitative prediction of the time, place, and severity of an impending hazard. Federal agencies must make greater efforts in data analysis and modeling for the benefit of State and local users who must prepare for impending disasters.

Warning and Dissemination. Warnings of impending hazards should come to Federal, State, and local officials in

an easy-to-understand, standardized format and from recognized sources. Current delivery of warnings to public officials should be improved by new technologies. Federal agencies should reexamine the procedures and methodologies used for warning and dissemination, so that emergency managers and responders can view the hazard on computer displays that show existing roads, lifelines, hazardous material locations, and other critical information. Less urgent information such as maps of long-range hazards could be obtained interactively through personal computer information services. Conventional channels for the dissemination of urgent warnings to the general public need to be broadened to include links to home and cellular telephones and television sets. Appropriate Federal agencies need to examine these alternatives and look for ways to disseminate information in the absence of electrical power. Finally, the Federal Emergency Management Agency (FEMA) should assist all emergency broadcast systems in obtaining the latest available technology before the end of the 1990's and test the effectiveness of these stations during catastrophic events.

WHILE THE NATURAL HAZARD IS STRIKING

Intervention

Even while a natural hazard is in progress, actions can be taken to reduce its impact. Such actions include sandbagging to hold water back during a flood or hurricane, getting under a table or in an interior doorway during an earthquake, or going to a cellar as a tornado approaches. During natural hazards such as droughts, wildfires, or insect and disease outbreaks, agencies can intervene in a coordinated effort to mitigate the damaging effects of those hazards. For those hazards that can be suppressed or controlled by a coordinated Federal, State, and local effort, added emphasis is needed to improve (1) coordination of disaster-response resources, (2) tactical and logistical responses to disasters, and (3) training of supplemental response forces at the scene of the event.

Coordination of Resources. Just before and during the onset of a natural hazard, existing or preplanned coordination centers organize and mobilize resources (people and equipment) to stop or reduce the severity of the hazard's impact. Initial priority should be on developing a natural disaster coordination and communication program that promotes an interagency approach to disaster events at all government levels. At the Federal level, for example, the Catastrophic Disaster Response Group, chaired by FEMA, coordinates Federal response efforts as it did during the Loma Prieta earthquake. Likewise, the U.S. Public Health Service, an agency of the Department of Health and Human Services, works with the States to provide health services, civilian health personnel, and health resources during emergencies. Similar organizations need to be in place at the State and local levels. Federal agencies should encourage these efforts.

Tactical and Logistical Response. This category includes evacuation, suppression, and control activities; the supporting organization and supplies for tactical forces at a disaster site; and rapid, early assessment of the health care needs of disaster-affected populations in order to efficiently match resources to needs and prevent further adverse health effects. Because the lead response agency does not always have the resources needed for suppression, an interagency, multilevel (Federal, State, and local) response system needs to be developed to ensure adequate resources. The Boise Interagency Fire Center in Idaho is one such example. From a central location, professionally trained State and Federal crews, mobile communication systems, food, equipment, supplies, and other support systems can be dispatched immediately to a disaster site anywhere in the Nation. As part of the U.S. strategy, Federal agencies, in cooperation with State and local governments, must ensure that the proper response mechanisms are in place at all levels of government by the year 2000.

On-the-Spot Training. Because a disaster, by definition, exceeds local response capacity, real-time training of volunteer and professional response forces is needed to suppress a disaster and thereby reduce its impacts. Onsite emergency training procedures need to be developed to ensure the safety and effectiveness of these response forces. The procedures should be part of the FEMA review of State and local emergency response plans and the exercise of those plans. During the 1990's, training procedures should be put in place for all emergency response plans at all levels of government.

AFTER THE NATURAL HAZARD STRIKES

Emergency Assistance

After a major disaster had exceeded the coping mechanisms of local and State governments, the Federal Government provides emergency services, communications, financial assistance, and, in some cases, special teams for search and rescue. To improve emergency assistance even further, we need to (1) enhance emergency assistance capabilities, (2) improve communications, (3) provide timely technical assistance, and (4) implement a national system of search-and-rescue teams.

Emergency Services. The Federal Government has formed a National Disaster Medical System designed to care for victims of an incident that exceeds the medical capability of an affected State, region, or Federal medical care system. In addition, when requested by the Governor of a State after a Presidential disaster declaration, the Federal Government can provide water and emergency power. The Federal Government should encourage State and local governments to construct water and power systems and medical facilities that can remain operational during and after a natural disaster.

Communications. When a disaster strikes, communication and public information stations are needed to handle inquir-

ies about disaster victims, where disaster assistance and emergency services can be obtained, and what to do during the recovery effort. Following previous disasters, many government officials and disaster victims have been unaware of the assistance that was available and how to obtain it.

Financial Assistance. Much of the financial assistance available after a disaster comes from State and local funds. When coping with a major disaster exceeds the capacity of a local or State government, Federal agencies can help. The U.S. Department of Agriculture (USDA), for instance, provides major financial assistance to farmers and ranchers struck by disasters. The Governor of an affected State can request assistance from the President through FEMA. This assistance includes funds for temporary housing, home repair, and individual and family grants and help to State and local governments and private nonprofit organizations that provide services of a governmental nature: education, utilities, emergency services, and medical custodial care. Public assistance may be used to fund clearance of debris, emergency protective measures for the preservation of life and property, and repair or replacement of roads, streets, bridges, public utilities, and recreational facilities and parks.

Search and Rescue. During and after some disasters, survivors are buried in the debris of damaged or destroyed buildings. Search and rescue must take place within hours after a disaster occurs. After 48 hours, few victims are found alive. Because time is of the essence, local search and rescue capabilities need to be improved. When that capability is still not enough, Federal, State, and local resources can be applied. A national system of search and rescue teams is needed. These teams can be "on call" and readily dispatched to areas needing their services. Consisting of members from the public and private sector, they must meet established criteria and be able to respond immediately following a disaster. A directory is also needed to list

state-of-the-art equipment that can be sent to disaster areas. FEMA, for example, has initiated an effort to organize a national search-and-rescue system in the United States. This system will identify, certify, train, equip, mobilize, and deploy civilian search-and-rescue task forces. Within 6 hours of activation, these task forces can meet at predetermined airfields and be airlifted by the Department of Defense to a disaster site.

Recovery

As the emergency period following a disaster wanes, a community enters a long period of recovery, redevelopment, and restoration. Mitigation is a key element in the recovery effort, providing an opportunity for Federal, State, and local governments to rebuild or remodel structures in accordance with acceptable disaster mitigation techniques such as elevating the lowest floors in flood-prone buildings, using fire- and seismic-resistant design codes, or removing structures from identified floodways. Principal elements of recovery include (1) damage assessment, (2) restoration and modification, and (3) information collection and dissemination to increase knowledge about natural disasters and improve plans for future probable events. These steps can substantially minimize the impact of future hazards. However, care should be taken that no recovery strategy for a specific hazard exacerbates vulnerability to other hazards.

Damage Assessment. Damage assessments after an event require, in part, good inventories of the conditions of buildings, structures, services, lifelines, and natural resources. Federal agencies need to individually or collectively prepare such inventories and evaluate the ability of natural and manmade systems to resist future natural hazards. Professional contacts, tools, resources, and effective damage assessment methodologies also need to be identified and listed in a resource data bank. Detailed,

realistic damage assessments are required to determine funding necessary for recovery.

Restoration and Modification. Disasters are sometimes referred to as opportunities to rebuild a community so that it will not suffer such great losses from future natural hazards. However, there must be a strong commitment from citizens and the local government of a disaster-affected community to rebuild in a manner consistent with the best hazard mitigation techniques and to recognize that a few months' delay and additional costs are worthwhile in order to avoid the same damage during the next disaster. Once cost estimates for repair, restoration, and rehabilitation are furnished, priorities must be established and decisions made on short- and long-term restoration projects and service modifications. The restoration phase should see the rebuilding of destroyed property, the implementation of rehabilitation plans, the relocation and substitution of resources and services such as water and sewage, and the modification of programs to mitigate against future disasters. Where feasible, this phase also includes the restoration and rehabilitation of ecosystems damaged by natural disasters. Federal agencies need to work with State and local governments to create a hazard mitigation mentality and to overcome the "it won't happen here" attitude. Hazard mitigation can come only through the efforts of local governments, assisted technically and financially by Federal and State Governments. Moreover, Federal agencies need to work with State and local governments to develop hazard mitigation plans that can be used in the recovery effort after a disaster.

Learning from Disasters. Responding Federal agencies, in partnership with other agencies and organizations in both the public and the private sectors, must conduct postevent audits of what went right and what went wrong. These audits should contain, at a minimum, the following: physical characteristics of the hazard, characteristics of land use in the impacted area, adjustments adopted in the area, the

extent to which adjustments functioned, ways in which governmental bodies responded in relation to preparedness plans and legal missions, efforts to reduce impact-related morbidity and mortality, and changes in operating procedures and policies for more effective future response to hazards. Information must then be disseminated widely, both domestically and internationally, to all levels of government, professionals, code organizations, private industry, and the public.

SPECIAL COOPERATIVE PROJECTS: U.S. STRATEGY FOR NATURAL DISASTER REDUCTION

A strong U.S. strategy needs major, unifying projects, built on existing activities, that reduce losses from natural hazards. We suggest four categories of special cooperative projects:

Natural Hazard Prediction Experiments: Research must be conducted in selected natural laboratories to improve the scientific basis of and methods for predicting natural hazards.

Disaster Prevention Resource Networks: Networks must be created to share information, people, and equipment, regionally and nationwide, for disaster prevention.

Hazard-Resistant Communities: Intensive application of disaster mitigation techniques will demonstrate how communities can increase their resistance to disasters.

Natural Hazards Round Tables: Thought-provoking forums must be held to ensure that various parts of the hazards community learn from one another.

Each project can make a special contribution to the Nation and also to the IDNDR and add interdisciplinary, multihazard activities that can best be begun in the cooperative climate of the 1990's. Each project provides opportunities for integrating the progress made in individual Research and Applications Elements of the strategy and for testing and evaluating, before full-scale implementation, proposed changes in hazard prevention and mitigation practices.

Natural Hazard Prediction Experiments

The U.S. strategy presents an opportunity for advanced research on the origins, processes, and, thus, predictability of natural hazards. In general, nature is the laboratory, and the interactions of hazardous events with society are the experiments. Those areas of the Nation and the world that experience more frequent events of small to moderate size can be used as natural laboratories to study and predict the effects of larger, more serious events. As physical and life scientists develop prediction capabilities for natural hazards, social scientists can examine the economic and public policy implications of natural hazard prediction.

We propose that U.S. scientists select one or more natural laboratories for intensive, multidisciplinary, multinational studies of each major hazard. These areas will be designated, for example, as "Decade Volcanoes," "Decade Floodplains," or "Decade Wildfire Areas." Focused effort in this relatively small number of natural laboratories will (1) advance the fundamental understanding of how each natural hazard system works, (2) advance the state of the art in the prediction of each hazard, (3) address societal responses to predictions, (4) serve as U.S. laboratories for international collaboration, and (5) demonstrate how multidisciplinary, multinational research can expand the frontiers of single-hazard, single-agency domestic research.

Some areas have already been selected and used for years—for example, a segment of the San Andreas fault near Parkfield, Calif., for an earthquake prediction experiment and the H.J. Andrews Experimental Forest near Eugene, Oreg., for landslide prediction. Mount Rainier in Washington State has just been nominated as a Decade Volcano, and other Decade laboratories will be selected soon.

If, as expected, other nations designate similar natural laboratories, exchanges between Decade laboratories

around the world will form a powerful basis for comparative studies and experiments. Each showcase or demonstration project can host colleagues from other nations. Participants will bring both the experience and the thought paradigms of their own countries to bear on the host nation's project. We expect the synergism and energy of these projects to be high.

Finally, some prediction experiments can best be conducted in large regions encompassing several countries and will thus, of necessity, be international projects. Such experiments will be especially applicable to hazards that affect large regions such as drought, hurricanes, insects, and diseases.

Disaster Prevention Resource Networks

Although some communities, States, and Federal agencies have a remarkably good capacity for coping with natural hazards, none has all of the expertise or physical resources needed to deal with the impacts of natural disasters. From time to time, even the most technologically advanced need help from their neighbors. It is necessary, wise, and efficient for those concerned with disasters to establish networks of information and physical and financial resources. Such networks will enable communities to handle routine matters by themselves but draw on others when needed. Pilot disaster prevention resource networks will be developed, each including an information resources network and one or more regional resource centers.

Information Resources Network. As a pilot project, a network that could initially cover a small geographic area will draw on selected data bases that have been reformatted into a common geographic information system (GIS) for easy access. New GIS technology permits interactive visu-

alization and analysis of any natural hazard or combination of hazards, population densities, streets, lifelines of communities at risk, and other information that can be shown on maps. Different types of information can be overlain, and degrees of risk can be aggregated. Data bases, drawn from various Federal agencies, will include base maps onto which special features can be plotted, including those related to each hazard and the community infrastructure. The GIS might also provide references to case studies of successful and unsuccessful disaster mitigation efforts, a directory of resource persons, and other nonspatial data. One important goal of such a network is to simplify a community's search for information from many sources and its efforts to compare information that is presently given at different scales and uses different terminology. To be successful, this project needs to be broken down into manageable units and the units prioritized for what managers really need.

Generalized maps of each hazard could be made available on line or on CD-ROM. Then, if possible, details of hazards within specific counties and cities could be added. Similarly, annotated bibliographies, case histories, or guides to resources could be made available on line or on CD-ROM. A hazards help line could be offered as part of this package. Eventually, when telecommunication links are established between most information sources and users, information could be updated in near real time.

Rapidly improving artificial intelligence (AI) expert system software and new graphics capabilities for small computers offer new potential for packages or modules that can guide State and local users through the process of gathering hazards information and using it in their decisions. Modules will cover many of the same topics presently covered by more conventional training courses but will have the added advantage of being linked directly to the data bases of a natural hazards GIS. Modules can include:

- **General hazards information.** For each category of natural hazard (for example, droughts, earthquakes, hurricanes, wildfires), a corresponding module will address the physical and biological nature of the hazard, its predictability, and current and developing options for mitigation. It should also note collateral hazards (cross references to other modules).

- **"How to" information.** Various topics included are:

  Multihazard assessment
  Risk assessment
  Assessing community interest in disaster prevention
  Reducing vulnerability of structures, lifelines, communities
  Building codes
  Land-use zoning
  Water conservation
  Alternative land and agricultural practices for hazard resistance
  Cost-benefit analysis of mitigation options
  Tapping Federal resources for disaster prevention
  Community and citizen education
  Warning systems
  Planning and coordinating for emergency response
  Emergency assistance
  Emergency services (for example, medical, water, power, food, shelter)
  Financial assistance (for example, Federal, State)
  Search and rescue
  Damage assessment
  Recovery planning to reduce future impacts and occurrences

Regional Resource Centers. Regional resource centers—such as the Boise Interagency Fire Center, FEMA's training facility at Emmitsburg, Md., and similar centers within various Federal agencies—will focus on training and preparation of educational materials. They will also focus on

emergency communications, command structure, interagency operating agreements, and stockpiles of disaster response equipment and supplies. Some may offer the full spectrum of information and operational support. They may also serve as disaster information centers—that is, as the focal points for information needed by and supplied to the general public. Each could serve as a training center for the natural hazards GIS/expert system package(s) proposed above. Each could also host visitors from other nations.

Opportunities for international disaster resource networking abound. The most difficult choices will be "where first?" One such project has already been planned—a regional hazards telecommunications network for the Caribbean and Central America. That network will facilitate two-way communication of meteorological, seismological, and other data throughout the region to central facilities for data analysis. On the basis of these data, these centers will be able to issue warnings to all member countries. This important project will serve a hurricane and flood prediction experiment and will disseminate information about all natural hazards and mitigation techniques.

Hazard-Resistant Communities

Only a relatively small number of communities take as many precautions, warranted by existing risk, as current knowledge and technology permit. Some of the barriers are political or bureaucratic; some reflect only a shortage of capital with which to take precautionary measures. We think that selected communities, in partnership with State and local governments and Federal agencies, can raise their standards of hazard preparedness to such high levels that they could serve as examples of what can be achieved and how it can be achieved. The success of these "hazard-resistant" communities can then be shared with other communities around the country.

The strategy will promote "hazard-resistant communities," in which intensive multiagency, multilevel, multidisciplinary efforts will be directed toward making communities resistant to natural disasters. Each community that strives to improve its resistance to natural hazards will have to adopt and implement demanding policies that require changes in building codes, new or modified agricultural land and water management practices, strengthening of structures, and land-use zoning. Federal and State Governments can assist local governments through legislation, direct and indirect financial incentives, and technical assistance. Such assistance may include grants for specific hazard mitigation projects, requirements that hazards be considered in the granting of federally backed mortgages (as in the National Flood Insurance Program), technical assistance through personal contacts or written material, training schools, or other incentives provided by Federal programs. Incentives from the private sector could include lowering insurance and, possibly, mortgage rates if local governments take measures to lessen the effects of natural hazards.

Emphasis will be on the application of existing knowledge. Work will begin with the use of GIS/AI expert systems to guide the collection of local hazards information. Using this local information, these GIS/AI expert systems will provide input to those making and implementing risk-reducing policy decisions.

Many programs, incentives, and partnerships already exist. These demonstration projects will not duplicate existing programs but will instead help to focus multiple programs in selected hazard-resistant communities. Communities that already have well-developed disaster prevention capabilities, such as the City of Los Angeles, could participate as demonstration areas or help other communities to do so.

The international component of this project will focus on the "networking" of communities worldwide that are faced with similar sets of natural hazards and that have (or wish to

begin) intensive efforts like those of hazard-resistant communities. For example, communities in Japan, the United States, the Caribbean nations, the Philippines, and other nations that are successfully coping with similar problems of earthquakes, hurricanes (typhoons), landslides, and floods could share the best of their strategies. Exchanges akin to those of "sister cities" could be a valuable part of this activity.

Natural Hazards Round Tables

Those who have worked in an interdisciplinary environment can attest to the excitement of working on a problem from many angles. Each of the preceding projects will offer interdisciplinary environments, but none will draw from the entire hazards community. Often, it is the people we don't normally talk with who bring the most stimulating new insights to the table. Therefore, the strategy will promote annual thought-provoking forums to ensure that all parts of the hazards community have a chance to learn from one another.

We propose a loosely hierarchical series of natural hazards "round tables," held successively through the year, to promote the flow of ideas from the grassroots up. First-tier round tables will be held within local communities and within relatively narrow scientific communities; representatives from each of these groups will then join progressively more general forums. Each year, round tables will address one or two problems that are of general interest and especially conducive to this type of discussion. Topics may include, for example, how to determine acceptable risk, how to make quantitative estimates of risk (including probabilities) understandable to the public, how to judge the social and economic cost effectiveness of hazards mitigation, whether and how to achieve standardization in predictions and warnings, and how specific disasters might have been

averted. Special emphasis will be given to methodologies and the most difficult issues of natural disaster reduction.

These round tables will be closely coordinated with an annual hazards conference convened by the University of Colorado and with any similar efforts that might be proposed by the National Research Council, provided that focus is maintained on just a few issues per year. The strategy will encourage extension of these round tables into the international arena by inviting foreign colleagues and counterparts to our round tables at all levels, local to national, and by offering to host one or more of the international round tables with representatives from other nations.

U.S. STRATEGY FOR NATURAL DISASTER REDUCTION BUDGET: FY 1990

FY 1990 Budget Summary

The SNDR conducted a program/budget analysis to show existing Federal natural disaster reduction activities; to identify gaps in knowledge, mitigation practices, and expertise that can be reduced by a coordinated effort; and to establish a base funding level for an effort that will benefit the Nation.

Tables 2a, 2b, 3a, and 3b present the results of the budget analysis by agency and by the Research and Applications Elements in the strategic framework. Tables 2a and 2b show focused dollars—that is, dollars spent on agency programs, activities, or new initiatives that address the explicit goals and objectives of the U.S. strategy. Tables 3a and 3b show contributing dollars—that is, those dollars committed to agency activities or new initiatives that are justified on a basis other than specific natural hazards research and applications but that contribute substantially to the goals and objectives of the U.S. strategy.

Conservative estimates of the average annual costs and losses from natural disasters in the United States exceed $6 billion. In 1989, they exceeded $15 billion. These figures by no means capture the costs of environmental degradation, short- and long-term recovery and rehabilitation, impacts on local and regional economies, and the intangible costs to human health and well-being caused by natural disasters. In comparison, focused Federal expenditures for natural disaster activities in FY 1990 exceeded $2.5 billion (tables 2a, 2b). In FY 1990, 4 percent of the focused dollars were devoted to research and 96 percent to applications.

Budget by Element

A perspective of the U.S. natural disaster effort can be gained by comparing focused Federal expenditures in each of the Research and Applications Elements. Contributing program expenditures are listed where relevant.

Research Elements

Climate, Weather, and Hydrologic Systems. FY 1990 focused expenditures were $20 million. Primary activities included investigations of severe weather (DOC/NOAA; NSF; NASA), floods (DOE; USDA/SCS; DOC/NOAA; USACE), and drought (USDA/SCS and FS; USACE). In some cases, such as hurricanes and coastal flooding, the relationships between severe weather events and the secondary results are better understood. In other cases, the linkages between climate, weather, and natural hazards such as drought, wildfires, and pestilence are less well known. Contributing dollars were $28.2 million in FY 1990.

Solid Earth Processes. FY 1990 focused expenditures were $53.5 million. Primary activities included research conducted by DOI/USGS on a variety of solid earth processes to improve the prediction of earthquakes, volcanic eruptions, and landslides. Research was also conducted by DOE, and grants were issued by NSF for related investigations. Contributing research was conducted by USACE on erosion, bank stabilization, and liquefaction. Contributing dollars were $13.5 million in FY 1990.

Ecosystem Processes. FY 1990 focused expenditures were $3.2 million. Research was conducted primarily by the USDA/FS to improve our understanding of wildfires and outbreaks of forest insects and diseases and to determine the impacts of these natural hazards on wildland ecosystems. Contributed research efforts by NASA, EPA, and DOE focused on ecosystem monitoring and change and on

Table 2a. Agency budgets for fiscal year 1990 for Research Elements (focused dollars)

[In millions of dollars]

Agency	Total budget	Climate, Weather, and Hydrologic Systems	Solid Earth Processes	Ecosystem Processes	Engineering Systems	Managed Environmental Systems	Behavior, Health, and Communication	Institutional Opportunities and Constraints	Economics
Agency totals	102.8	20.0	53.8	3.2	20.9	2.5	0.0	1.5	0.9
DOE	.0	.0	.0	.0	.0	.0	.0	.0	.0
EPA	.0	.0	.0	.0	.0	.0	.0	.0	.0
FEMA	.0	.0	.0	.0	.0	.0	.0	.0	.0
FERC	.0	.0	.0	.0	.0	.0	.0	.0	.0
HUD	.0	.0	.0	.0	.0	.0	.0	.0	.0
NASA	.0	.0	.0	.0	.0	.0	.0	.0	.0
DOC/NIST	2.0	.1	.0	.0	1.9	.0	.0	.0	.0
DOC/NOAA	13.2	13.2	.0	.0	.0	.0	.0	.0	.0
NSF	34.5	4.7	10.0	.0	17.5	.0	.0	1.5	.8
AID/OFDA	.0	.0	.0	.0	.0	.0	.0	.0	.0
USACE	.0	.0	.0	.0	.0	.0	.0	.0	.0
USDA/FS	7.8	.5	.0	3.2	1.5	2.5	.0	.0	.1
USDA/SCS	.3	.3	.0	.0	.0	.0	.0	.0	.0
DOI	45.0	1.2	43.8	.0	.0	.0	.0	.0	.0

Table 2b. Agency budgets for fiscal year 1990 for Applications Elements (focused dollars)

[In millions of dollars]

Agency	Total budget	Preparation	Prediction and Warning	Intervention	Emergency Assistance	Recovery
Agency totals	2663.1	760.2	328.5	1139.1	149.3	286.0
DOE	216.5	211.0	.5	.0	.0	5.0
EPA	.0	.0	.0	.0	.0	.0
FEMA	409.8	122.4	16.9	.5	.0	270.0
FERC	11.3	1.8	9.5	.0	.0	.0
HUD	.0	.0	.0	.0	.0	.0
NASA	81.2	.0	.0	.0	81.2	.0
DOC/NIST	.0	.0	.0	.0	.0	.0
DOC/NOAA	285.8	.0	285.7	.0	.0	.1
NSF	1.0	1.0	.0	.0	.0	.0
AID/OFDA	60.0	4.0	2.0	.0	54.0	.0
USACE	798.8	23.4	.7	765.0	.6	9.1
USDA/FS	424.0	44.4	4.6	372.7	1.0	1.3
USDA/SCS	104.5	85.7	5.4	.9	12.5	.0
DOI	270.2	266.5	3.2	.0	.0	.5

Table 3a. Agency budgets for fiscal year 1990 for Research Elements (contributing dollars)

[In millions of dollars]

Agency	Total budget	Climate, Weather, and Hydrologic Systems	Solid Earth Processes	Ecosystem Processes	Engineering Systems	Managed Environmental Systems	Behavior, Health, and Communication	Institutional Opportunities and Constraints	Economics
Agency totals	57.6	28.2	13.5	7.0	7.5	1.1	0.1	0.1	0.1
DOE	3.0	.4	.7	.5	1.0	.1	.1	.1	.1
EPA	2.5	.0	.0	1.5	.0	1.0	.0	.0	.0
FEMA	.0	.0	.0	.0	.0	.0	.0	.0	.0
FERC	.0	.0	.0	.0	.0	.0	.0	.0	.0
HUD	.0	.0	.0	.0	.0	.0	.0	.0	.0
NASA	37.0	20.0	12.0	5.0	.0	.0	.0	.0	.0
DOS/NIST	6.0	.0	.0	.0	6.0	.0	.0	.0	.0
DOC/NOAA	7.3	7.0	.3	.0	.0	.0	.0	.0	.0
NSF	.0	.0	.0	.0	.0	.0	.0	.0	.0
AID/OFDA	.0	.0	.0	.0	.0	.0	.0	.0	.0
USACE	1.8	.8	.5	.0	.5	.0	.0	.0	.0
DA/FS	.0	.0	.0	.0	.0	.0	.0	.0	.0
USDA/SCS	.0	.0	.0	.0	.0	.0	.0	.0	.0
DOI	.0	.0	.0	.0	.0	.0	.0	.0	.0

Table 3b. Agency budgets for fiscal year 1990 for Applications Elements (contributing dollars)

[In millions of dollars]

Agency	Total budget	Preparation	Prediction and Warning	Intervention	Emergency Assistance	Recovery
Agency totals	732.6	140.3	162.0	13.8	0.5	416.0
DOE	22.5	20.0	.5	.5	.5	1.0
EPA	.0	.0	.0	.0	.0	.0
FEMA	.0	.0	.0	.0	.0	.0
FERC	.0	.0	.0	.0	.0	.0
HUD	.0	.0	.0	.0	.0	.0
NASA	.0	.0	.0	.0	.0	.0
DOC/NIST	.0	.0	.0	.0	.0	.0
DOC/NOAA	158.7	.2	158.5	.0	.0	.0
NSF	.0	.0	.0	.0	.0	.0
AID/OFDA	.0	.0	.0	.0	.0	.0
USACE	487.2	55.9	3.0	13.3	.0	415.0
USDA/FS	.0	.0	.0	.0	.0	.0
USDA/SCS	.0	.0	.0	.0	.0	.0
DOI	64.2	64.2	.0	.0	.0	.0

the ecological effects of natural disasters. Investigations are needed to better understand and predict multiple-hazard interactions, ecosystem responses to environmental stressors, origins and behavior of wildfires and pestilence outbreaks, and the effects of catastrophic events on environmental quality and health. Contributing dollars were $7.0 million in FY 1990.

Engineering Systems. FY 1990 focused expenditures were $20.9 million. Primary activities included research grants issued by NSF to investigate the effects of high wind loads and strong ground motion on structures and lesser expenditures by DOC/NIST, USDA/FS, and USACE. USACE examined the effects of ground motion on structures and also conducted studies on search-and-rescue techniques, remote sensing, and GIS. Emphasis has been placed on the reaction of structures to stress, "intelligent buildings," hazard-resistant materials and design, and research leading to the upgrading of local building codes in vulnerable areas. Contributing dollars were $7.5 million in FY 1990.

Managed Environmental Systems. FY 1990 focused expenditures were $2.5 million. Vegetation management research focusing on the use of prescribed fire and research to develop biological controls for major forest pests were conducted by the USDA/FS in an effort to reduce the impacts of hazards on the natural environment. EPA's research on methods to determine the environmental and ecological impacts of genetically engineered biological control agents contributed to this research effort. Contributing dollars were $1.1 million for FY 1990.

Behavior, Health, and Communication. There were no FY 1990 focused expenditures reported for this area. HHS/CDC investigated the health and medical consequences of Hurricane Hugo, the Loma Prieta earthquake, tornadoes in Illinois and Kansas, a cyclone in Bangladesh, and the eruption of Mount Pinatubo in the Philippines. DOE contributing dollars were $0.1 million for FY 1990.

Institutional Opportunities and Constraints. FY 1990 focused expenditures were $1.5 million. Most of this research was conducted under grants issued by the NSF along with some work by DOE. Limited data are available to show what role public and private sector institutions play in minimizing losses, injuries, and damages from natural disasters. Contributing dollars were $0.1 million for FY 1990.

Economics. FY 1990 focused expenditures were $0.9 million. Most of the research was conducted under grants issued by NSF. Additional studies were done by DOE. Accurately estimating the costs and benefits of disaster reduction measures, the economic impacts of natural hazards, and the costs of rehabilitation is difficult. Additional research in these areas would greatly aid economic analyses and enhance decisionmaking for disaster reduction. Contributing dollars were $0.1 million for FY 1990.

Applications Elements

Preparation. FY 1990 focused expenditures were $494.8 million. DOE and FEMA conducted major disaster preparation activities. Significant efforts were also made by the USACE and USDA/SCS and FS. These preparation efforts include plans, construction, training, exercises, and establishment of necessary management mechanisms. The Presidential Order requiring all Federal facilities to be earthquake proofed should increase expenditures in this area temporarily during the next few years. Although HHS/CDC did not report expenditures, it played a major role in developing contingency plans for a catastrophic earthquake in California before the Loma Prieta earthquake and is currently working with the Central U.S. Earthquake Consortium to enhance emergency preparedness and response procedures for a catastrophic earthquake in the New Madrid seismic zone. Contributing dollars were $76.1 million in FY 1990.

Prediction and Warning. FY 1990 focused expenditures were $328.5 million. The majority of the funding was for DOC/NOAA's modernization of the National Weather Service. Lesser amounts were spent by DOE, FEMA, FERC, AID/OFDA, USDA, USACE, and DOI/USGS for prediction and warning. Expenditures were for improving the accuracy and timeliness of warnings, data collection and development of warnings, and the systems used to disseminate those warnings. Contributing dollars were $162 million in FY 1990.

Intervention. FY 1990 focused expenditures totaled $1,139.1 million. Most of this funding reflected USACE flood and coastal-storm prevention and mitigation activities and USDA/FS efforts to coordinate presuppression forces, suppress wildfires, and train firefighting forces. To a lesser extent, FEMA and USDA/SCS also conducted intervention activities. Contributing dollars were $13.8 million in FY 1990. These USACE dollars focused on efforts to ensure that existing flood-control works are viable and effective.

Emergency Assistance. FY 1990 focused expenditures were $149.3 million, reflecting primarily NASA's emergency communications satellite operations, AID/OFDA's expenditures overseas, and USDA/SCS activities in rural areas. HHS/CDC conducted emergency assistance operations in the United States and many other countries (expenditures were not reported). Lesser amounts were spent by USACE and USDA/FS for emergency assistance. Contributing dollars were $0.5 million in FY 1990.

Recovery. FY 1990 focused expenditures were $286 million and reflect the Federal contribution, primarily through FEMA, to domestic recovery from natural disasters. To a lesser extent, DOE, USDA/FS, DOC/NOAA, USACE, and DOI/USGS contributed to these efforts. The aim is to reduce unbudgeted, postevent expenditures, which are routinely handled through supplemental appropriations, in this category and in the previous one. Contributing dollars

were $416 million in FY 1990. The USACE dollars reflected the operation and maintenance of USACE projects.

Budget by Agency

Individual agency efforts reflect their particular mission and involvement in scientific, technical, and operational activities to reduce the occurrence and impacts of natural disasters.

Department of Energy. FY 1990 focused expenditures were $216.5 million for updating hazard models; developing design standards and guides; evaluating safety risks due to natural hazards; modifying and strengthening existing buildings and facilities; designing and constructing new facilities; energy emergency activities, including interaction with State and Federal agencies and energy industries; facility and site emergency planning, preparedness, and response activities; research and development; technology transfer, training, conferences, and learning from disasters; and reporting and evaluating the losses due to natural hazards at DOE sites. Contributing dollars were $25.5 million for FY 1990.

Environmental Protection Agency. EPA works to prevent and respond to hazardous material releases and related incidents that are caused by natural disasters. Building on EPA's existing statutory response activities under the National Oil and Hazardous Substances Pollution Contingency Plan, EPA will provide managerial and technical leadership to State and local governments requesting assistance with hazardous materials releases, damage to hazardous materials containers, fires involving hazardous materials, stabilizing leaks and spills to protect public safety and the environment, and related incidents caused by natural disasters. EPA also conducts environmental research contributing to our understanding of natural hazards. The Environmental Monitoring and Assessment Program pro-

vides statistically determined baselines on ecosystem status from which to measure and understand the impacts of disasters. Research is also conducted to determine the environmental and ecological impacts of genetically engineered biological agents and to assess the cumulative loss of wetlands on the frequency and severity of floods. Contributing dollars were $2.5 million for FY 1990.

Federal Emergency Management Agency. FY 1990 focused expenditures totaled $409.8 million. FEMA, more than any other Federal agency, provides financial and technical assistance to State and local governments to prepare for, respond to, and recover from natural disasters. This assistance is delivered through the Civil Defense Program, which provides a system of survival capabilities to protect life and property from natural hazards through the construction of emergency operation centers and warning systems and the training of State and local emergency managers. Other FEMA programs assisting the natural hazard reduction efforts of State and local governments are:

- The National Flood Insurance Program, which makes flood insurance backed by the U.S. Government available to communities that have agreed to adopt and enforce floodplain management ordinances to reduce future flood losses through wise utilization of their floodplains.

- The Fire Prevention and Control Programs of the U.S. Fire Administration, which provide training and grants that support the efforts of State and local governments to reduce the number of fires nationwide and the loss of life and property from fire.

- The National Hurricane Preparedness Program, which provides financial assistance, in cooperation with DOC/NOAA and USACE, to develop State hurricane evacuation plans and property protection procedures to reduce the loss of life and property from hurricanes.

- The National Earthquake Hazards Reduction Program, in which FEMA, together with USGS, NIST, and NSF, provides to State and local governments the materials and assistance needed to educate citizens living in earthquake-prone areas about earthquake hazards, the technical guidance and assistance for erecting seismic-resistant buildings and implementing other mitigation procedures, and the training and information for preparedness, response, and recovery from earthquakes.

- The Disaster Assistance Program, which provides individual and public assistance to communities struck by a disaster. FEMA coordinates the Federal effort to assist in recovery activities and provides financial assistance to affected disaster victims.

Federal Energy Regulatory Commission. FY 1990 focused expenditures totaled $11.3 million for monitoring the safety of non-Federal hydroelectric developments. The expenditures were for engineering projects, inspections, and prediction and warning. Although FERC does not contribute dollars directly to disaster reduction research, it has actively participated in the Electric Power Research Institute's (EPRI) research activities on dam safety, for which EPRI has a budget of over $3 million annually. In addition to its responsibility for inspecting over 2,000 non-Federal hydroelectric developments, FERC also inspects DOE dams, pursuant to a Memorandum of Agreement with DOE. The annual budget for inspecting DOE dams is approximately $200,000.

Department of Health and Human Services/Centers for Disease Control. HHS/CDC expenditures (not reported) are for disaster preparedness, prevention, response, and research activities. The agency's responsibilities in the area of emergency preparedness and response included (1) provision of technical and epidemiologic assistance to State and local governments before and after disasters, (2) documentation and quantification of the public health consequences

of different types of natural and technological disasters, (3) identification of potential strategies through risk factor analysis that may prevent or mitigate these consequences, (4) development of prevention programs and contingency measures, (5) development and maintenance of national systems for acute environmental hazard surveillance that tracks deaths and serious injuries related to natural disasters, (6) rapid assessment of health care needs in the immediate postdisaster period, (7) assessment of health risk, and (8) provision of epidemiologic and scientific support to other agencies involved in disaster planning and response. As a recently designated World Health Organization Collaborating Center for Disaster Preparedness and Response, HHS/CDC can also provide similar assistance to foreign governments and intergovernmental organizations such as the Office of the U.N. Disaster Relief Coordinator, UNICEF, and the League of Red Cross and Red Crescent Societies.

Department of Housing and Urban Development. There is no HUD funding identified exclusively for natural hazard mitigation. In FY 1990, however, $22.8 billion was expended for grants, structure rehabilitation, mortgage insurance, and subsidies. Because all HUD projects must meet existing building codes, a major national benefit of this strategy would be to strengthen those codes on the basis of focused research. Additionally, the 1990 National Affordable Housing Act mandates that HUD conduct seismic risk assessment studies and develop seismic safety standards in compliance with Executive Order 12699 on Seismic Safety.

National Aeronautics and Space Administration. FY 1990 focused expenditures totaled $81.2 million for emergency assistance. Of this, $1.15 million was being expended on the development of improved search-and-rescue capability. The balance represented a portion of the cost of developing satellite-based mobile communications for use in emergency assistance. In addition, research efforts from the Global Change Research Program (including portions of

the EOS and Earthprobe missions) contribute substantially to the U.S. strategy. These efforts include measurements of rainfall, wind velocities, soil moisture, and crustal strain. Contributing dollars were $37 million in FY 1990.

Department of Commerce/National Institute of Standards and Technology. FY 1990 focused expenditures totaled $2 million. Of the $1.9 million allocated to Engineering Systems, $1.3 million are one-time funding, and the remaining $0.6 million constitute the base funding. DOC/NIST's Building and Fire Research Laboratory performs research in natural hazard reduction including improving seismic design criteria for new and existing buildings and lifelines. This research focuses on developing technical criteria and methodologies for strengthening and repairing existing structures and improved technical bases for codes and standards for new and existing buildings and structures. Contributing dollars were $6 million for FY 1990.

Department of Commerce/National Oceanic and Atmospheric Administration. FY 1990 focused expenditures totaled $299 million. The majority was used for the modernization of the NWS; research in climate, weather, and hydrology; and predictions and warnings of atmospheric and oceanic hazards. Smaller amounts were spent on monitoring solid earth processes and on natural hazard preparation and recovery. Contributing dollars were $166 million in FY 1990.

National Science Foundation. FY 1990 focused expenditures totaled $34.5 million to support research on extreme wind structure, characteristics, and effects; solid earth processes and characteristics and the effects of strong motion on structures; extreme hydrologic events and their processes, characteristics, and consequences; social, institutional, and economic impacts of natural disasters; risk management; and expert and decision-support systems.

Agency for International Development/Office of U.S. Foreign Disaster Assistance. OFDA administers the U.S. Government's International Disaster Assistance (IDA) Program in Disaster Prevention, Mitigation, and Preparedness (PMP) and provides international disaster relief. OFDA collaborates with and supports Federal agencies and other public and private entities and coordinates PMP activities with host governments and international organizations, especially in developing countries. The U.S. policy in worldwide disaster prevention emphasizes cost-effective intervention to save lives, reduce suffering, and protect economic assets.

FY 1990 focused expenditures totaled $60 million for disaster assistance abroad, including relief ($54 million) and preparedness ($6 million). Of the $54 million, $25 million was under AID/OFDA's regular appropriations, and $29 million was borrowed from other AID accounts under Section 492 of the Foreign Assistance Act (FAA). An additional $50 million was available under AID/OFDA's borrowing authority (Section 492, FAA).

U.S. Army Corp of Engineers. FY 1990 focused expenditures were $798.8 million for activities accomplished under the agency's emergency preparedness, mitigation, intervention, and recovery programs, which provide for the development of agency plans, exercises, and training; support State and local preparedness and evacuation planning efforts; and provide for interagency planning and coordination activities. Expenditures also included funding for the evaluation, design, and construction of specific projects to mitigate the threats from natural hazards such as floods, hurricanes, coastal storms, and droughts. Contributing funds primarily provide for operation and maintenance of projects and facilities that mitigate the threat of various natural hazards. USACE research and development programs focus on applications. Although research and development dollars identified for natural hazard reduction are

few, many products developed for other purposes have been successfully applied to mitigating the impacts of recent disasters. Contributing dollars were $489 million in FY 1990.

Department of Agriculture/Forest Service. FY 1990 focused expenditures were $431.8 million. The majority of funding was for preparation (primarily emergency planning, wildfire prevention, and wildland fuel modification) and wildfire suppression. Lesser amounts were spent on research examining ecosystem processes; interactions between people, structures, and hazards; vegetation management and biological controls; linkages between climate, weather, and hazards; and post-hazard recovery. Contributing dollars were not reported.

Department of Agriculture/Soil Conservation Service. FY 1990 focused expenditures totaled $104.8 million. Funding was used to aid local communities sponsoring projects to reduce flood and drought hazards; to support programs providing assistance for emergency intervention and recovery; to promote education and awareness; to assist drought prediction and warning; to improve community mitigation planning; and to conduct research on the relationships between soil moisture regimes and agricultural productivity.

Department of the Interior/U.S. Geological Survey. DOI conducts hazard and risk assessments for vulnerability reduction in conjunction with the stewardship of Federal lands and resources. The USGS conducts focused research toward predictions of earthquakes, volcanic eruptions, and landslide hazards, operates seismic networks and volcanic observatories, and conducts other activities to predict and warn of those hazards. The USGS also conducts research in hydrologic processes and gathers data on streams and watersheds that contribute to NOAA/NWS's flood forecasts. FY 1990 focused expenditures for research, preparation, prediction and warning, and recovery totaled $49.8 million.

EPILOGUE: THE FUNDAMENTAL CHALLENGE

Natural disasters occur each year throughout the United States and the world, exacting a heavy toll in human suffering, property loss, and destruction of natural resources. This U.S. strategy to reduce the impact of natural hazards is an opportunity and a challenge to reduce that terrible domestic toll. The 1990's present a challenge to advance our understanding of hazard processes and predictability, to reduce mismatches between risk and preparation, and to control losses through engineering, natural resource management, and other socially responsible and cost-effective measures. It is a challenge to prevent natural hazards from becoming natural disasters.

The basic strategy calls for Federal agencies to integrate existing programs with innovative, interagency, multidisciplinary, international approaches to disaster reduction. In this spirit, we join with other nations participating in the International Decade for Natural Disaster Reduction to create a safer, more productive Nation and world.

APPENDIX: U.S. STRATEGIC LINKAGES

Linkages are an essential part of the SNDR's strategy. The primary linkages will be:

- **Between agencies,** to maximize efficiency, establish or maintain complete systems for hazard mitigation, and ensure that the efforts of each agency complement those of others wherever possible. The CEES/SNDR will provide a substantial part of this linkage by supplementing existing interagency coordination mechanisms such as the National Earthquake Hazard Reduction Program (NEHRP) and by linking earthquake research and applications through the DOI/USGS, NSF, DOC/NIST, FEMA, and 20 other Federal agencies and the Catastrophic Disaster Response Group (CDRG), which links all agencies involved in the Federal Natural Disaster Response Plan.

- **Between disciplines,** to better understand physical and biological systems (for example, systems of drought and wildfires or earthquakes and volcanic eruptions), to share lessons and technology that are common between hazards (for example, technology for multihazard warnings), and to strengthen bonds between natural science, social science, and applications efforts to reduce natural disasters.

- **Between various levels of government,** from the intergovernmental United Nations and its IDNDR, through the SNDR of the Federal Government, to all interested State and local governments.

- **Between programs,** including international programs such as the International Geosphere Biosphere Program (IGBP) and the International Decade for Natural Disaster Reduction (IDNDR); national programs such as the U.S. Global Change Research Program (GCRP) and the

U.S. strategy for natural-disaster reduction and other programs for each hazard or applications activity such as NEHRP and the U.S. Weather Research Program (USWRP). The IGBP and GCRP look at environmental change over long time scales and broad geographic areas.

- **Between nations**, so that disaster prevention can draw on the expertise of counterparts in many countries. The world is a large, open laboratory that experiences many more natural disasters than any single nation. Each country needs to learn from others. Many countries are establishing national programs for the Decade, and the SNDR strategy recognizes the importance of U.S. interaction with these programs.

- **Between sectors**, such as government, the private sector, academia, and private voluntary organizations, each of which makes a complementary contribution to disaster mitigation. The National Research Council's U.S. National Committee for the Decade for Natural Disaster Reduction will work closely with the Federal Government's CEES/SNDR. The U.S. strategy also has strong linkages to two major CEES programs, the Global Change Research Program and the U.S. National Weather Program.

GCRP seeks to gain a predictive understanding of the interactive physical, geological, chemical, biological, and social processes that regulate the total Earth system and thereby establish the scientific basis for national and international policy formulation and decisions relating to natural and anthropogenic changes in the global environment and their regional impacts. Emphasis is on long-range, large-scale climate changes. In contrast, the U.S. strategy focuses on short-term, rapid-onset events. The two, however, are closely linked. The key policy interest regarding global change is the effect of such change on the frequency and intensity of severe local events, such as hurricanes, storm surges, and regional and seasonal

changes in precipitation patterns. Moreover, both programs encompass drought as a focus of interest. A major difference is that GCRP is a research program designed to provide a basis for long-range policy decisions, whereas the U.S. strategy includes actually implementing research findings in preparing for natural disasters; improving existing mitigation, warning, and communication systems; intervening when certain events are in progress; and implementing recovery and emergency management strategies.

USWRP builds on the multibillion-dollar U.S. investment in weather-observing technology and associated telecommunications and automated data processing to improve prediction of local- and regional-scale weather, with emphasis on severe, highly localized events.

- **Between individuals**, including linkages between organizations and programs that make disaster reduction possible. Individuals and linkages between individuals turn possibilities into reality.

BACKGROUND READING

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