The *Grand Challenges for Disaster Reduction* outlines a ten-year strategy crafted by the National Science and Technology Council's Subcommittee on Disaster Reduction (SDR). It sets forth six Grand Challenges that, when addressed, will enhance community resilience to disasters and thus create a more disaster-resilient Nation. These Grand Challenges require sustained Federal investment as well as collaborations with state and local governments, professional societies and trade associations, the private sector, academia, and the international community to successfully transfer disaster reduction science and technology into common use.

To meet these Challenges, the SDR has identified priority science and technology interagency implementation actions by hazard that build upon ongoing efforts. Addressing these implementation actions will improve America's capacity to prevent and recover from disasters, thus fulfilling our Nation's commitment to reducing the impacts of all hazards and enhancing the safety and economic well-being of every individual and community. This is the tsunami-specific implementation plan. See also **sdr.gov** for other hazard-specific implementation plans.

What is at Stake?

DEFINITION AND BACKGROUND. Tsunamis—large, rapidly moving ocean waves resulting from disturbances on the ocean floor—are among the most devastating of all hazards. United States coastal communities are threatened by tsunamis generated by both local and distant sources.

IMPACTS. The Great Alaskan Earthquake and Tsunami was one of the most disastrous seismic events in United States history. The event began when the largest earthquake in North American history struck the Alaskan coast on March 28, 1964. The earthquake caused 115 deaths, 106 of which were the result of tsunamis generated by the quake. Five tsunami waves impacted the United States Pacific Coast from Alaska to California and Canada, resulting in $84 million in damages.[1]

Local tsunamis give residents only a few minutes to seek safety. Tsunamis of distant origin give residents more time to evacuate the threatened coastal areas, but require timely and accurate tsunami forecasts of the hazard to assure proper response and to avoid costly false alarms. For example, residents of Alaska can experience either a local earthquake and local tsunami or tsunamis of distant origin, while residents of Hawaii and the west coast generally experience hazards from distant tsunamis. The 1946 tsunami, which was the most devastating in Hawaiian history, originated in the Aleutian Islands, but resulted in waves of up to 17 meters (55 feet) in height striking Hawaii. This event ultimately resulted in 170 deaths and permanent damage to the city of Hilo.[2]

Similarly, Pacific Northwest residents can experience a local tsunami that also may have an impact on the distant states of Alaska and Hawaii. A tsunami in the Caribbean could result in a local tsunami for Puerto Rico that also impacts Atlantic coast communities in the Southeast as a distant tsunami. Of the two, local tsunamis can pose a greater threat to life because of the short time between generation and impact.

The Indian Ocean tsunami of December 26, 2004 gave rise to levels of loss and grief unprecedented in the history of natural hazards in the region. The massive impact was due to a lack of public awareness, effective warning systems, and implementation of mitigation measures. For example, rapid evacuation to inland areas would have saved many lives. Recognizing the complexity and scope of the sustained efforts needed to ensure tsunami risk reduction in the decades to come, hazard assessment, accurate warnings, response planning, and new or improved actions in public awareness, mitigation, and research are needed. All of these efforts require sustained coordination, attention, and support on the Federal, state, and local level. The National Science and Technology Council's 2005 report, *Tsunami Risk Reduction for the United States: A Framework for Action*, calls on the National Tsunami Hazard Mitigation Program, a Federal-state partnership led by NOAA, to "develop, coordinate and sustain an effective and efficient tsunami risk reduction effort in the United States over the long term."

TSUNAMI

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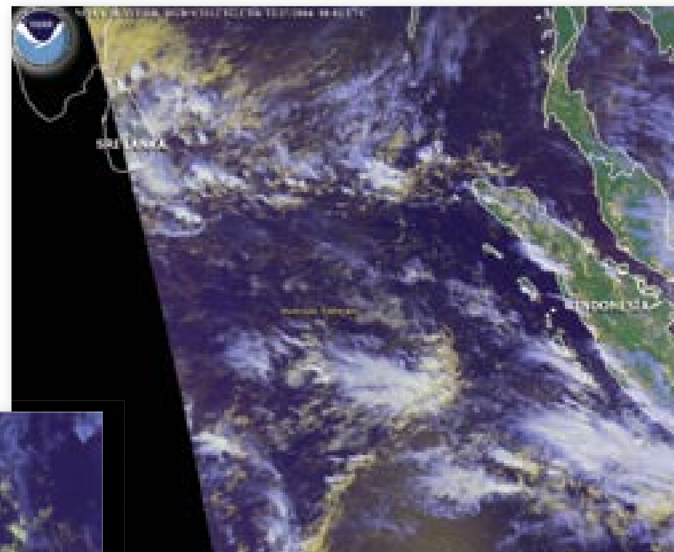
Grand Challenges for Disaster Reduction: Priority Interagency Tsunami Implementation Actions

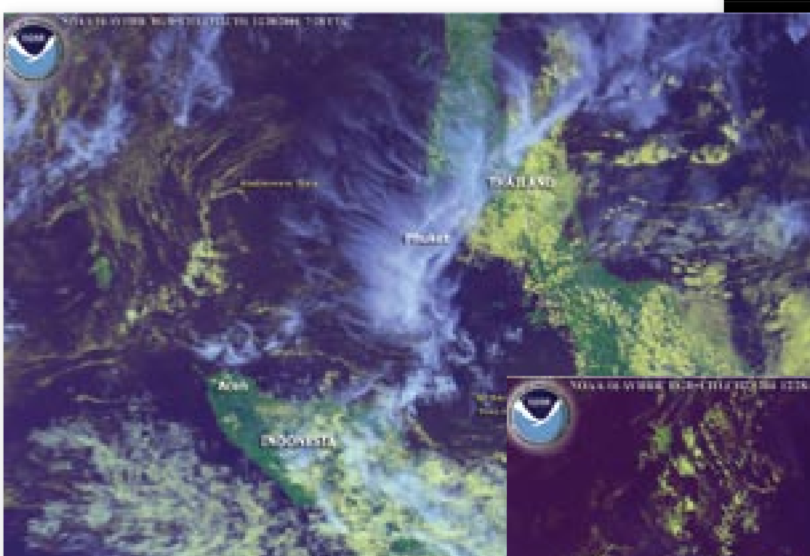
GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ■ Improve tsunami and seismic sensor data and infrastructure for better tsunami detection;
- ■ Enhance tsunami forecast capability along our coastlines (Pacific, Atlantic, Caribbean, and Gulf of Mexico) by increasing the number of Deep-ocean Assessment and Report of Tsunamis (DART) buoys, tide gauges, and seismic sensors feeding real-time data into on-line forecast models;
- ➤ Develop standardized and coordinated tsunami hazard and risk assessments for all coastal regions of the United States and its territories;
- ➤ Encourage data exchange and interoperability among all regional tsunami and all-hazard warning systems, coordinated by the Intergovernmental Oceanographic Commission's sub-Commission for the Caribbean.

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ■ Develop improved and sustained monitoring and research of both the generating mechanisms and the physical characteristics of the tsunami and more accurate description of the sites at risk;
- ■ Research and better understand the protective role coastal marshes, coral reefs, barrier islands, and other coastal features play during a tsunami;
- ➤ Conduct an annual review of the status of tsunami research and develop a strategic plan for tsunami research in the United States.





Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ◆ Develop engineering advancements for sea walls and energy dissipaters that will minimize impact;
- ◆ Develop coastal management plans that will protect coastal features that act as natural energy dissipaters to minimize the tsunami impact;
- ◆ Promote development of model mitigation measures and encourage communities to adopt construction, critical facilities protection, and land-use planning practices to reduce the impact of future tsunamis.

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

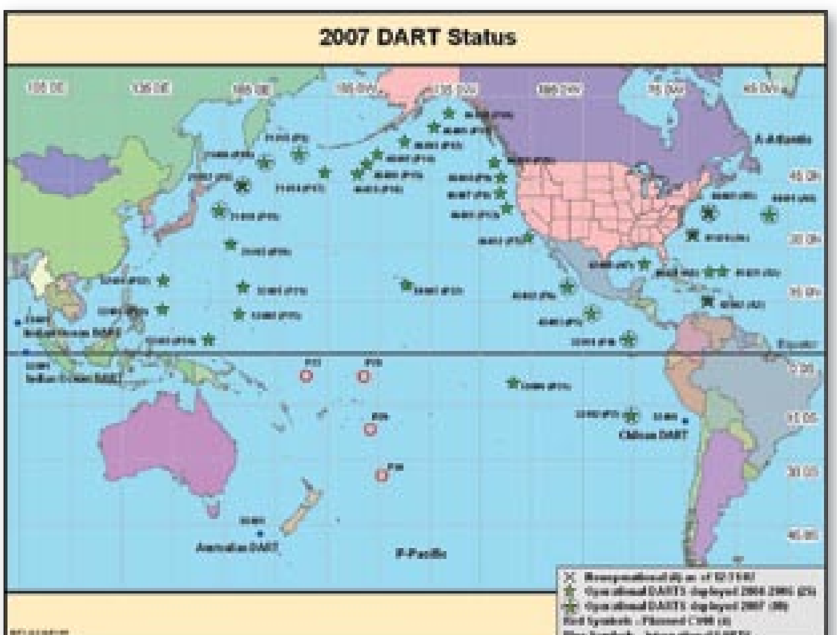
- ■ Develop risk assessments and inundation models to inform the location of lifelines, hospitals, schools, power plants and utilities, fire and police stations, and equipment away from the risk area or harden those structures for adequate protection from the assessed tsunami risk.

GRAND CHALLENGE #5: Assess disaster resilience.

- ■ Develop improved and standardized assessments of societal, economic, and environmental vulnerability to, impacts of, and a more robust response and recovery capacity related to tsunami;
- ■ Develop effective land use plans based on risk assessments and better topographic and bathymetric maps to predict inundation levels and possible effects;
- ■ Improve use of risk assessment tools, mitigation practices, evacuation plans, and timely and accurate warnings to promote risk-wise behavior by decision makers and individuals.

GRAND CHALLENGE #6: Promote risk-wise behavior.

- ■ Increase outreach to all communities at risk to raise awareness, improve preparedness, and encourage the development of tsunami response plans;
- ■ Ensure interoperability between the United States' national system and other regional tsunami warnings systems;
- ■ Provide technical expertise and assistance, as appropriate, to facilitate the development and enhancement of the international tsunami and all-hazard warning systems, including for the Indian Ocean;
- ◆ Employ geographically specific communication and dissemination strategies for extended warnings and probabilistic forecasts based on improved social science research into individual response;
- ◆ Increase the effectiveness of warnings and evacuations through informed community planning and annual drills.



Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this tsunami-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Coastal communities will be better able to prepare for the tsunami threat by understanding the characteristics of both distant and local tsunami sources and potential tsunami frequency. Continued broad scientific research will increase our understanding of tsunami processes and impacts, and will develop more efficient and effective risk assessment and risk communication prediction, preparedness, mitigation, and warning measures.

Communities at risk know when a hazard event is imminent. More accurate and timely warnings will be disseminated with greater timeliness. Outreach and education will focus on appropriate actions in response to local and distant tsunamis.

Individuals at risk are safe from hazards. Preparedness will be achieved through the increased TsunamiReady communities that have response plans, enhanced communications, and heightened awareness of their citizens. As a result, fewer lives will be lost, economic losses will be less, and recovery periods will be shortened. With a better understanding of the threat and impacts, better, sustained actions can be taken prior to the occurrences of the event.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Due to effective land-use planning, preparedness, and warning, a tsunami could strike and not harm the built environment or cause loss of life.

Acronyms

DART	Deep-ocean Assessment and Report of Tsunamis
IOCARIBE	Intergovernmental Oceanographic sub-commission for the Caribbean

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To meet these Challenges, the SDR has identified priority science and technology interagency implementation actions by hazard that build upon ongoing efforts. Addressing these implementation actions will improve America's capacity to prevent and recover from disasters, thus fulfilling our Nation's commitment to reducing the impacts of all hazards and enhancing the safety and economic well-being of every individual and community. This is the volcano-specific implementation plan. See also **sdr.gov** for other hazard-specific implementation plans.

What is at Stake?

DEFINITION AND BACKGROUND. A volcano is a vent at the Earth's surface through which magma (molten rock) and/or associated gases erupt; it also refers to the cone-shaped hills and mountains built by erupted magma. Within the United States, 169 volcanoes are in current or recent eruptive state or are capable of reawakening in the future. However, only three of the most threatening volcanic centers in the U.S.— Kilauea, Mount St. Helens, and Long Valley Caldera—are monitored at levels commensurate with the threats they pose.[1]

IMPACTS. Following the 1980 eruption of Mount St. Helens, 57 people died, more than 500 sq km (311 miles) of forests, streams, and lakes were devastated,[2] and the surrounding communities suffered a $1 billion loss in 1980 dollars to the economy, forestry, agriculture, local businesses, and structures.[3,4] If such an eruption had occurred at Mount St. Helens in 2005, economic losses would have exceeded $3 billion.

An eruption of similar scale at Mount Shasta or Mount Rainier would result in greater loss. Fiery avalanches of volcanic rock, ash, and gas, termed pyroclastic flows, can reach more than 6,000 people[5] in the communities of Mount Shasta City and Weed on the flanks of Mount Shasta volcano in less than 10 minutes, and more than 100,000 people are at risk from debris flows, termed lahars, originating from Mount Rainier.[6]

In addition to hazards on the ground, clouds of volcanic ash emitted from erupting volcanoes pose a significant threat to aircraft en route. Since 1973, there have been more than 100 reports of jet-aircraft encounters with volcanic ash, several of them involving in-flight engine failure.[7] An estimated $100 million of damage was suffered by the aviation industry in Alaska as a result of the 1989–90 eruptions of Mount Redoubt alone.[8] Because volcanic ash clouds can be blown thousands of miles downwind, no U.S. volcano is too remote to represent a serious threat to air traffic.

VOLCANO

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Nor is any community on the ground truly safe from the effects of the largest eruptions. Enormous volumes of ash and the gas SO_2, injected into the atmosphere by large eruptions, can cause global cooling, shortening growing seasons and reducing crop yields. For example, the eruption of Pinatubo in 1992 placed about 18.1 million metric tons (20 million tons) of SO_2 in the atmosphere, lowering the average temperature at Earth's surface by as much as 1.3°C (2.3°F) over 3 years,[9] and the eruption of Tambora volcano in Indonesia caused a "year without a summer" in North America in 1816, with snow storms and killing frosts in June, July, and August that were disastrous for New England agriculture.[10] Climatic effects of larger eruptions such as occurred at Yellowstone approximately 640,000 years ago would be prolonged and could threaten the very fabric of society.

Grand Challenges for Disaster Reduction: Priority Interagency Volcano Implementation Actions

GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ■ Deploy a National Volcano Early Warning System, working with the Consortium of U.S. Volcano Observatories, Federal, state, and local emergency managers, and land-management agencies;
- ■ Establish a national 24x7 Volcano Watch Office with full alerting capabilities and authoritative information about unrest and eruptive activity;

- ■ Expand monitoring tool box to include emerging technologies such as Interferometric Synthetic Aperture Radar, and self-organizing, event-driven, smart monitoring networks;
- ■ Invest in information technology improvements, such as increased bandwidth, common software for data analysis, and neutral communication protocols to improve communication and data exchange between volcano observatories, Federal agencies, and responders;
- ■ Launch a United States civilian Synthetic Aperture Radar satellite;
- ➤ Expand efforts to improve monitoring capability at under-monitored volcanoes;
- ➤ Provide accurate forecasts of future ash cloud locations to aircraft controllers;
- ➤ Provide accurate forecasts of ash fall and air quality to emergency managers and health officials in affected communities;
- ◆ Increase satellite remote sensing capability for thermal imaging, detection of ash clouds by split-window technique, and detection of volcanic gas;
- ◆ Establish a readily accessible data archive of United States volcano monitoring data;
- ◆ Develop a worldwide database on volcanic activity by working with national and international partners (e.g., United States Group on Earth Observations, the Integrated Global Observing Strategy, and the Global Earth Observation System of Systems).

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ■ Improve eruption forecasts for high-threat volcanoes and improve understanding of magmatic processes beneath volcanoes based on long-term patterns of eruptive behavior as well as monitoring observations;
- ➤ Test utility of unmanned aerial vehicle platform-based analysis of volcanic gases (CO_2, SO_2, and others), and thermal, visual, and radar imaging;
- ➤ Improve source and transport terms for ash cloud models to better understand the movement, separation, and gas necessary to form the clouds;
- ◆ Determine the natural controls on eruptive style and create three-dimensional databases, or "virtual volcanoes," for each high-threat volcano that can be used to facilitate interpretation of monitoring results;

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

- ◆ Develop global climate models for very large eruptions to predict their effects on the world's agriculture, natural resources, and economies.

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ■ Complete regional, national, and international volcanic ash response plans to ensure aviation safety, and partner with volcano observatories and civil aviation authorities worldwide under the auspices of the Federal Coordinator for Meteorology and the International Civil Aviation Organization to better share information relevant to mitigation of the volcanic-ash threat to aviation;
- ➤ Develop eruption response plans for all high-threat United States volcanoes to optimize mitigation by efficient avoidance and evacuation;
- ◆ Design and construct engineering solutions to slow, trap, or divert debris and lava flows, where practicable.

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

- ■ Complete hazard assessments for all dangerous U.S. volcanoes to ensure communities, land managers, and developers have complete, accurate, and up-to-date information on volcanic hazards and volcanic activity in their area necessary to make eruption response plans and wise zoning and development decisions;
- ➤ Translate results from volcano hazard assessments into risk assessments based on up-to-date assessment of population, property, and infrastructure at risk;
- ➤ Evaluate the potential long-term impact of increased sediment loads near all high-threat volcanoes following eruptions on streams, rivers, wetlands, lakes, and dams;
- ➤ Develop plans for minimizing disruption to power grids, communication pathways, and transportation on the ground and in the air.

GRAND CHALLENGE #5: Assess disaster resilience.

- ■ Develop comprehensive geographical informational systems coverage for all high-threat volcanoes and potentially affected areas to provide a detailed overall assessment of societal, economic, and environment vulnerability, and track improvements in disaster resilience in terms of reduced exposure of population and infrastructure to volcanic hazards;
- ➤ Evaluate potential direct impact of ash fall and volcanic blasts on agricultural lands and wildlands and the indirect impact caused by eruption-induced global climate change;
- ◆ Track improved avoidance of volcanic ash by aircraft in terms of reduced time that aircraft operate under uncertain eruption conditions.

GRAND CHALLENGE #6: Promote risk-wise behavior.

- ■ Educate individuals living or working in potentially affected areas on volcanic hazards, and coordinate efficient use of monitoring systems, data, and communication, including standardized messaging systems, and land-use planning and decision-making across agencies and institutions;
- ➤ Establish regional, national, and international volcanic ash response plans for the aviation industry;
- ➤ Conduct disaster response drills to improve coordination between field responders, volcanologists, and emergency response centers.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this volcano-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Improved understanding of volcanic behavior will allow decision makers to advance beyond early detection of a possible eruption to accurate forecast of its precise timing, violence, and duration. Comprehensive volcano monitoring using *in situ* monitoring networks and remote-sensing technologies will detect the tell-tale signs of unrest at reawakening volcanoes so that no U.S. volcano will erupt without individual awareness. Data produced by these monitoring activities will contribute to a steadily improving database on volcanic behavior that, coupled with process-oriented research, geologic studies to determine the "personality" of the Nation's most threatening volcanoes, and results from new technologies such as InSAR, will steadily improve understanding of processes that occur deep beneath volcanoes.

Communities at risk know when a hazard event is imminent. Comprehensive monitoring of all the Nation's volcanoes, coupled with improved understanding of volcanic processes, will increase warning times, which are currently in the range of hours or days, to weeks or longer, providing communities at risk time to prepare and evacuate, and ensuring that scientific, emergency management, and commercial response will not lag behind the evolving behavior of a volcano as it advances toward eruption. Volcanic unrest does not always culminate in eruption, and long-term volcano monitoring will provide sound, ongoing, scientific information to communities and emergency managers throughout unrest episodes so that problems related to over-reacting or under-reacting will be minimized.

Individuals at risk are safe from hazards. By receiving more accurate interpretations of unrest and forecasts of eruptive behavior, emergency managers and other decision makers will be able to respond appropriately and cost-effectively to volcanic hazards while assuring that no lives are lost and damage to property and disruption of transportation and communication networks are minimized. Timely and accurate warnings to en route aircraft will prevent dangerous encounters with volcanic ash while minimizing costly unnecessary redirection. Creation of ground evacuation and aviation response plans for the Nation's most dangerous volcanoes and implementation of a regular review schedule will ensure rapid and consistent transmission of warnings, enable cost-effective response, and minimize confusion, loss of life, and damage to property.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Complete and accurate assessment of the potential volcanic hazards at each of the Nation's most threatening volcanoes will create valuable "behavioral histories" for each high-threat volcano and identify areas of greatest risk. This will provide a foundation for wise zoning and investment so that lives, property, and critical infrastructure and facilities such as fire stations and hospitals are not constructed in areas of high risk. As volcanoes advance toward eruption, communities will respond appropriately as a result of improved communication between scientists and decision makers through development of community response plans and improved public education on volcanic hazards. Improved understanding of volcanic processes will result in better forecasts of eruption violence and duration, minimizing the societal disruption of unnecessary evacuation.

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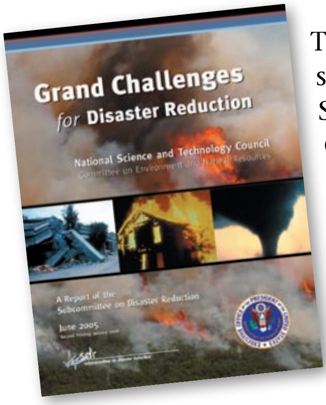

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What is at Stake?

DEFINITION AND BACKGROUND. Unplanned wildland fires (wildfires) impact tens of millions of acres annually around the world. Wildfires burn homes, damage infrastructure and natural resources, kill and injure firefighters and the public, impact local economies and the global environment, and cost billions of dollars per year to manage and control.

IMPACTS. Most of the area burned, cost, and other impacts of wildfire derive from a small number of very large fires.[1] An average of 2 million hectares (5.1 million acres) a year burned in the United States between 1995 and 2004; this is about 135 percent of the average burned area between 1965 and 1994. Federal agencies spend an average of $1.2 billion per year on fire suppression[2] and state and local agencies contribute millions more.

Of the ten events in the United States with the largest fire-related property losses since 1950, five were wildland-urban-interface fires.[3] The number of homes at risk is likely to grow as more people move into wildland-urban interface areas.

Wildfires with uncharacteristically high intensity can also damage natural resources affecting ecosystem recovery, decreasing productivity, and stimulating severe erosion and flooding. Observed increases in fire size and negative resource and societal impacts from wildfire result from a combination of factors, including fire suppression, past logging, grazing and other management activities, climate variability, and changing land use. Almost every wildland ecosystem in North America has a history of fire, but the patterns of fire frequency and fire type (e.g., surface fire vs. crown fire), as well as how these patterns have changed over time, vary greatly.

WILDLAND FIRE

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Grand Challenges for Disaster Reduction: Priority Interagency Wildland Fire Implementation Actions

GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ■ Develop national databases of burn severity and fire perimeters for both wildland and wildland-urban-interface fires;
- ■ Implement continuity missions for moderate-resolution satellite data (15-30 m) for characterizing fuels and burn severity and for active fire remote sensing;
- ➤ More fully integrate across hazards to identify and illustrate interactions, including environmental benefits of natural wildland fires;
- ➤ Develop national geospatial coverage and modeling systems for fuel types, fire regimes, and condition classes appropriate for a new generation of fire models;
- ➤ Use Earth observation systems (ground and remote sensing) to develop and regularly update fuels, weather, and other data bases needed for fire prediction and monitoring;
- ➤ Develop and support analysis, computing, and communication capabilities to improve risk-informed assessments and analysis;
- ◆ Create geospatial data layers and integrated information, decision support systems, and models to support fire management planning and incident response.

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ■ Develop an interagency coordinating group for wildland and wildland-urban-interface fire research and development;
- ➤ Improve understanding of the processes of wildland fire events to accurately model and predict the potential occurrence, behavior, and impacts of wildland fire on resources, the environment, and physical infrastructure;
- ◆ Integrate new process understanding into improved 3-D fire behavior models that incorporate complex fuels (including structures), terrain, and fire/atmosphere interactions into predictions of fire probability, fire behavior, fire severity, fire emissions, smoke transport, and ecosystem fire effects.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ■ Assess the benefits of fuel treatments, other preparedness activities, societal attitudes, and decision-making processes in reducing potential impacts;
- ➤ Improve understanding of costs and benefits of wildland fire and fuel management;
- ➤ Develop and implement integrated landscape and larger-scale modeling and analysis systems for wildland fire planning and wildland-urban-interface community design that incorporate risk mitigation, fuels, fire behavior, smoke transport, resource and social values;
- ➤ Use remote sensing and burn severity mapping to monitor fuel treatment effects and effectiveness;
- ◆ Develop risk-based methods for deciding on the best strategies for mitigating the negative effects of wildland fire on ecosystems and communities;
- ◆ Understand the factors that motivate individuals to undertake risk mitigation activities.

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

- ➤ Assess the fire safe characteristics of community designs, including layout, landscaping, and structure design and building materials, and make recommendations for improved fire safety. Improve information and tools for homeowners and planners on fire-safe construction, landscaping, and community planning;
- ➤ Develop data and validated models to assess how well different community and landscape designs and post-fire restoration activities mitigate fire risk and damage, including offsite effects such as flooding and erosion, and damage to transportation and energy infrastructure;
- ◆ Develop improved approaches to increase the resistance of infrastructure and communities to damage from wildland fire and its aftereffects.

GRAND CHALLENGE #5: Assess disaster resilience.

- ■ Assess logistical needs and evacuation plans for a variety of fire scenarios, including wildland and wildland-urban-interface fires;
- ■ Understand why individuals evacuate or choose to stay;
- ➤ Link fire safe community information with geospatial data for evaluating and predicting local to national impacts of fuel and fire management and community design;
- ➤ Establish methods to assess the adequacy of community resources for a successful response to a likely fire hazard;
- ◆ Improve and apply validated methods to enable consistent, rapid, and accurate fire severity mapping and assessment of the benefits of natural wildland fire and the risk of severe erosion, flooding, and other ecosystem damage;
- ◆ Develop methods to model recovery of fire-impacted ecosystems under various climate change scenarios;
- ◆ Develop improved systems to assist homeowners and communities to recover from impacts of wildland fire;
- ◆ Create common tools for assessing impacts of wildland fire as well as validated methods to enhance resilience to wildland fire and restore fire-impacted ecosystems and communities.

GRAND CHALLENGE #6: Promote risk-wise behavior.

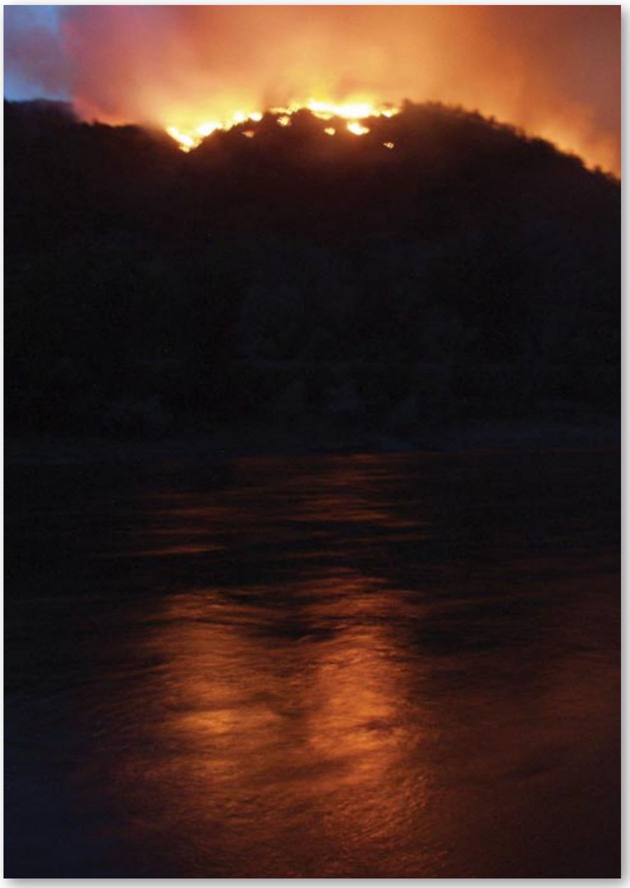
- ■ Evaluate effectiveness of alternative approaches to risk communication, emergency warning, and decision-making on fire management, prevention, and mitigation;
- ➤ Study the effectiveness of resource management and firefighter response and alternative management strategies at altering outcomes, including benefits to safety, costs, natural resources, and communities;
- ➤ Develop and deliver real-time decision support tools during fire incidents to help managers identify wildlands, communities, and structures most at risk and the most appropriate tactical responses;
- ◆ Develop national and global capabilities and tools to effectively illustrate and communicate immediate to long-term risks from wildland and wildland-urban-interface fires to managers, decision-makers and individuals;
- ◆ Integrate with multi-hazard risk communication systems for emergency warning.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this wildland fire-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Integrated regional-to-global monitoring systems, predictive models, and decision support tools yield accurate information on potential wildland fire severity, extent, and effects to emergency managers and other decision makers. Fire behavior, fire effects, and smoke transport models support planning to minimize the negative impacts of fire on ecosystems and the environment (water and air). Better understanding and ability to predict the factors controlling wildfire patterns, risks to human health and infrastructure, and socioeconomic impacts will produce appropriate and cost-effective management responses for suppression, hazard mitigation, and recovery.



Communities at risk know when a hazard event is imminent. Improved warning systems will use state-of-the art models of fuel condition, fire behavior, smoke transport, and fire/weather interactions to provide communities with both long-term and timely and accessible short-term information on predicted hazard events.

Individuals at risk are safe from hazards. Decreases in uncharacteristically severe wildland fires and the development of fire-resistant structures and communities lead to reduced negative impacts of fire on property, human life and human health. Reduction of hazardous fuels, better community planning, and improved decision support tools support appropriate management response to wildfires through improved planning, mitigation, and preparedness.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Wildland fire is managed to benefit wildland ecosystems and cause minimal resource damage; public awareness and fire-safe planning and construction have led to greatly decreased property loss from wildland-urban-interface fires; and costs of unnecessary fire suppression have been reduced. Synthesized wildland fire mapping and characterization, community planning, building codes, zoning regulations, and community/agency partnerships combined into a land-use decision-making tool resulting in decreased structural losses and economic impacts from wildland-urban-interface fires. Fire-affected ecosystems are restored and managed to support multiple values and societal benefits, consistent with maintaining healthy, sustainable forests and rangelands. Restoration and maintenance decisions are science-based. Improved fuel and fire management decrease the negative ecosystem and resource impacts of uncharacteristically severe wildland fire.

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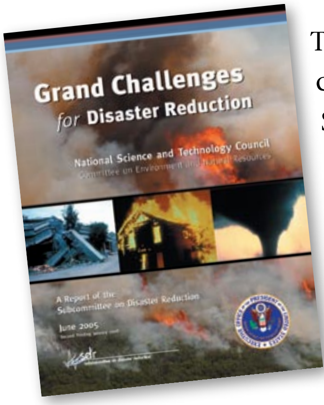

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To meet these Challenges, the SDR has identified priority science and technology interagency implementation actions by hazard that build upon ongoing efforts. Addressing these implementation actions will improve America's capacity to prevent and recover from disasters, thus fulfilling our Nation's commitment to reducing the impacts of all hazards and enhancing the safety and economic well-being of every individual and community. This is the winter storm-specific implementation plan. See also **sdr.gov** for other hazard-specific implementation plans.

What is at Stake?

DEFINITION AND BACKGROUND. Each year, nearly every state in the United States faces the hazards of winter weather, heavy snow and rain, freezing rain, strong winds, and cold temperatures. Despite the societal and economic impacts, the natural processes that produce severe winter weather and its effects are not well understood. Real-time measurements of the structure and composition of clouds, which are important for understanding the processes producing precipitation, do not exist. Techniques for measuring snow and snowfall depend solely on manual observations, and the resulting datasets are often incomplete and inaccurate. In fact, two different datasets of weather-related mortality report opposite findings. One dataset (the National Climatic Data Center's Storm Data) records more heat-related deaths per year than cold-related deaths, whereas another dataset (the National Center for Health Statistics Compressed Mortality Database) records the opposite, with nearly four times the number of cold-related deaths than heat-related deaths.[1]

IMPACTS. Currently, forecasting winter weather is difficult and high-risk because the same weather event occurring at different times of the day can produce drastically different societal results. For example, an inch of wet snow during rush hour on a weeknight will produce a dramatically different impact than an inch of wet snow on Saturday night. Also, imprecise winter weather

WINTER STORM

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predictions lead to expensive, reactive economic accommodation of winter weather rather than a more proactive economic stance that could minimize costs.

Weather information providers and consumers have not embraced a probabilistic approach to these forecasting challenges that would help significantly decrease the nearly 7,000 deaths, 600,000 injuries, and 1.4 million accidents a year that occur due to adverse winter driving conditions, by extending winter weather watch and warning lead times.[2]

Grand Challenges for Disaster Reduction: Priority Interagency Winter Storm Implementation Actions

GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ■ Assess and fill gaps in observations, training, technology, capacity, and organization that may prohibit efficient exchange of information;

- ■ Establish a depository for winter weather data in a common data format;
- ➤ Provide accurate identification of precipitation type and area of occurrence to within 10 km (6 miles) resolution to emergency managers and response personnel;
- ➤ Develop GIS-data-based, integrated weather information, road availability information, satellite tracking, satellite delivery, and interaction to support an integrated winter weather decision support system.

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ■ Understand the transition region between rain and snow by researching the thermodynamic, dynamic, and microphysical environment;
- ➤ Measure precipitation at the surface and aloft, from multi-wavelength polarization radar, from moisture information in the transition zone, and vertical air motion;
- ➤ Develop 36-hour geo-reference forecast for counties that describes the probability of severe winter weather;
- ➤ Deploy networks of automatic snow sensors to measure liquid equivalent in real time;
- ➤ Develop new remote-sensing and *in situ* techniques for measuring the constituent particles inside clouds, and lower-atmospheric temperature and moisture fields;
- ➤ Develop flexible and adaptable decision support tools based on radar/satellite/*in situ* observations that, through joint data assimilation, provide critical information on cloud microphysics,

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

rain/freezing/frozen precipitation, banded structures, orographic influences, and spatial patterns and their evolution;

- ➤ Develop accurate quantitative precipitation forecasts, especially for freezing rain and snow accumulations, which use improved observational, assimilation, and modeling techniques (e.g., space resolution observations of atmospheric pressure).

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ■ Understand social and economic barriers to and incentives for adoption of mitigation strategies and winter storm preparations;
- ◆ Expand winter storm climatologies to provide improved engineering standards for ice, wind, and snow on structures (e.g., buildings and communications, electricity, gas, sewage, transportation and water infrastructure).

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

- ■ Educate individuals and emergency managers about the varying impacts of winter weather on critical infrastructure based on specific meteorological and sociological parameters (e.g., time of day, day of week, urban vs. rural, surface temperature);
- ➤ Develop protocols and standards for rapid repair and restoration of critical infrastructure and other essential facilities subjected to wind, snow, and ice loads;
- ➤ Model the potential effects of severe winter weather on critical infrastructure and essential facilities in advance of storms and immediately after to predict and reduce vulnerability in the short-term and long-term;

- ◆ Develop improved engineering standards, smarter transportation systems, more resilient critical infrastructure and essential facilities in addition to cost-effective technology to ensure that these facilities maintain robust operations during severe winter weather.

GRAND CHALLENGE #5: Assess disaster resilience.

- ■ Develop community response, contingency, and evacuation plans based on knowledge of extreme weather events derived from long-term data analysis;
- ■ Coordinate inter-agency, detailed post-storm assessment of damage, injuries, and deaths;
- ■ Develop flexible and effective mitigation plans for transportation infrastructure and public health preparedness.

GRAND CHALLENGE #6: Promote risk-wise behavior.

- ■ Improve individual understanding of probabilistic forecasts through a coordinated national outreach effort;
- ■ Improve education and outreach at the individual (e.g., automated calls to those at risk), community, state, and Federal levels;
- ■ Develop a weather communication system for transportation systems (e.g., weather alerts along interstates, smart highways);
- ■ Deploy a seamless suite of reliable and accurate probabilistic winter-weather forecasts, warnings (0–12 hours), watches (12–72 hours), weekly outlooks (3–8 days), and seasonal outlooks.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this winter storm-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Accurate regional winter weather climatologies will include probabilities of ice storms and blizzards to enhance public awareness of weather hazard risks.

Communities at risk know when a hazard event is imminent. More precise, detailed forecasting for snow, sleet and/or freezing rain in each community, neighborhood, and specific street addresses will yield better, more actionable warnings. More accurate winter weather watches and warnings can be issued with more time to prepare and mitigate.

Individuals at risk are safe from hazards. Standards and technologies will enable cost-effective, state-of-the-art winter storm resilient provisions to be adopted as part of state and local building codes and improved resilient design of transportation systems.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Accurate, localized predictions of winter weather impacts will offer significant payoffs to maintain infrastructure and lifelines services for communities with minimal interruption.

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COASTAL INUNDATION

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What is at Stake?

DEFINITION AND BACKGROUND. Coastal inundation is the flooding of coastal lands, including wave action, usually resulting from riverine flooding, spring tides, severe storms, or seismic activity (tsunami). With over 50 percent of the United States population living in the coastal zone[1] and as the source of more than half of the nation's economic productivity,[2] the impacts of coastal inundation can be severe. Long-term vulnerability and future impacts are exacerbated by sea-level variability and land subsidence as well as long- and short-term climate change affecting wave heights and coastal and riverine water levels. As a result of Hurricanes Katrina and Rita in 2005, coastal inundation throughout Louisiana, Mississippi, and Alabama left millions without power and tens of thousands in temporary housing,[3] and severely impacted critical coastal and riverine ecosystems. In addition, our nation's energy supply, ability to ship goods, and overall commerce were significantly affected.

IMPACTS. Coastal inundation is a major cause of natural disaster deaths in the United States. The largest natural disaster death toll from a single event was the Galveston hurricane in 1900 wherein at least 6,000 people died, the vast majority as a result of the surge associated with the storm.[4] One need only look at the devastation from Hurricane Katrina in 2005 including levee failures and subsequent flooding to see how much coastal inundation can impact a population.

Tsunami inundation has also impacted the United States and the Caribbean, causing more than 3,000 fatalities over the past 150 years. Inundation can also permanently alter or damage coastal and riverine ecosystems, which provide an important buffer for communities and significant habitat for migratory birds, and are critical for sustaining fisheries.

Insurance losses related to coastal inundation can be catastrophic as well. Repetitive flood loss, of which coastal inundation is a significant part, is the largest expense for public insurance claims.[5] National Flood Insurance Program claims are expected to top $22 billion from Hurricane Katrina alone, $7 billion more than all combined claims in the 30-year history of the program.[6] In Louisiana, an estimated 118 square miles of critical wetlands were lost due to Hurricane Katrina,[7] and the revenue losses from forestry, wildlife, fisheries, and other natural resource benefits have been estimated at over $1 billion.[8]

Grand Challenges for Disaster Reduction: Priority Interagency Coastal Inundation Implementation Actions

GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ■ Ensure the operability of *in situ* tide and water-quality monitoring stations so that real-time flooding information is available to decision makers throughout the storm;
- ■ Inventory existing observations and models, improve critical observational and information delivery components, and develop observation-based decision-support systems;
- ■ Inventory existing or planned wave-hindcast models, sea-level models, and storm-surge and inundation models and assess their strengths and weaknesses, required developmental and operational data inputs and costs, and enhance linkages with climate model projections;
- ■ Seek interagency agreements on developing and sharing data and information to support the generation of high-resolution coastal Digital Elevation Models (DEMs);
- ■ Build critical framework databases, including but not limited to, high-resolution coastal topographic, shallow bathymetric, and water level data;
- ➤ Develop, maintain, and enhance robust and open data archives and retrieval systems;
- ➤ Establish and maintain a national geographic information database of inundation hazard, vulnerability, and risk;
- ➤ Develop sophisticated, flexible, and adaptable decision-support tools so existing and new data and products can be effectively incorporated and utilized;
- ➤ Further develop probabilistic inundation hazards prediction and methods to effectively quantify and communicate risk.

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ■ Establish common interfaces, standards, and goals for inundation modeling;
- ■ Evaluate capabilities of High Frequency Radar (HFR)/Synthetic Aperture Radar (SAR) for swell/wave and deformation measurements;
- ■ Select output from climate model simulations that can be used to generate future scenarios of climate for input into inundation models;
- ■ Develop coastal wind/wave climate maps and shoreline process models to better understand and predict the seasonal and long-term aspects of coastal erosion and inundation in populated coastal environments;
- ■ Assess the impacts of climate change on coastal inundation, especially in relation to wave heights, riverine and coastal water levels, and storm surge;
- ➤ Observe and assess interactions of coastal inundation with critical coastal and riverine resources and ecosystems;
- ➤ Conduct atmospheric re-analysis for input to wave-model, sea level, and storm surge and inundation models;
- ◆ Use high-resolution coastal topographic and shallow bathymetric databases to establish and

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

maintain a national coastal DEM, which will improve inundation models. Incorporate the vertical datum transformation software tool to more effectively characterize relative elevation and vulnerability;

- ◆ Determine the climate scale factors at the global, regional, and local levels that relate to sea level variability and rise;
- ◆ Continuously improve inundation source modeling technology and data sources.

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ■ Develop an understanding of the social, cultural, and economic factors that promote or inhibit adoption and enforcement of promising mitigation strategies or technologies;
- ■ Develop outreach and training programs to enhance state and local government capacity to adopt improved mitigation strategies and policies;
- ➤ Develop strategies for mitigating negative impacts on coastal zone ecosystems;
- ➤ Develop improved and more accessible mitigation strategy models (e.g., HURREVAC computer software, risk and vulnerability tools, improved DEMs and maps) and other technical assistance to state and local governments that are adopting new mitigation strategies and policies;
- ➤ Develop a coastal inundation GIS system using information on historical and projected probabilities of various categories of sea level incursion to help identify socio-economic impacts of vulnerable regions/areas/populations.

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

- ■ Model the impacts of events affecting the infrastructure, including the effects of seismic activity, waves, and coastal change (i.e., erosion, inlet formation);
- ■ Examine the interaction between wind and inundation to determine the impact on building foundations and critical infrastructure;
- ➤ Focus research on new mitigation technologies for purpose of avoidance, resistance, rapid repair and restoration of critical infrastructure and other essential facilities;
- ➤ Model the impacts of changes in coastal zone ecosystems on infrastructure vulnerability;

- ◆ Provide the technical basis for revised codes and standards for critical infrastructure and essential facilities by using risk and vulnerability assessment tools.

GRAND CHALLENGE #5: Assess disaster resilience.

- ■ Develop an interagency program for provision of coastal high-resolution maps, including elevation, land use and land cover, to improve coastal assessments;
- ■ Facilitate coordinated, inter-agency post-event assessment of infrastructure and ecosystem damages, injuries, and deaths for all coastal hazards;
- ■ Assess and improve every community's ability to respond to coastal inundation, including assessing vulnerability, evacuation capability, and public knowledge of appropriate preventative actions;
- ➤ Develop and distribute community assessment tools.

GRAND CHALLENGE #6: Promote risk-wise behavior.

- ➤ Strengthen the capacity of local communities, states, and regional associations to reduce vulnerability to prepare for and manage coastal inundation and wave action risks by identifying and implementing actionable strategies that incorporate scientific and technological advances to inform practices that enhance community resilience to coastal hazards;
- ➤ Facilitate expanded networks of communication and education to produce "hazards literacy;"
- ➤ Develop timely and focused data, information, and GIS decision-support tools to provide information to individuals as well as outreach training efforts on understanding and using the information.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this coastal inundation-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Improved and more readily available outreach and education programs disseminated through diverse media in partnership with local and state governments will enable users to fully capitalize on existing and newly developed inundation products and information. Better understanding of coastal inundation processes combined with outreach to individuals and government decision makers will enhance their understanding of the risks of coastal inundation and the benefits of strategies to mitigate impacts and improve resilience.

Communities at risk know when a hazard event is imminent. Through improved observation technologies and new and improved modeling capabilities, forecasters will have the necessary information to improve warning accuracy and lead time. An integrated "all-hazards" approach improves the effectiveness of warnings, modeling, communication, planning, and building techniques by integrating the many aspects that contribute to coastal inundation.

Individuals at risk are safe from hazards. Through improved observations, modeling, and decision support tools, communities will have the necessary information to identify areas of the community at risk, where inundation vulnerabilities lie, and what can be done to mitigate damage and improve resilience.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Repetitive flood loss, of which coastal inundation is a significant part, is the largest expense for public insurance claims. By having improved inundation models and decision support tools to better inform citizens and decision makers, steps can be taken to protect vulnerable areas, reduce the number of vulnerable structures being rebuilt in flood-susceptible areas, and increase infrastructure resilience to the effects of coastal inundation damage. Through improved risk and vulnerability assessment tools and appropriate planning and mitigation strategies, critical infrastructure and ecosystems at risk from coastal inundation can be identified. As a result, preparations can be made to mitigate damage to natural resources and to protect new and existing infrastructure through retrofit, effective backup mechanisms, and alternative options.

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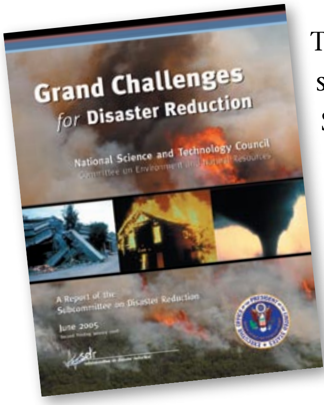

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DROUGHT

What is at Stake?

DEFINITION AND BACKGROUND. Drought is a persistent and abnormal moisture deficiency that has adverse effects on vegetation, animals, or people. Drought is a unique natural hazard because it is slow-onset, has nonstructural impacts, and can be defined in meteorological, hydrological, agricultural, natural resource, and/or socioeconomic terms.

IMPACTS. Societal, environmental, and economic impacts of drought are enormous. Annual direct losses to the United States due to drought are estimated at $6-8 billion, making it on average the most costly of natural disasters affecting our nation.[1] During the spring and summer of 2002, moderate to extreme drought over much of the United States resulted in an estimated $10 billion in damages. The 2002 drought also contributed to major wildfires in 11 western states. Over 2.8 million hectares (7 million acres) were burned, resulting in 21 deaths and the loss of $2 billion in damages. Droughts with over $1 billion in damages also occurred in 1996, 1999, 2000, and 2005.[2]

The agriculture industry is the largest consumer of water in the United States and very sensitive to droughts. This was particularly evident during the 1988 drought that affected 35 states. Rainfall totals over the Midwest, Northern Plains, and the Rockies were 50–85 percent below normal, causing severe soil damage and a decrease in productivity of both crops and livestock. Total agricultural losses from this event are estimated at $40 billion.[3] Drought causes steep increases in agricultural production costs due to reductions in

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soil productivity, increased plant and animal susceptibility to disease and insects, and the need to purchase and import supplemental water sources.[4] Often these effects will continue to be felt long after the drought has subsided. Impacts of drought on natural resources include decreased forage on rangelands, increased mortality in forests and shrublands (from both direct drought effects and indirect effects of increased susceptibility to insects and disease), and increases in severity and breadth of wildfires.

Grand Challenges for Disaster Reduction: Priority Interagency Drought Implementation Actions

GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ■ Implement and expand the National Integrated Drought Information System (NIDIS), including development of the NIDIS web portal;
- ■ Develop, expand, and link information systems tracking impact and losses related to hydro-meteorological events and seasonal fluctuations and associated drought effects, including water supply, hydropower, crops, rangeland, wildland fire, carbon sequestration and invasive species;
- ➤ Leverage activities with international partners, such as World Meteorological Organization (WMO) and bilateral collaborators, to deliver improved drought information;
- ➤ Develop interagency protocols, coordinated and integrated drought observations, analysis, and predictions;
- ➤ Assess science and technology needs for improved drought planning, mitigation, and response, including decision support tools, community involvement, drought response triggers, insurance and financial strategies, and demand efficiencies;
- ➤ Develop and improve drought-monitoring capabilities at the state and local level, including improved impact assessment technology.

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ■ Monitor and analyze key physical, environmental, and societal variables associated with drought and related planning triggers. Key variables include: land use, climate data, soil moisture, stream flow, ground-water levels, reservoir and lake levels, snow-covered area, snow water storage, canopy water, and chlorophyll content of vegetation (e.g., for agriculture, forest and rangeland health, and fire risks);
- ➤ Design drought research efforts to be multi-disciplinary and well-coordinated among relevant state and federal agencies, universities and the private sector to improve predictive capability of seasonal/multi-decadal droughts;
- ◆ Improve understanding of major climate processes related to drought through satellite and meteorological data and model development.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ➤ Develop technologies that enable more efficient water use and conservation;
- ➤ Support research and development of more drought-resilient crops;
- ➤ Focus on planning strategies, collaborative decision support tools, and assessment science to create comprehensive mitigation strategies;
- ◆ Develop improved capabilities at the state and local level for drought preparedness planning;
- ◆ Develop sophisticated decision-support tools, available through the NIDIS web portal, so drought monitoring and prediction products can be effectively incorporated into decisions to mitigate impacts on public health, critical infrastructure, and provision of public utilities and services.

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

- ➤ Investigate drought predictions and indicators to improve operational decision making for water supply, transportation, hydropower, and irrigation;
- ➤ Incorporate social science research into effective public communications calling for demand reduction during drought and improving demand-side efficiencies;
- ➤ Develop improved information for water supply operation, transportation, hydropower, irrigation augmentation systems, and for the development of new supplies and estimation of demand-side efficiencies.

GRAND CHALLENGE #5: Assess disaster resilience.

- ■ Assess societal, economic, and ecosystem/environmental vulnerability, impacts, and response capacity to drought;
- ■ Research economic impacts of drought and quantify the monetary benefits of improved drought prediction and mitigation;
- ■ Improve coordination of Federal, state, local, and international activities for drought planning and emergency response;
- ■ Develop meaningful socio-economic and ecosystem/environmental impact drought indices for use by decision makers and the general public including research into human actions that increase drought severity;
- ➤ Identify and track the metrics of observable drought impacts at county and sub-county scales by blending *in situ* and satellite observations.

GRAND CHALLENGE #6: Promote risk-wise behavior.

- ■ Strengthen the capacity of states, Native American Tribal Governments, and watershed communities to manage and respond to drought risks;
- ➤ Develop Federal-state-local partnerships to identify actionable strategies and incorporate scientific and technological advances to inform practices that reduce drought vulnerability;
- ➤ Develop evaluation and feedback mechanisms for drought information system refinements;
- ➤ Improve systems for communicating drought information and essential public actions.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this drought-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Because of its slow onset over space and time, drought can only be identified through the continuous collection of climate and hydrologic data. Modernizing legacy observing systems, increasing the spatial density of key variables, integrating synoptic satellite views, and leveraging newly established state and local observing networks will greatly enhance drought monitoring. Enhanced understanding of natural climate cycles will improve forecasts of droughts associated with such cycles.

Communities at risk know when a hazard event is imminent. To enhance decisions and minimize costs, drought warning systems will provide credible and timely drought risk information and forecasts. Targeted advances in scientific research and forecast model development will provide decision makers with credible information that can be used in planning and preparation for future changes in drought expanse and severity. Advancements in areas such as warm-season precipitation forecasting will enhance drought forecasting, which will benefit drought planning and preparedness activities.

Individuals at risk are safe from hazards. More centralized and direct access to available drought information will enable users to fully capitalize on existing and newly developed drought models. Education of decision makers will enhance the understanding and application of drought indicators for identifying drought severity thresholds.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. A shift from crisis management to risk management will enable a more drought-resilient society. Better understanding of drought-related impacts such as increased wildland fire risk, interruptions to business activity, and impacts on major population centers will enhance drought planning, mitigation, and response activities.

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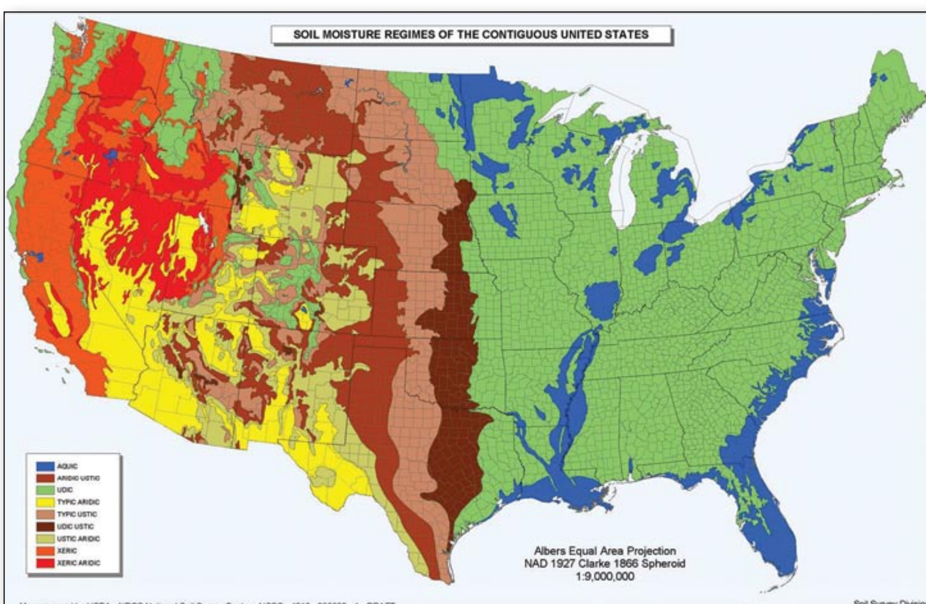

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What is at Stake?

DEFINITION AND BACKGROUND. Each year the United States experiences thousands of earthquakes with an average of seven large enough to cause serious damage.[1] Seventy-five million Americans in 39 states face significant risk from earthquakes, and 26 urban areas are particularly vulnerable to earthquakes.[2] Congress established the National Earthquake Hazard Reduction Program (NEHRP) in 1977 to translate scientific and engineering advances into practice. In addition to the four NEHRP agencies — FEMA, NIST, NSF, and USGS — a number of other agencies contribute to the overall Federal effort to reduce the toll that earthquakes take on the Nation.

IMPACTS. Earthquakes hold the potential to deliver devastating blows to urban areas across the Nation with projected losses up to a quarter-trillion dollars from a single event.[3] As the population increases, expanding urban development encroaches upon areas susceptible to earthquakes, increasing the risk to life and property. In addition to strong shaking from the main shock and aftershocks, secondary effects can be cascading or compounding, including:

- Fires can occur as a result of ruptured gas lines, and if water main breakages occur, this combination makes fire fighting very difficult. Fires destroyed much of San Francisco in 1906 and contributed to the loss of 100,000 lives in the great Tokyo earthquake of 1923. An earthquake striking Los Angeles during a time of hot, dry winds — such as when the wildfires of 2007 occurred — could cause firestorms throughout the city and in neighboring wildlands.
- Landslides are a common post-earthquake event, particularly if the earthquake strikes during periods of heavy rains in already saturated soils.
- Liquefaction has been responsible for a tremendous amount of damage in historical earthquakes around the world. It occurs when ground shaking reduces the strength and stiffness of the soil, which loses the ability to support the foundations of structures. In a repeat of the 1811–12 earthquakes in the central United States New Madrid Zone, liquefaction and failure of levees and riverbanks could make the Mississippi River unnavigable.
- The December 26, 2004 disaster in the Indian Ocean was a solemn reminder that earthquakes can also trigger tsunamis with devastating effect.

EARTHQUAKE

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Grand Challenges for Disaster Reduction: Priority Interagency Earthquake Implementation Actions

GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ■ Integrate an earthquake component into multi-hazard demonstration projects in high-hazard Pacific states to show the efficacy and viability of integrated, end-to-end, disaster reduction frameworks and networks;
- ■ Expand the Advanced National Seismic System to improve seismic monitoring and deliver rapid, robust earthquake information products;
- ■ Upgrade real-time capability of global seismic networks and deploy Caribbean stations in support of the President's tsunami warning initiative;
- ➤ Develop, test, and deploy algorithms for rapid earthquake source characterization and notification;
- ➤ For all urban areas with moderate to high seismic risk, produce ShakeMaps that show the variation of shaking intensity within minutes after an earthquake based on near real time data transmission from densely spaced seismic networks.

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ■ Develop new seismic hazard assessments for Alaska and California that reflect earthquake recurrence intervals and stress triggering;
- ➤ Develop realistic and reliable physics-based models of earthquake processes;
- ➤ Fully explore the predictability of earthquakes based on testable and credible methods, and provide objective reviews of predictions;
- ➤ Expand LiDAR coverage to identify active faults and characterize earthquake hazards;
- ➤ Develop Earth observation technologies such as Interferometric Synthetic Aperture Radar (InSAR) and other airborne and satellite instruments that can monitor the spatial pattern of surface deformation associated with crustal strain;
- ➤ Make full use for hazard reduction of the seismic, geodetic, and other data streams emerging from the EarthScope initiative;
- ◆ Maintain commitment to long-term monitoring and research activities;
- ◆ Deliver urban seismic hazard maps that show probable variations in hazard at a neighborhood scale.

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ■ Produce key aspects of next-generation performance-based seismic design approach for buildings;
- ■ Develop and test new concepts, materials, technologies, and predictive simulation tools for the seismic design of structural systems and geomaterials by making full use of the George E. Brown, Jr. Network for Earthquake Engineering Simulation;
- ■ Through problem-focused research projects, facilitate technology transfer of fundamental research products to the practitioner community;
- ■ Support a national data archive resource for design studies that captures experimental data as well as field reconnaissance data;
- ■ Develop improved modeling procedures for analysis techniques found in building codes and standards;
- ■ Develop uniform risk assessment methodologies;
- ■ Refine isolation systems to mitigate damages to buildings, transportation structures, and other lifelines;
- ■ Invest in materials research to develop new, more resilient materials and/or enhance existing materials;
- ➤ Incorporate revised national seismic hazard maps into next-generation model building codes;
- ➤ Improve the usability and acceptance of national model building codes by developing more accurate, simplified methods for analyzing building and lifeline responses to earthquake-induced ground motions;
- ◆ Install MEMS (Micro-Electro-Mechanical Systems) structural health monitoring system throughout new structures and in major retrofits. Sensors exceeding critical thresholds would sound alerts transmitted to emergency response centers;
- ◆ Infuse newly emerging sensor technologies into "smart structure" designs that sense damage and provide active/semi-active control of structural response to earthquake-induced motions.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

- ■ Develop performance-based design criteria based on actual infrastructure, research, and other work for design and retrofit methods;
- ➤ Produce comprehensive seismic design guidelines for major specialized structural systems (e.g., ports and harbors);
- ➤ Focus research on new mitigation technologies for purpose of avoidance, resistance, rapid repair and restoration of critical infrastructure and other essential facilities;
- ➤ Provide the technical basis for revised codes and standards for critical infrastructure and essential facilities by using risk and vulnerability assessment tools;
- ➤ Improve system reliability and survivability by applying newly emerging sensor technologies to control structural response in critical systems;
- ➤ Improve lifeline survivability through applying improved decision-making tools, redundancy, automated network assessment and shutoff systems, system hardening and network optimization technologies;
- ◆ Predict collateral damage and cascading failures based on models of infrastructure interdependencies;
- ◆ Research soil-structure interaction to prevent failures caused by liquefaction;
- ◆ Develop automated early-warning systems capable of reducing impact to critical infrastructure in urban centers at a distance from the earthquake epicenter.

GRAND CHALLENGE #5: Assess disaster resilience.

- ➤ Extend existing risk and loss assessment software to serve as a primary tool for recovery planning and mitigation strategy development at the state and local levels. Collect cost-benefit information on the value of monitoring and notification capabilities;
- ➤ Use consistent methodologies and supporting technologies to assess the current condition of structures to provide baseline performance estimates and to assess the vulnerability of the built environment to future events. These results will be used to evaluate post event conditions as well as to guide the upgrading of performance for structures needing retrofit.

GRAND CHALLENGE #6: Promote risk-wise behavior.

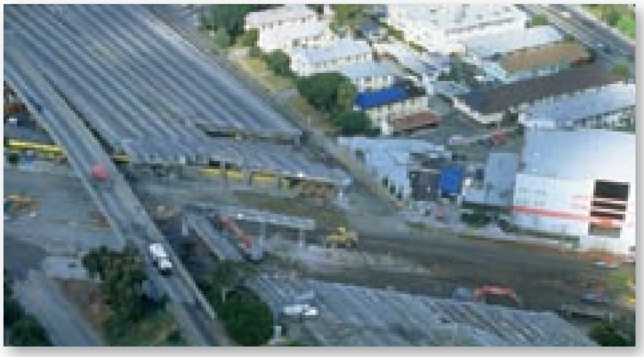
- ■ Implement the Common Alerting Protocol (CAP) into earthquake notification systems to improve integration into multi-hazard warning systems;
- ■ Develop scenarios for impact of likely earthquakes in high-risk urban areas, incorporating latest hazard data, HAZUS loss estimates, and local engineering, geoscience, planning, and emergency management expertise to deliver a comprehensive picture of potential losses and encourage mitigation measures;
- ➤ Develop standardized disaster impact statements to provide individuals and communities with the necessary tools to understand what to expect from a specific natural hazard warning;
- ➤ Ensure that difficult-to-reach sectors of society will understand recommended actions and know how to access safety information and warnings. Address special needs groups, such as the elderly, in preparedness planning;
- ➤ Develop reliable tools for evaluating risk prior to entering partially collapsed structures;
- ➤ Build hazards awareness through K-12 education and extend to appropriate offering of earthquake courses in colleges and universities.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this earthquake-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Government officials, the private sector, and individuals will have access to increasingly accurate assessments of earthquake risk that incorporate the vulnerability of homes, transportation systems, lifelines, emergency and health care facilities, communications systems, business activity, and the general functions of society. These assessments and lessons learned from past earthquakes will be used to develop improved building construction codes and practices, plan for future development, and prepare for earthquake response.



Communities at risk know when a hazard event is imminent. Robust monitoring systems will determine that an earthquake is underway and transmit that information as rapidly as possible, in some cases before the shaking arrives, to provide early warning for more distant sites. The same monitoring systems will determine the extent and severity of ground shaking. By the time the shaking stops, information on the areas with the greatest damage and impacts to lifelines and other critical facilities will be available to emergency managers and first responders, allowing them to prioritize deployment of resources.

Property losses and lives at risk in future earthquakes are minimized. Performance-based design codes for constructing new and strengthening existing buildings will permit owners and engineers to manage property loss risks while ensuring that life safety is not compromised. Improved technology transfer from research to building code application will ensure that new, cost-effective construction technologies will be employed, improving economic competitiveness and further enhancing life safety. Data obtained from instrumented buildings will lead to new earthquake-resistant design and construction concepts. Enhanced use of loss estimation software and more effective employment of the social sciences will result in improved land use planning and better-informed public policy decision-making. Federal agencies and national earthquake code-making bodies will work hand in hand with state and local agencies to facilitate adoption of effective building codes and disseminate critical mitigation information to all corners of the Nation.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Techniques for constructing new infrastructure and retrofitting existing infrastructure will be based on best practices. Buildings will be structurally sound after an earthquake, and critical facilities can be reoccupied without delay. Transportation systems are easily repaired and open for service with minimal interruption to support response and recovery efforts. Recovery will be more effective as communities are able to make informed decisions based on an improved understanding of the true costs.

Acronyms

FEMA Federal Emergency Management Agency
HAZUS Hazards United States loss estimation
NIST National Institute of Standards and Technology
NSF National Science Foundation
USGS United States Geological Survey

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What is at Stake?

DEFINITION AND BACKGROUND. Floods are an overflow or inundation from a river or other body of water and causes or threatens damage. Floods occur in all regions of the United States, at all times of the year. One in three Federal disaster declarations is a result of flooding. An increase in population, more development in flood-prone areas, an increase in the frequency of heavy-rain events over the last fifty years, and impacts of wildland fire and land use changes have resulted in an increase in flood-related losses. Many of these losses are mainly caused by inundation but can also be the result of strong currents damaging structures and undermining foundations.

IMPACTS. In the last 100 years more than 9,000 people have died as result of inland flooding in the United States. In 2002 alone, 42 fatalities resulted from severe flooding, a majority of which could have been avoided if the victims had practiced risk-wise behavior.[1] Property damage from all types of flooding, from flash floods to large river floods, averages $2 billion a year.

The 1993 Mississippi Basin Flood was among the most severe disaster events in recent U.S. history, resulting in an estimated $12–$16 billion in damages.[2] More than 10,000 homes were destroyed during this event, and millions of crop acres were ruined by inundation.[3] Thousands of people had to be evacuated, and many of them were never able to return to their homes. The event also severely damaged forests and other

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wildlands and disrupted the local and national transportation infrastructure leaving major roads, rivers, bridges, and commercial airports out of service.

Flooding as a consequence of Hurricane Katrina caused the evacuation of New Orleans in August/September 2005 and, at this time, damages have been reported in excess of $100 billion,[4] with an estimated 1,464 deaths and 135 people still missing.[5]

Grand Challenges for Disaster Reduction: Priority Interagency Flood Implementation Actions

GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ■ Strengthen hardware and improve placement for critical stream gages;
- ➤ Coordinate the use of existing Earth observation technologies and develop new Earth observation technologies and networks to collect more detailed flood-related data over larger areas (e.g., elevation data from LiDAR, existing soil moisture conditions, more detailed precipitation data, stream elevations from satellites, greater radar coverage in areas subject to flash flooding, and more multiparameter stream gages);
- ➤ Improve sensor network designs that couple *in situ* and Earth observations and operational capabilities to provide data needed for predicting and sensing hazards using physical process models;
- ◆ Improve instrumentation and densification of the stream gage network transmitting data in real time;
- ◆ Exploit digital elevation data to develop comprehensive mapping of inundation scenarios, referenced to the national stream gage network and river forecast points.

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ➤ Research the dynamic relationship between precipitation and its timing, land cover and land use, and patterns of erosion and sedimentation;
- ◆ Develop new or enhanced statistical and deterministic physical process and real-time models for rapid assessment of the likelihood of flooding for small and large basins; improve understanding of the interdependencies between floods and other hazards, such as landslides; and model the effects of climate and land use change;

- ◆ Develop improved data and models on impacts of wildland fire on flooding;
- ◆ Test and validate flood models and decision support systems with increased emphasis on exploitation of national geospatial data sets for soils, land cover, and elevation;
- ◆ Understand the impacts of climate change on flood risk by area.

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ■ Improve understanding of the consequences of unmitigated risk and develop strategies to foster pre-disaster mitigation;
- ➤ Evaluate the long- and short-term effects of alternate mitigation strategies, including hillslope and channel treatments;
- ➤ Conduct social science research into behavior related to risk and mitigation;
- ➤ Develop knowledge of the interdependencies necessary for cumulative impact analysis, collect the data necessary for valid cost benefit analysis of mitigation, and conduct research on the individual and community-level factors associated with local adoption of mitigation measures;
- ➤ Develop a tool kit of hydraulic, hydrologic, meteorologic, economic, and socioeconomic models for evaluation of structural and nonstructural mitigation measures and educational materials that improve communities' understanding of risk and the significance of mitigation alternatives;

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

- Develop new models and decision support systems for land use planning that relate land use change to flood risk by encouraging the use of rating systems that establish links between flood code and ordinance enforcement to serve as an incentive for flood insurance rate reduction (e.g., FEMA's Community Rating System Building Code Effectiveness Grading Schedule).

GRAND CHALLENGE #4: **Reduce the vulnerability of infrastructure.**

- ■ Analyze the vulnerability of infrastructure systems to flood hazard, identify critical infrastructure vulnerable to flooding, and propose mitigation strategies;
- ➤ Conduct vulnerability analysis to reduce the risk of cascading failures and identify the potential impact of flooding on water supply and waste-water and fortify those structures and systems.

GRAND CHALLENGE #5: **Assess disaster resilience.**

- ➤ Develop effectiveness measures for land-use controls, zoning, insurance strategies, mitigation plan development, adoption, and enforcement for all major floodplains to create an index of resilience;
- ➤ Develop a methodology that enables assessment of resilience and conduct a comparison of actual losses to those that would have occurred using alternative mitigation strategies;
- ➤ Develop flood risk maps based upon ongoing and potential, future development of watersheds so that maps stay current and property owners understand how development does (ongoing) and can (potential) impact their vulnerability and risk;
- ◆ Facilitate immediate post-flood-event analyses to immediately capture lessons learned that can assist future recovery operations as well as provide measures to determine the most appropriate alternatives regarding the restoration, modification, or removal of impacted facilities;
- ◆ Continue oversight of the effects of land use change on flood and drought;
- ◆ Improve methodologies to analyze the effects of development alternatives.

GRAND CHALLENGE #6: **Promote risk-wise behavior.**

- ➤ Identify and develop effective methods to educate individuals and decision makers about flood threats so they can make more informed decisions when purchasing land and structures;
- ➤ Develop integrated, targeted, multi-media systems for issuing warnings on flash floods, flooding due to dam or levee failure, and more slowly developing flood events;
- ➤ Develop behavioral understanding and perform other research necessary to develop effective messaging and messaging technologies to permit targeted, rapid dissemination of flood threat information;
- ➤ Fully integrate flood hazard information and the impacts of large-scale disturbance and land cover and land use change on flooding into planning studies;
- ◆ Develop evacuation plans for all flood plains;
- ◆ Foster productive interaction between individuals, communities, and the development industry on strategies for resilient development;
- ◆ Develop more effective incentives for risk-wise development and building practices using revised codes, standards, and zoning regulations.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this flood-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. The dynamic relationship between precipitation and its timing, disturbance events, land cover and land use, and patterns of erosion and sedimentation will be better understood and mapped. Improved numerical models, inundation mapping, visualization, and decision-support tools will help each community identify their risk and vulnerability to flood hazards. The ongoing reevaluation of the 100-year recurrence interval will determine if that is an appropriate indicator of risk.

Communities at risk know when a hazard event is imminent. Improved instrumentation, more consistent data, better Digital Elevation Models (DEMs), improved behavioral understanding, and warning systems will be used to communicate risk and vulnerability more effectively prior to and during flood events of all types.

Individuals and property at risk are safe from hazards. Fewer vulnerable structures will be built in flood-prone areas thanks to improved understanding of inundation areas, risk, human behavior, and the benefits of zoning, enforcement, and mitigation.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Losses will be reduced through improved coordination in prediction, modeling, and mitigation techniques for hurricanes, coastal and inland flooding, flooding and landslides, and other interrelated hazards.

Acronyms

FEMA Federal Emergency Management Agency
LIDAR Light Detection and Ranging

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What is at Stake?

DEFINITION AND BACKGROUND. A heat wave is a prolonged period of warm season temperatures well above normal for the area, often accompanied by high humidity. Heat waves can persist from a couple of days to several weeks and are often accompanied by periods of little or no rain and, in cities, by poor air quality. Heat waves are among the most deadly of all weather events.

IMPACTS. Although extreme events such as hurricanes, tornadoes, and floods make headlines for widespread physical destruction and heavy loss of life, more than 8,900 deaths were directly attributed to excessive heat from 1979 to 2002 in the United States[1] and thousands more died as a result of heat-related causes.[2] In the summer of 1980, approximately 1,700 deaths were directly attributed to persistent and oppressive heat that affected the East and Midwest. The Midwest heat wave of 1995 killed at least 465 people in Chicago alone.[3]

Heat wave impacts are widespread. While a large number of deaths may not occur in a single city every year, the cumulative impacts across broad regions over several days to weeks can result in heavy loss of life.

In an average year, 175 Americans die from the direct effects of extreme heat[4] due to a combination of factors such as failure to take adequate precautions, high humidity, lack of adequate ventilation or air conditioning, poor health, and old age. Many more hundreds of deaths are associated with excessive heat attributed to heart attack, stroke, and also respiratory stress. Most deaths occur in urban areas where concrete, asphalt, and physical structures raise temperatures in urban heat islands, and nighttime temperatures remain above average.

Heat waves also impact farming and ranching through loss of cattle and other livestock. The 1999 drought in the United States, associated with unusually warm temperatures, led to farm net income losses of approximately $1.35 billion.[5] About 25 percent of the United States' harvested cropland and 32 percent of the pastureland were affected. Transportation is impacted by highway and railway buckling, and mechanical failures to trucks and railroad locomotives. Heat waves also can lead to water and electricity shortages and to severe and often extensive wildfires.

HEAT WAVE

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Grand Challenges for Disaster Reduction: Priority Interagency Heat Wave Implementation Actions

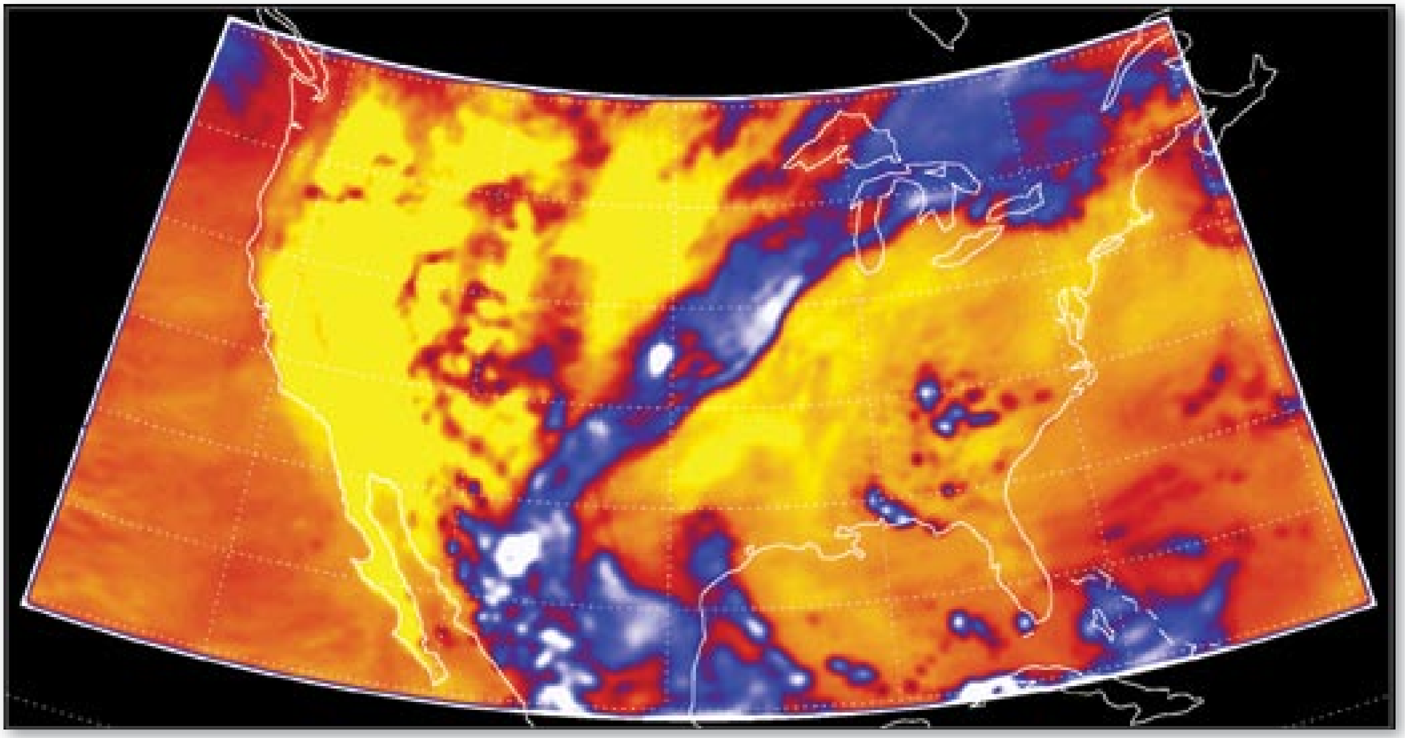
GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ➤ Through advanced communication technology, improve reporting timeliness and accessibility to surface meteorological observations essential to monitoring and forecasting heat wave severity in urban and rural areas of the country;
- ➤ Assess and fill gaps in observations, training, technology, capacity, and organization that may prohibit efficient communication of heat wave forecasts;
- ➤ Provide near real-time reporting of weather conditions to support heat wave monitoring and forecasting through a fully integrated Federal-to-local network of surface observing systems;
- ➤ Improve forecast accuracy of daily maximum temperature by 0.6° C (1.0º F) to support energy production and delivery;
- ➤ Create monitoring and assessment tools for identifying location-specific conditions that are likely to be life threatening to at-risk individuals (e.g., Operational Heat Health Warning System for every National Weather Service forecast area in the United States, increasing the number of Weather Forecast Offices with the capability to use this system from the current 16 to over 120).

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ■ Develop heat wave climate indices that can be used in anticipating future heat wave events and monitoring long-term heat wave event changes based upon climate;
- ■ Identify the amplification of high-pressure areas, the roles of phenomena such as the El Niño-Southern Oscillation, and micro-scale influences that can moderate or exacerbate the severity of a heat wave;
- ➤ Improve mid- and long-range models and the accuracy of forecasted conditions that affect human health, agriculture, transportation, and power distribution.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)



GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ■ Identify at-risk individuals, establish responsive health surveillance and alert systems, create a network of social service and support volunteers, establish infrastructure such as cooling locations/ shelters and telephone help-lines, and institute other response mechanisms to ensure essential life-saving actions are provided when needed;
- ➤ Use meteorological thresholds for each community that identify conditions conducive to the deterioration of human health by applying the synoptic air mass classification approach for heat wave assessment and forecasting.

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

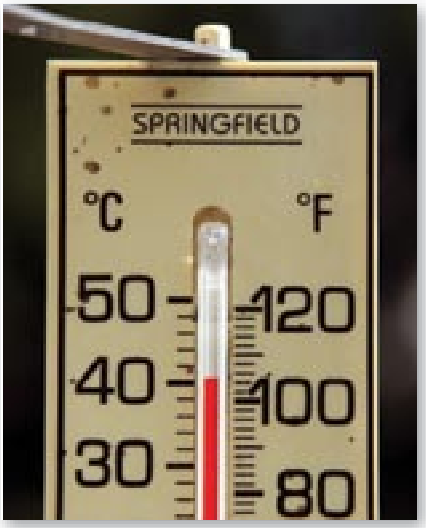
- ◆ Provide a technical basis for revised standards and codes that integrate local climatological and meteorological knowledge to improve standards for the built environment, improve safety, and increase power distribution infrastructure, railway, roadway and pipeline resistance to excessive heat.

GRAND CHALLENGE #5: Assess disaster resilience.

- ■ Study outcomes of past heat waves to distinguish effective and ineffective mitigation and response strategies and technologies;
- ■ Complete risk assessments for at-risk populations in each community.

GRAND CHALLENGE #6: Promote risk-wise behavior.

- ■ Expand the forecast areas for heat warning systems (e.g., Heat Health Warning System);
- ■ Improve individual, community, state, and Federal understanding of the serious risks associated with excessive heat and the potential for human health crises when extreme heat events occur;
- ■ Emphasize the danger signs for heat-related illnesses;
- ◆ Deploy a seamless suite of reliable and accurate heat wave forecast products to support 10 to 14-day advance notification.



Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this heat wave-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Through application of local climatology, individuals are aware of the potential for heat waves in their region.

Communities at risk know when a hazard event is imminent. A national heat health warning system will identify community-specific conditions that threaten individual health and provide improved notification and warning to at-risk individuals.

Individuals at risk are safe from hazards. Public/private partnerships will foster outreach to at-risk individuals and a ready-public based on improved mid- to long-term forecasting of heat wave episodes.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. New technologies will be employed to safeguard power distribution, roads, rails, aviation, ports, and pipelines during heat waves. Individuals and businesses can plan their energy usage more effectively.

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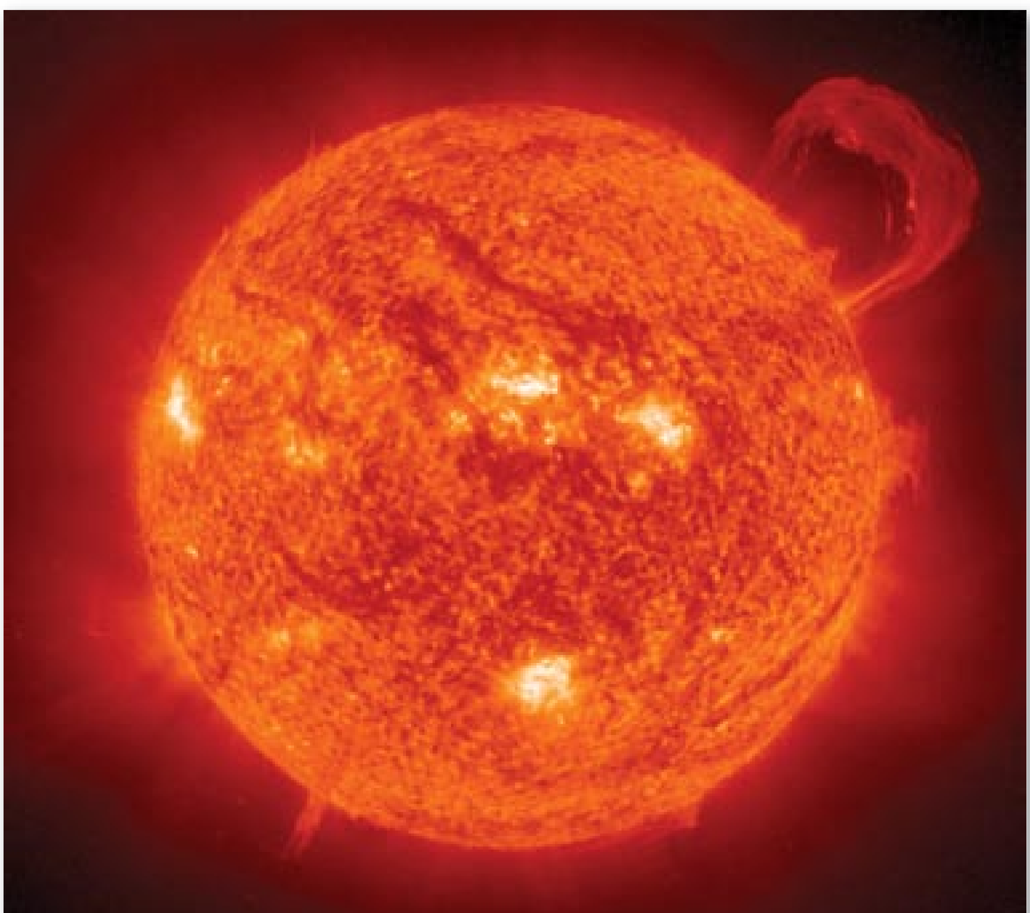

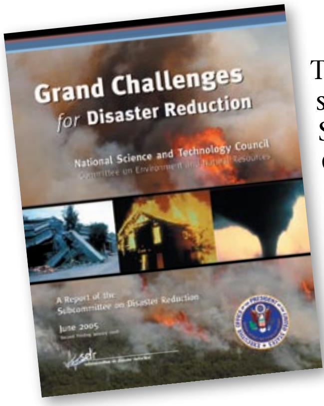

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To meet these Challenges, the SDR has identified priority science and technology interagency implementation actions by hazard that build upon ongoing efforts. Addressing these implementation actions will improve America's capacity to prevent and recover from disasters, thus fulfilling our Nation's commitment to reducing the impacts of all hazards and enhancing the safety and economic well-being of every individual and community. This is the human and ecosystem health-specific implementation plan. See also **sdr.gov** for other hazard-specific implementation plans.

What is at Stake?

DEFINITION AND BACKGROUND. Human and ecosystem health hazards are conditions that predispose a person to adverse health outcomes (e.g., death, illness, injury, or disability), or result in the deterioration of ecosystem structure and functioning (e.g., acid rain, habitat degradation, animal or plant deaths, introduction of invasive species, community changes, loss of biodiversity).

IMPACTS. Recently, concern about an avian influenza pandemic and its potentially massive deleterious consequences on human and ecosystem health has mobilized the attention of the United States Government. This is one of many health hazards that our Nation and the world are facing.

The emergence of the West Nile virus in the United States in 1999 has caused annual outbreaks, leading to significant neuroinvasive disease in humans, infections in at least 58 mosquito species, and unprecedented mortality in birds. An estimated cost of the epidemic in Louisiana from June 2002 to February 2003 was $20.1 million.[1]

Similarly, in the environment, the increase in geographic distribution, frequency, and severity in the development of harmful algal blooms (HABs) has important ramifications on human and ecosystem health ranging from respiratory distress to death in both human and aquatic life.

HABs also have a large economic impact. In the past, the cost of HABs to our economy was estimated to be about $50 million per year. Recently, the frequency and severity of major HABs outbreaks have increased, and costs can exceed $50 million for one event alone.[2] Alien invasive species, including plants, animals, and microorganisms, cause up to $120 billion in damage annually in the U.S.[3] These affect agricultural and ecosystem productivity and the health of forests, rangelands, croplands, and land and aquatic ecosystems, in addition to resulting in human health impacts.

Human and ecosystem health disasters also can be consequences of other disasters such as earthquakes, floods, or volcanic eruptions. For example, in public health, major hurricanes such as Hurricanes Katrina and Rita in August–September 2005 led to extensive and significant short and long-term impacts on the health and well-being of affected communities in the Gulf Coast. Deaths from the events have exceeded 1,464 in states directly affected by the hurricanes and in those states housing displaced persons.[4] Long-term and chronic effects have yet to be estimated. In the environment, the progressive destruction of marshes and wetlands along the Gulf Coast, especially in Louisiana and Mississippi, increased the impacts of these two hurricanes by reducing the protection of the coastal zones. As a result, the extensive flooding and accompanying widespread pollution of soils and waters dramatically increased the magnitude of the original disaster.

HUMAN AND ECOSYSTEM HEALTH

A report of the Subcommittee on Disaster Reduction
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An element of the National Science and Technology Council

Grand Challenges for Disaster Reduction: Priority Interagency Human and Ecosystem Health Hazards Implementation Actions

GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ■ Research the fundamental processes in human and ecosystem health that predispose adverse human health outcomes or result in ecosystem structure and function deterioration;
- ■ Improve human and environmental health monitoring systems and protocols to identify, describe, collect, analyze, and interpret emerging infectious agents and other health hazards (e.g., organisms, toxic substances, etc.). These monitoring systems must be accurate and specific to allow for the correct identification of the threat;
- ■ Develop and improve the timeliness and accuracy of human and ecological health forecasts;
- ■ Assess the impacts of natural resource use on ecosystem health and the capacity of ecosystems to respond to hazards;
- ➤ Continue developing new technologies to detect agents that threaten human and ecosystem health;
- ➤ Using more comprehensive models, develop clear, actionable risk and vulnerability assessments based on data from monitoring systems and global observation networks (for diseases and environmental data);
- ➤ Develop searchable ecological and public health databases for early detection of emerging threats;
- ◆ Develop and improve remote, *in situ*, permanent, and mobile environmental and human health monitoring systems to collect and analyze data in real time;
- ◆ Facilitate and increase coordination between terrestrial, aquatic, and atmospheric monitoring systems.

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ■ Use an interdisciplinary approach to expand and enhance the knowledge base of short-term, long-term, and cumulative risk factors and processes associated with hazard-related events to identify potential health and ecological adverse outcomes;
- ■ Increase the workforce competence for human health care workers and ecosystem resource managers to address health and ecological threats by improving training;
- ■ Assess the impacts of climate change and other global changes (e.g., increased input of nutrients in the environment, land-use changes, increased use of antibiotics in animal and food supplies) on human and ecosystem health;
- ➤ Understand the baseline and status of ecosystem health and human public health in order to track and monitor the impact of disease-causing agents and other health hazards;
- ➤ Research the evolution of health threats by using remote-sensing capabilities and tools, laboratory detection techniques and instrumentation, methods for ground-based assessments, and improved modeling capabilities;
- ◆ Understand the cumulative effects of stressors and hazards in human populations and ecosystems to better target causative agents and processes;
- ◆ Integrate biological, physical, chemical, and epidemiological models to provide accurate and timely forecasts of human and ecosystem health-related events and their impacts;
- ◆ Improve the use of surveillance networks, remote and *in situ* environmental monitoring systems, genomics, and cellular fingerprinting to better understand human and ecosystem health hazards;
- ◆ Develop models and scenarios to identify the impact of human intervention on human and ecosystem health and to evaluate programmatic, scientific, environmental, social, psychological, and economic consequences of specific decisions.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ■ Improve guidelines for use by state and local government officials to prepare for and respond to human and ecological health threats;
- ■ Develop and pre-deploy stockpiles, tools, and supplies that can be used at the onset of human and ecological health events requiring resources for response;
- ■ Improve coordinated, geographically focused human and ecosystem health mitigation plans to enhance region-specific and local emergency preparedness and response;
- ■ Recommend actions that can prevent or reduce adverse effects of hazards on human and ecosystem health;
- ■ Integrate new information about known and emerging human and ecosystem health hazards;
- ➤ Use interdisciplinary knowledge from recurring and emerging human and ecological health threats to provide the foundation for national and local preparedness and mitigation strategies;
- ➤ Implement a comprehensive prevention and mitigation strategy for known and emerging human and ecosystem health threats;
- ➤ Develop and improve human and environmental decontamination gears, capabilities, plans, and protocols for chemical, biological, radiological, and other hazardous substances;
- ➤ Accurately model the outcomes of natural and technological hazards in specific geographic areas and the outcomes of various management decisions, scenarios, and land-use strategies on the environment;
- ◆ Reduce human and ecosystem susceptibility to future hazards by restoring human and ecosystem health following a hazard;
- ◆ Integrate new research about the potential human and ecosystem health impacts of climate change into mitigation strategies;
- ◆ Sustain local capabilities to effectively mitigate the adverse impacts of human and ecosystem health hazards.

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

- ■ Assure that access to critical care facilities, emergency response, and emergency management services is maintained following disasters;
- ■ Note which infrastructures are at risk during any detrimental event. Assess the risks of a subsequent human or ecological disaster;
- ■ Properly repair critical infrastructure immediately following a disaster.

GRAND CHALLENGE #5: Assess disaster resilience.

- ■ Strengthen programs for community training in emergency medicine and environmental preventive and corrective actions;
- ■ Assess availability of rapid response capabilities to quickly detect, diagnose, and treat human and ecosystem injuries, disease, and detrimental conditions (e.g., invasive species, climate change);
- ■ Assess the capabilities available to prevent and control chronic human and ecosystem health conditions and other long-term adverse effects;
- ➤ Restore human and ecosystem health from post-disaster conditions to pre-disaster states by instituting recovery programs such as injury rehabilitation, mental recovery, suicide and domestic violence prevention, water system integrity evaluation, food water safety, vector control (monitoring and surveillance), and ecosystem and natural population restoration;
- ➤ Develop pilot projects for recovery and restoration techniques (e.g., replanting of multiple species in areas decimated by diseases or parasitic invasion, restoration of coastal marshes, diagnostic tools for mental health);
- ➤ Evaluate the effectiveness, appropriateness, and timeliness of responses to a hazard-related event;
- ➤ Provide risk assessments to determine the likelihood and potential impacts of hazard-related events and to identify at-risk communities or areas;
- ◆ Develop a database of lessons learned from past disaster events with human and ecological health impacts.

GRAND CHALLENGE #6: Promote risk-wise behavior.

- ■ Create educational products to effectively communicate recommendations for protective action and preventive behavior;
- ➤ Develop protocols to evaluate the scientific basis and reach interagency agreement on best practices for individual actions before, during, and after an event;
- ➤ Communicate clear messages that can be understood by all in harm's way about the risks associated with an impending hazard;
- ◆ Develop early warning systems that: (1) incorporate research findings from the social sciences; (2) leverage the latest innovations in dissemination technologies; and (3) provide actionable information in real time, based on solid scientific information and on state-of-the-art models to protect critical facilities, infrastructure, and vulnerable populations and ecosystems.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this human and ecosystem health-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. New and improved tools or methods (such as portable kits for rapid identification of bacteria, viruses, or toxins, genetic analysis, field assessment methods, or diagnostic models) will significantly increase public health officials' and resources managers' ability to identify, collect, monitor, analyze, and interpret health and environmental threats in real time. The potential for cascading health and ecosystem health hazards will be understood following all hazard events.

Communities at risk know when a hazard event is imminent. New and improved risk assessments, near real-time forecasts, early warning systems, and new approaches to identify specific ecosystem and human health threats in near real-time will alert decision makers to the initiation, timing, path, potential spread, and severity of human or ecosystem health conditions, thus reducing the adverse impacts of the hazards.

Individuals at risk are safe from hazards. Improved personal and collective protective behavior will prevent, reduce, or control human and ecosystem health deterioration. Pre-deployment of diagnostic equipment and material (e.g., medicine or diagnostic kits), public and ecological health services, and trained personnel will lead to more effective response.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Coordinated, geographically focused human and ecosystem health mitigation plans will enhance region-specific and local emergency preparedness and response. Human and ecosystem health will be restored from post-disaster to pre-disaster conditions after all events.

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What is at Stake?

DEFINITION AND BACKGROUND. A hurricane develops when a tropical storm intensifies and winds reach 74 miles per hour. On average, there are six hurricanes in the Atlantic Ocean each year during hurricane season (June–November). Over a three-year period, approximately five hurricanes strike the United States coastline between Texas and Maine.[1] When hurricanes move onto land, the heavy rain, strong winds, and waves can damage communication, transportation, and utility infrastructures.

IMPACTS. According to FEMA, hurricanes account for seven of the top ten most costly disasters in United States history. The state of Florida was struck by four major hurricanes in 2004 with losses totaling $42 billion.[2] This was considerably more than the losses resulting from Hurricane Andrew in 1992, which had set the standard for single hurricane losses in the United States. The 2005 hurricane season included 27 named storms and 15 hurricanes, 6 of which struck the United States.[3]

The losses due to Hurricanes Katrina, Rita, and Wilma in 2005 are still being determined, but early estimates place damages from Hurricanes Katrina and Rita upwards of $150 billion.[4]

This dwarfs the losses due to any disaster in the United States and approaches a significant percentage of the United States Gross Domestic Product.

Recent storms demonstrated how hurricanes can affect the entire United States and its economy, from energy to raw materials to food supplies. Minimizing the impacts of hurricanes depends upon constant, sound land-use planning and development decisions as well as effective response immediately prior to storm landfall. The multi-agency U.S. Weather Research Program, authorized by Congress in 1994, placed the improvement of hurricane forecasts as its highest priority in 1997. Since then, the program has significantly improved hurricane track forecasts and how those forecasts and warnings are communicated to individuals. In 2004, Congress recognized the unique role of wind hazards and created an Interagency Working Group consisting of NIST, NSF, NOAA, and FEMA to plan, manage, and coordinate windstorm impact reduction for the Nation.

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Grand Challenges for Disaster Reduction: Priority Interagency Hurricane Implementation Actions

GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ■ Improve mechanisms for information exchange between Federal agencies involved in wind hazard reduction, state and local decision makers, and non-Federal stakeholders;
- ➤ Assess and fill gaps in observations, training, technology, capacity, information, and organization on the Federal, state, and local level;
- ➤ Accelerate development and deployment of integrated Earth observing systems, models, and forecast platforms to warn those who are directly at risk.

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ■ Build on accomplishments of the U.S. Weather Research Program to accelerate improvements in hurricane forecasts;
- ➤ Improve global coverage of scatterometer and radiometer space-based remote sensing systems;
- ➤ Develop high-resolution global and regional cloud-resolving forecast models to simulate and forecast hurricane structure, track, and intensity;
- ➤ Improve understanding and modeling of atmosphere-ocean interactions; understand the physics of hurricane genesis;
- ➤ Improve airborne observing capabilities, including the use of remotely piloted vehicles;
- ➤ Increase density of and strengthen *in situ* and surface-based remote sensing platforms over land and ocean and develop mobile platforms and networks to opportunistically gather data needed for post-storm assessment and model enhancements;
- ◆ Develop sophisticated decision support systems (e.g., HAZUS) for risk assessment and impact prediction.

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ■ Exchange information between all levels of government about interpreting hurricane risk assessments, forecasts, building codes and best building practices, protection of critical infrastructure, and public education on risk, response, and mitigation. Pay particular attention to individuals who are often at greatest risk, such as the economically, socially, and medically disadvantaged;
- ➤ Develop a comprehensive wind storm climatology to provide the technical basis for improved building codes and predictive numerical engineering models of wind effects on structures;
- ➤ Identify expected inter-annual, decadal, and multi-decadal changes in hurricane activity and intensity;
- ➤ Develop improved methods for assessing risk, social vulnerability, and ecosystem impacts to inform mitigation choices in coastal areas.

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

- ➤ Examine the interaction between wind, storm surge, and shallow water waves to determine the impact on building foundations, critical infrastructure, and vegetation;
- ➤ Assess the vulnerability of critical communication, transportation infrastructure, and essential facilities to hurricanes;

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

- ➤ Develop an improved loss estimation modeling tool (e.g., HAZUS);
- ◆ Create robust and storm-ready communication systems, essential facilities, and transportation infrastructure.

GRAND CHALLENGE #5: **Assess disaster resilience.**

- ■ Assess structural and non-structural hurricane protection, including natural barriers, levees, and land use;
- ■ Support intelligent community planning and investment strategies and protect natural resources with comprehensive risk assessments;
- ■ Develop comprehensive pre-event recovery plans;
- ➤ Assess response and recovery of terrestrial and coastal ecosystems to hurricane damage.

GRAND CHALLENGE #6: **Promote risk-wise behavior.**

- ■ Support social science research on individual, organizational, and community responses to disaster warnings;
- ■ Identify common characteristics of risk-wise behavior and factors facilitating effective warning compliance;
- ■ Identify obstructions to the most effective communication of risk from time scales of hours before landfall to decades in the future;
- ■ Promote individual understanding of forecast and warning statements—in particular, an understanding of the uncertainty in this information—and encourage appropriate actions;
- ➤ Facilitate more effective communication and use of communication systems (i.e., direct automated calls to those at risk) to improve public understanding of hurricane risks, mitigation procedures, and evacuation procedures;
- ◆ Improve development of appropriate response, contingency, and evacuation community plans based on knowledge of extreme weather events derived from long-term data collection and analysis.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this hurricane-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Combined assessment methods will allow better understanding of structural, social, and economic impacts of hurricanes.

Communities at risk know when a hazard event is imminent. Through improved observation technologies and improved modeling capabilities, forecasters will have the necessary information to provide accurate and understandable forecasts of hurricane track, intensity/structure, sea state/waves, storm surge, winds, precipitation, flooding, and inundation up to 5 days prior to landfall. This improved capability will lead to improved warning accuracy and lead time and more efficient and effective preparedness, including evacuation.

Individuals at risk are safe from hazards. The coordinated distribution of information about risk and preparedness combined with effective decision-making tools will lead to more timely and accurate warnings as well as appropriate and efficient evacuation.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. New, more accurate methods for understanding and assessing risk perception and risk communication including the utilization and effectiveness of non-structural mitigation measures and improved structural design will make communities more disaster resilient.

Acronyms

FEMA Federal Emergency Management Agency
HAZUS Hazards United States Loss Estimation
NIST National Institute of Standards and Technology
NOAA National Oceanic and Atmospheric Administration
NSF National Science Foundation

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LANDSLIDE AND DEBRIS FLOW

The *Grand Challenges for Disaster Reduction* outlines a ten-year strategy crafted by the National Science and Technology Council's Subcommittee on Disaster Reduction (SDR). It sets forth six Grand Challenges that, when addressed, will enhance community resilience to disasters and thus create a more disaster-resilient Nation. These Grand Challenges require sustained Federal investment as well as collaborations with state and local governments, professional societies and trade associations, the private sector, academia, and the international community to successfully transfer disaster reduction science and technology into common use.

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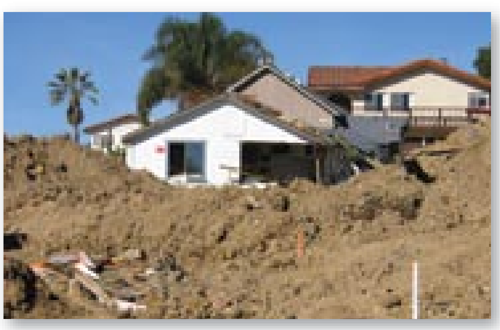
What is at Stake?

DEFINITION AND BACKGROUND. Landslides are triggered by a number of mechanisms, including intense rainstorms and earthquakes, wildland fire, coastal erosion, and the loss of permafrost in arctic regions. The most dangerous landslides are debris flows where slope material becomes saturated with water resulting in a slurry of rock and mud picking up trees, houses, and cars, thus, at times, blocking bridges and tributaries, causing flooding along its path.

IMPACTS. Landslides, debris flows, and other forms of ground failure affect communities in every state of the Nation. Despite advances in science and technology, these events continue to result in human suffering, billions of dollars in property losses, and environmental degradation every year.[1] Approximately two-thirds of the United States population lives in counties where landslide susceptibility is moderate to high.[2]



Landslides routinely disrupt lifelines, such as transportation routes and public utilities, causing billions of dollars in direct property loss annually. Equally as important, but much harder to measure, are the indirect costs encountered when community business and social activities are disrupted. The United States has experienced several catastrophic debris-flow events in recent years. In 1985, a massive debris flow in southern Puerto Rico killed 129 people, inflicting the greatest loss of life by a single landslide in United States history. More recently, in December 2003, 14 people died in Waterman's Canyon in southern California following summer wildfires. The 1982-83 and 1983-84 El Niño season triggered landslide events that affected the entire western United States, including California, Washington, Utah, Nevada, and Idaho. A more recent event, the 1997-98 El Niño rainstorms in the San Francisco Bay area, produced thousands of landslides and caused over $150 million in direct public and private losses.[3]

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Grand Challenges for Disaster Reduction: Priority Interagency Landslide and Debris Flow Implementation Actions

GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ■ Increase the use of Interferometric Synthetic Aperture Radar as well as airborne and ground-based side-looking LiDAR for more accurate landslide hazard assessments, susceptibility mapping, and to determine the volumes of susceptible material and possible runout distances;
- ➤ Inventory sensors needed to predict and monitor landslides. Determine and fill critical gaps.

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ➤ Research landslide initiation processes to better understand the interaction between soil type, texture, terrain grade, weather, fire, and other hazards;
- ➤ Develop better rainfall threshold models for landslides in areas routinely threatened by hurricanes and winter rainy seasons;
- ➤ Better integrate models that evaluate post-wildfire debris flow and landslide potential with near real-time rainfall estimates that blend *in situ*, radar, and satellite observations.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ➤ Develop improved structural mitigation techniques for landslide hazards;
- ➤ Evaluate effectiveness of alternative treatments for post-fire rehabilitation and restoration of severely burned slopes on reducing landslides and debris flows hazards.

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

- ◆ Inventory and assess the vulnerability of the Nation's most critical infrastructure to landslide hazards;
- ◆ Utilize research and data from past events to provide the technical basis for codes and standards and local zoning decisions that will locate hospitals, schools, power plants, and other essential facilities away from the risk area, or retrofit to provide adequate protection from the assessed landslide risk.

GRAND CHALLENGE #5: Assess disaster resilience.

- ■ Incorporate the use of risk analysis techniques to guide loss reduction efforts at the state and local levels;
- ➤ Update the national landslide susceptibility map and state landslide susceptibility maps;
- ➤ Produce landslide hazard maps for communities at risk throughout the U.S.;
- ➤ Complete risk assessments for at-risk communities;
- ➤ Provide information necessary to develop effective land use plans and policies for at-risk communities;
- ➤ Develop comprehensive pre-event recovery plans.

GRAND CHALLENGE #6: Promote risk-wise behavior.

- ■ Develop a guidebook with best practices for mitigating landslide hazards and train local decision makers to use it efficiently and effectively;
- ■ Test a pilot warning system for debris flows following fires in Southern California and expand the system to other parts of California;
- ■ Develop a warning system that utilizes an emergency communication network, forecasting ability, and geologic expertise;
- ■ Continue to build better links between the fire fighting community, landslide researchers, forest managers, and communities most at risk near forested areas;
- ➤ Identify and develop effective methods to educate individuals and decision makers about landslide threats so they can make more informed decisions when purchasing land and structures;
- ◆ Test and expand the warning system for debris flows to other susceptible regions.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this landslide and debris flow-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. More communities across the Nation will have landslide susceptibility and hazard maps by combining more robust rainfall threshold models with more accurate and detailed weather forecasting and high-frequency, spatially continuous precipitation monitoring. Agencies will be better able to incorporate landslide and debris flow risk reduction into long-term planning and event response.

Communities at risk know when a hazard event is imminent. Communities will incorporate landslide susceptibility and hazard maps into their land use and emergency response plans. More accurate and effective warning systems will be the result of high frequency, spatially continuous precipitation monitoring and accurate weather forecasting at the local level through expanded existing radar networks and next-generation radar development.

Individuals at risk are safe from hazards. The integration of earthquake, volcano, landslide, flood, and other hazards data will improve the effectiveness of modeling, warnings, response, and recovery efforts for communities at risk. Individuals and communities will know how to protect themselves from dangerous and costly landslides through professional training and community outreach.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Fewer people will be in the path of landslides due to improved zoning and land use decisions. Communities will be more aware of potential landslide and debris flow hazards and can respond quickly.

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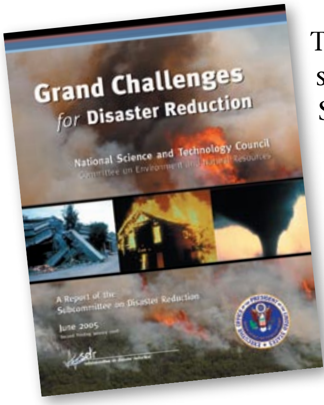

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What is at Stake?

DEFINITION AND BACKGROUND. Technological hazards involve the release of hazardous substances that impact human health and safety, the environment, and/or the local economy. Hazardous substances are chemicals, toxic substances, gasoline and oil, nuclear and radiological material, and flammable and explosive materials, in the form of gases, liquids, or solids. Because such hazards exist during production, storage, transportation, use, or disposal, the impacts to our oceans, groundwater systems, streams, rivers, agriculture, air quality, and urban areas continue to be significant.

Criminal and terrorist threats to facilities that house technological hazards are additional concerns that must be considered when assessing risk and developing prevention and mitigation strategies. Failures in cyber-infrastructures, failures of upkeep, human error and accidents, and naturally occurring events such as hurricanes, floods, earthquakes, and fires also can cascade into a technological disaster.

IMPACTS. In July of 2001, a train traveling through the Howard Street Tunnel in Baltimore, Maryland was derailed, causing a major chemical spill.[1] Flames from the resulting chemical fire reached temperatures up to 1000°C (1800°F). The liquid fuel contained in the tanker cars sustained the fire for several hours causing significant damage to the tunnel and completely destroying all contents of the train. The event caused major disruption to the local infrastructure and necessitated the evacuation of several facilities, including Camden Yards.

TECHNOLOGICAL DISASTERS

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Grand Challenges for Disaster Reduction: Priority Interagency Technological Disasters Implementation Actions

GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ➤ Improve and coordinate the databases of industrial hazard threats to communities with all Federal, state, and local response agencies;
- ➤ Improve GIS databases to map critical infrastructure, industry, public health services, and other facilities in order to identify locations of technological hazards and improve information sharing through common-format data collection and dissemination via interoperable systems;
- ➤ Enable sophisticated spatial modeling and dynamic population movement at local levels in all GIS databases;
- ➤ Develop a comprehensive toolkit of evaluation procedures, risk-assessment tools, and computational technologies that can be used in the field;
- ➤ Improve detection and assessment technologies and improve hazard prediction methodologies to enable risk reduction;
- ◆ Integrate science-based improvements into regulations;
- ◆ Develop new technologies to detect the presence of biological, chemical, and radiological contaminants in the air, water, or on surfaces in near-real time.

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ➤ Research the basic mechanisms behind contaminant fate and transport in air, water, and through the earth to improve understanding of commonly used hazardous chemicals and new materials as they are introduced; of situations that can lead to release; of dispersion rates in air, water, and soil; of immediate threat to the community including fires and explosions; and of short and long-term impacts on the environment, public health, and the economy.

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ■ Establish an interagency committee for Technological Hazards coordinated through the SDR as a focal point for collaborative government, private sector, and academic research into the short-term and long-term effects of technological disasters;
- ■ Develop improved, security-based design standards for new facilities, transportation containers, and storage devices;
- ■ Develop improved design standards for environmentally sound and rapidly deployable clean-up technologies;
- ➤ Implement science-based improvements in regulatory guidance for local, state, and Federal zoning and mitigation plans;
- ◆ Develop new chemicals, materials, and industrial processes which are environmentally and physiologically benign and reduce consumer reliance on hazardous substances;
- ◆ Develop improved design standards for new facilities, infrastructure, transportation containers, and storage devices.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

➤ Create advanced computational models to assess the public health, economic, and environmental impacts of technological disasters on communities, and to assess the effectiveness of hazard identification, prediction, preparedness, and mitigation methods;

◆ Develop disaster-resilient technologies to mitigate the effects of technical hazards on critical infrastructures.

GRAND CHALLENGE #5: Assess disaster resilience.

■ Establish and communicate a consensus on acceptable risk levels and appropriate individual protective measures in places where individuals live, work, and play;

■ Develop new, more accurate technological hazard maps;

■ Develop community evacuation plans based on scientific research of likely hazard scenarios and public responses;

■ Incorporate lessons learned into a synthesis of risk assessment, prediction, mitigation, response, and recovery methodologies to assess and understand the impacts of technological disasters on interdependent infrastructure, public health, the environment, the economy, and the community as a whole;

◆ Assess how well local decision makers, emergency managers, and individuals understand the technological hazards that exist in their community, and the training of response personnel and individuals about appropriate responses to probable, local technological disasters.

GRAND CHALLENGE #6: Promote risk-wise behavior.

■ Develop a best practices guide for community warning systems;

■ Research and implement effective regulatory and enforcement approaches;

➤ Develop rapid risk assessment and risk communication strategies to inform decisions by individuals, state and local emergency managers, and response personnel;

➤ Offer increased incentives and methods for safer operation of hazardous facilities and materials transport;

➤ Cultivate a strong network of capable, communicative, and prepared local community leaders and emergency responders, educated about the technological hazards they face and the technical and communication skills needed to prevent, mitigate, and respond to such disasters;

◆ Develop and install new, more advanced detection and warning systems for all facilities and at-risk communities;

◆ Foster a ready-public, educated, prepared, and capable of receiving information and taking life-saving actions in the event of a technological disaster;

◆ Establish an effective nationwide and geographically specific warning system;

◆ Develop a strong network of capable, prepared Federal, state, and local authorities, emergency managers, and first responders, educated about the likelihood of technological disasters in the Nation, states, and local communities with technical and communication skills needed to prevent, mitigate, respond to and recover from such disasters.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this technological disasters-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Owners and operators will adhere to guidelines and safely operate facilities. Individuals, decision makers, and emergency management personnel will understand the technological hazards that exist in their community and will have prepared appropriate responses to potential technological disasters.

Communities at risk know when a hazard event is imminent. Reliable information will be acquired in a common format and conveyed via interoperable systems, fostering information sharing and more rapid information dissemination. There will be faster, appropriate, safe responses from emergency responders and emergency management officials at all levels of government as well as more effective, timely warnings.

Individuals at risk are safe from hazards. Safer materials will exist, and there will be lower probability for release of hazardous materials. The consequences associated with different aspects of possible technological disasters will be predicted with certainty and conveyed to an educated, ready-public capable of implementing individual protective measures, developing evacuation plans, and taking life-saving actions.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Prior consensus will be reached among all levels of government and industry-appropriate protective measures during response and recovery operations. New products, processes, and technologies will deliver value without threatening public safety or the environment. Improved technical basis for construction materials and design standards will reduce the consequences of technological disasters. Improved contamination and decontamination methods will reduce mortality/morbidity.

Reference

1. McGrattan, K.B., and Hamins, A., 2003: Numerical Simulation of the Howard Street Tunnel Fire, Baltimore, Maryland, July 2001. Available online at **http://fire.nist.gov/bfrlpubs/fire03/PDF/f03086.pdf**

The *Grand Challenges for Disaster Reduction* outlines a ten-year strategy crafted by the National Science and Technology Council's Subcommittee on Disaster Reduction (SDR). It sets forth six Grand Challenges that, when addressed, will enhance community resilience to disasters and thus create a more disaster-resilient Nation. These Grand Challenges require sustained Federal investment as well as collaborations with state and local governments, professional societies and trade associations, the private sector, academia, and the international community to successfully transfer disaster reduction science and technology into common use.

To meet these Challenges, the SDR has identified priority science and technology interagency implementation actions by hazard that build upon ongoing efforts. Addressing these implementation actions will improve America's capacity to prevent and recover from disasters, thus fulfilling our Nation's commitment to reducing the impacts of all hazards and enhancing the safety and economic well-being of every individual and community. This is the tornado-specific implementation plan. See also **sdr.gov** for other hazard-specific implementation plans.

What is at Stake?

DEFINITION AND BACKGROUND. A tornado is a violently rotating column of air extending from a thunderstorm to the ground. Tornadoes may appear nearly transparent until dust and debris are picked up or a cloud forms within the funnel. The average tornado moves from southwest to northeast, but tornadoes have been known to move in any direction. The most violent tornadoes are capable of tremendous destruction with wind speeds of 112 m/s (250 mph) or more. The swath of damage can be in excess of 1.6 km (one mile) wide and 80.5 km (50 miles) long.

Tornadoes come in all shapes and sizes and can occur anywhere in the United States at any time of the year. Tornadoes have occurred in every state, but they are most frequent east of the Rocky Mountains during the spring and summer months. In the southern states, peak tornado season is March through May, while peak months in the northern states are during the summer. Tornadoes are most likely to occur between 3 and 9 p.m. but can happen at any time.

In 2004, Congress recognized the unique role of wind hazards and created an Interagency Working Group consisting of NIST, NSF, NOAA, and FEMA to plan, manage, and coordinate windstorm impact reduction for the Nation.

IMPACTS. Although tornadoes occur in many parts of the world, they are found most frequently in the United States. In an average year, 1,200 tornadoes cause 70 fatalities and 1,500 injuries nationwide.[1] The most expensive tornado outbreak in United States history and the deadliest of the year occurred May 3 and 4, 1999 in Oklahoma and Kansas. In less than 21 hours, a total of 74 tornadoes touched down across the two states, with as many as four tornadoes from different storms on the ground at once.

One of those storms, an F-5 tornado, the strongest on the Fujita Tornado Scale, moved along a 61-kilometer (38-mile) path, from Chickasha through south Oklahoma City and the suburbs of Bridge Creek, Newcastle, Moore, Midwest City, and Del City. With 8,000 buildings[2] damaged, the Oklahoma City tornado is the most expensive single tornado in history, causing about a billion dollars in damage. In all, the tornadoes killed 46 people, injured 800, and caused $1.5 billion in damage.[3]

TORNADO

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The event proved the effectiveness of the watch and warning program in the modernized National Weather Service, showing improvement with an average warning lead time of 18 minutes for the event (up from a national 11-minute average), with some areas receiving more than 30 minutes notice before being hit. NOAA storm researchers estimate that more than 600 people would have died in the absence of watches and warnings.[4]

Grand Challenges for Disaster Reduction: Priority Interagency Tornado Implementation Actions

GRAND CHALLENGE #1: Provide hazard and disaster information where and when it is needed.

- ■ Assess and fill gaps in observations, training, technology, capacity, and organization that may prohibit efficient exchange of information;
- ■ Promote collaborations and partnerships between Federal agencies through existing facilities (e.g., Hazardous Weather Test Bed, the Short Term Prediction Research and Transition Center, the Joint Center for Satellite Data Assimilation, and the Hydrometeorology Test Bed) to transition from research to operations;
- ■ Provide data compatible with the operational communications and dissemination systems (e.g., the National Weather Service) to inform forecasts;
- ➤ Improve resolution (space and time) of real time *in situ* and remotely sensed measurements of the near-storm environment;
- ◆ Create stable, efficient, fast data assimilation models with appropriate atmospheric characterization to produce tornado warnings up to 45 minutes in advance, severe thunderstorm warnings up to 60 minutes in advance, and watches up to 8 hours in advance;
- ◆ Speed delivery of remote-sensing satellite products.

GRAND CHALLENGE #2: Understand the natural processes that produce hazards.

- ■ Improve predictive models through enhanced physical understanding, data assimilation, and spatial resolution;
- ■ Deploy new sensors, such as dual polarized radars, to better understand cloud microphysics;
- ➤ Develop integrated data observation systems, models, and forecast platforms to reduce costly and unnecessary evacuations;
- ➤ Verify tornado initiation and dissipation by conducting field experiments and gathering new data;
- ➤ Improve data assimilation techniques for high-resolution models;
- ◆ Deploy new sensors, such as phased array radar, to increase spatial and temporal input needed for high-resolution, small-scale numerical models;
- ◆ Develop operational forecast models to track tornado intensity changes and provide a better understanding of the expected frequency and magnitude of these events.

GRAND CHALLENGE #3: Develop hazard mitigation strategies and technologies.

- ■ Evaluate the response of the built environment to tornadoes by investigating load path, ultimate capability conditions, and the building envelope;
- ■ Assess the impact of wind and windborne debris;
- ■ Explore the near-ground and channeling/shielding effects of winds on buildings through testing and instrumentation;
- ➤ Provide a technical basis for revised standards and codes that integrate local climatological and meteorological knowledge to improve standards for the built environment, improve safety, and reduce structural loss during tornadoes.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

GRAND CHALLENGE #4: Reduce the vulnerability of infrastructure.

- ➤ Develop and deploy new technologies that aid in better design, rapid repair, and restoration of critical infrastructure and other essential facilities;
- ➤ Measure the response of bridges and other highway structures to tornadoes, including stability, serviceability, and functionality leading up to and through the tornado event;
- ➤ Develop mitigation strategies with local authorities, such as burying power and communication cables.

GRAND CHALLENGE #5: Assess disaster resilience.

- ■ Coordinate inter-agency, detailed post-storm assessment of damage, injuries, and deaths;
- ■ Assess local preparedness and enhance local resilience through the National Weather Service Storm Ready Program.

GRAND CHALLENGE #6: Promote risk-wise behavior.

- ■ Educate individuals, communities, states, and the Federal agencies about the risks associated with tornadoes and appropriate actions to take;
- ■ Distribute seasonal outlooks, explain longer lead time warnings, and emphasize preparedness and the importance of taking appropriate action during a watch or warning;
- ■ Employ communication and dissemination strategies for extended warnings and probabilistic forecasts based on improved social science research into individual response;
- ■ Informed community planning and annual drills will lead to more effective warnings and evacuations;
- ■ Direct automated calls to those at risk (e.g., reverse-911);
- ◆ Create interactive, portable, and adaptable forecast, warning, and decision support systems based on high-resolution numerical models, high-resolution observations, and improved algorithms to alert emergency managers, emergency personnel, and individuals in real time about locally occurring severe storms.

Key: ■ Short Term Action (1-2 years) ➤ Medium Term Action (2-5 years) ◆ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this tornado-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Risk assessments based on regional tornado climatology and seasonal outlooks provide local information to those at risk.

Communities at risk know when a hazard event is imminent. Predicting tornadoes by community, neighborhood, and specific street address will yield better, more actionable warnings and fewer lives lost. Real-time information dissemination and decision-support tools will be used by emergency personnel and local, state, and Federal emergency management officials.

Individuals at risk are safe from hazards. Tornado impact reduction practices at all levels of government will be aided by training and outreach programs to build a ready-public. Informed planning and annual drills will lead to more effective warnings and evacuations.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Public-private partnerships fostering technology transfer programs will enhance response and recovery capabilities using improved tornado damage and loss estimation tools. Standards and technologies will enable cost-effective, state-of-the-art tornado-resistant provisions to be adopted as part of state and local building codes.

Acronyms

FEMA Federal Emergency Management Agency
NIST National Institute of Standards and Technology
NOAA National Oceanic and Atmospheric Administration
NSF National Science Foundation

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