EARTHQUAKE


Grand Challenges for Disaster Reduction

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 earthquake-specific implementation plan. See also **sdr.gov** for other hazard-specific implementation plans.

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.

A report of the Subcommittee on Disaster Reduction
www.sdr.gov

An element of the National Science and Technology Council

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.**

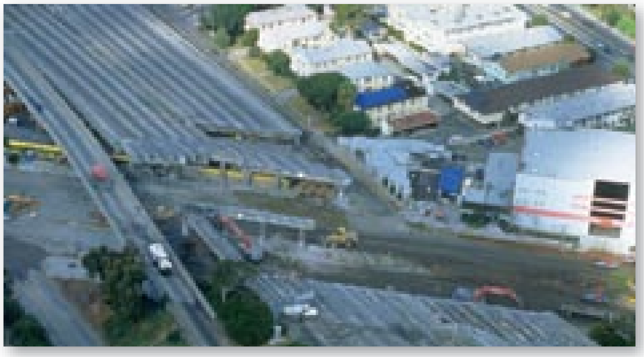
- ■ Implement the Common Alerting Protocol (CAP) into earthquake notification systems to improve integration into multi-hazard warning systems;
- ■ Develop scenarios for impact of likely earthquakes in high-risk urban areas, incorporating latest hazard data, HAZUS loss estimates, and local engineering, 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

References

1. "Earthquake Facts and Statistics," USGS, **http://neic.usgs.gov/neis/eqlists/eqstats.html**
2. "Requirements for an Advanced National Seismic System," United States Geological Survey Circular 1188, 1999, p. 5
3. Field et al., 2005, Loss estimates for a Puente Hills blind-thrust earthquake in Los Angeles, California. Earthquake Spectra, vol. 21, n.5, pp. 329-338