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

References

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