Whether caused by acts of nature, human error or even malevolence, disasters are an increasingly costly threat. Although most people assume they will not become victims, individual risk grows as homes and businesses encroach deeper into disaster-prone regions. That risk can be personal or structural – or both.

Research gives us hope. Early warning systems developed over the past several decades have prevented countless deaths and injuries. Structural impact is another matter. Despite improved building codes and practices, more people are building in risky locations. The rate of property destruction and rebuilding is increasing, and costs are rising. In 2005, Hurricane Katrina proved yet again just how much destruction disasters can cause.

Regardless of origin—from hurricanes to earthquakes, blackouts to terrorist attacks—disasters can seem overwhelming. Yet their impact need not be crippling. The National Science Foundation works with the Administration and other federal agencies in a coordinated effort to anticipate disasters and minimize their effects.
When we learn about dangers, we find ways to counter them

Without a comprehensive understanding of disasters, it is impossible to prepare for them. Knowledge is critical, whether for determining how weather systems develop, estimating the path of volcanic debris, recognizing triggers before a ground-shaking seismic event, or even gauging how an individual’s decisions—from a utility employee to a public official—can put entire communities at risk.

With the right information, researchers, communities and planners can work together to craft an effective response for almost any conceivable crisis and learn how to confront them more effectively in the future.
Hurricanes, tornadoes, torrential rains and other severe weather drive many of the most devastating natural disasters. University researchers and experts at NSF’s National Center for Atmospheric Research (NCAR) have spent the past several decades studying the most fundamental properties of weather, including observations of enormous thunderstorm complexes through the BAMEX project and the search for tornado origins in the VORTEX project.

In the field, storm chasers learn much about local and regional weather at the scene of the devastation. Across the country, armadas of instrument-packed vans, trucks and airplanes race to rendezvous with storm systems. In the past 10 years, experts have taken advantage of a new tool: radar-equipped trucks, some carrying a dish antenna 8 feet across.

During storm chases, Doppler On Wheels (DOW) systems train their electromagnetic beams on twisters and violent storms to gather data on the inner workings of tumultuous weather phenomena — the newest Rapid-Scan model uses six simultaneous beams to collect 3-D data in about 10 seconds. The truck can get within half a mile of a tornado and record detailed images, including spiraling bands of clouds and concentric rings of debris.

"Across the country, armadas of instrument-packed vans, trucks and airplanes race to rendezvous with the weather."

Those mobile Doppler radars—similar to the larger systems used for local or airport weather—are critical for what they reveal about the structures of tornadoes, hurricanes and other violent storms.

Joshua Wurman and Jerry Straka developed DOW over a decade ago while conducting research at the University of Oklahoma. Wurman, now an adjunct professor at Penn State, continues to use the technology in his work at the Center for Severe Weather Research (CSWR) in Boulder, Colo.
even the study of fires. Data collected by these systems contribute to advanced computer simulations, which have in turn led to new discoveries about dangerous weather.

DOW has mapped the 3-D structure of tornadoes and documented their lifecycles, and uncovered a major, yet previously unknown, hurricane phenomenon – intense, organized wind streaks in the boundary air-mass between the land surface and the storm that can influence damage when a hurricane makes landfall.

With such highly detailed knowledge of storm structures, scientists are now gaining a better understanding of how, and when, tornadoes will form.
Computer models developed at the National Center for Atmospheric Research (NCAR) help us understand how weather patterns develop. From the models, meteorologists are learning which conditions lead to devastating storms – knowledge that helps communities prepare for disasters before they strike.

Some of the largest computer models are even helping predict climatic effects, the broad-scale changes to weather patterns over time. Several models are helping scientists determine which regions are most likely to be affected by drought, severe storms and other impacts from global warming.

Credit: Bob Wilhelmson, NCSA and the University of Illinois at Urbana-Champaign; Lou Wicker, National Severe Storms Laboratory, National Oceanic and Atmospheric Administration; Matt Gilmore, Lee Cronce, Department of Atmospheric Sciences, University of Illinois. Visualization by Donna Cox, Robert Patterson, Stuart Levy, Matt Hall, Alex Betts, NCSA.
Volcanic eruptions are more common in the United States than many people may realize.

While the Hawaiian islands are familiar hot spots, such threats as Mount St. Helens, Mount Ranier and even the enormous caldera that is Yellowstone National Park may pose a significant risk for millions of people in the continental United States.

Michael Sheridan and his colleagues at the State University of New York (SUNY) at Buffalo are developing technology that may identify not only the areas that could be affected by dangerous volcanic flows, but also the expected paths of destructive, hot avalanches and debris and the probability that a given locality could be inundated.

Combining mathematical modeling, geologic simulations, geographic information science, scientific computing and virtual reality, the researchers will ultimately provide accurate information on geologic dangers to scientists, civil-defense authorities and residents living in the shadow of a volcano.

The scientists use detailed satellite data of volcanoes and surrounding terrain to develop realistic, 3-D flow models and simulations. According to Sheridan, more people than ever before are living close to active volcanoes, so advanced technologies for estimating and limiting risks from volcanic activity hold enormous promise for safeguarding human lives.
The Earth’s dynamic tectonic plates can trigger disasters: earthquakes, volcanoes and tsunami all stem from the motions of the planet’s crust.

Earthquakes are perhaps the least predictable natural disasters. As part of NSF’s EarthScope project, scientists are installing a network of Global Positioning System (GPS) receivers to continually record the constant, yet often difficult to detect, movements of earthquake faults throughout southern California.

EarthScope is a $200 million program that will reveal much about the structure and evolution of the North American continent, from hundreds-of-kilometer spans to fractures less than a millimeter wide.

GPS is one of the most important new technologies to emerge in decades for the study of earthquakes. Information from the network of receivers will reveal the accumulation of strain along fault lines – data that will help scientists determine regional earthquake hazards and the complex motions of specific faults. Ultimately, the information may help public officials devise better emergency preparedness strategies and changes to building codes.
For those already living in high-risk areas, researchers are trying to learn more about the root causes behind disasters and why some structures survive them while others do not.

Supported in part by a rapid-response NSF Small Grant for Exploratory Research, Beverley Adams of ImageCat, Inc., Kishor Mehta of Texas Tech University and their colleagues focused on damage caused by Hurricane Charley, the most devastating U.S. storm of 2004.

By analyzing high-resolution pictures captured from space, the researchers found they could rapidly assess damage to a vast number of buildings, a technique that may one day prove invaluable to first responders and public officials trying to allocate resources after a crisis.

Evidence of storm damage is short-lived – due to natural causes such as erosion, and to the cleanup and restoration that follow the crisis. Rapid-response researchers like Adams must arrive on the scene before critical knowledge is lost to those efforts. By adding satellite imagery to their ground-based surveys, the team was able to record the condition of up to 2,500 buildings each day. Earlier methods were lucky to catch 100 buildings in the same day’s work.
Many power system researchers believe that the enormous Northeast blackout of 2003 was a combination of hazards, such as untrimmed tree limbs, and weaknesses in the overall United States power grid system.
Compounding the problem, other stations may become isolated due to the multiple failures – these plants also go out of service since they no longer have a path along which to send their power.

Limitations in the computer networks, and even procedures, linking power plants in the grid can drive this cascading process. At this point, the blackout is well underway.

Many power system researchers believe that the enormous Northeast blackout of 2003 resulted from a combination of hazards, such as untrimmed tree limbs, and weaknesses in the overall United States power grid system.

Researchers at the NSF-supported Industry/University Cooperative Research Center on Power Systems Engineering (PSERC) have been tackling the problem of blackouts and developing tools to both understand these events and make the power system more reliable. The researchers are currently testing several new software tools that will quickly alert power-system operators when a catastrophe is imminent. They hope to provide enough warning to allow operators to make rapid decisions that could prevent the spread of power disruptions from one region to the next.

Next: Understanding Disasters >> Choices and Consequences
Sometimes, disaster damage is made worse by people’s choices to live in high-risk areas. Understanding how to help people avoid risky homesite choices is a start. Homes built along floodplains or in drought-prone regions are particularly vulnerable – in 2003 alone, Southern California wildfires destroyed 750,043 acres and 3,710 homes, and took 24 lives in just 15 days.

Research into how human emotion drives decisions can also help us understand how personal choices make a crisis worse. Howard Kunreuther of the University of Pennsylvania's Wharton School and his colleagues found that most people living in areas prone to floods, earthquakes, hurricanes and other devastating natural disasters take no steps to protect themselves or their property.

These residents ignore precautions proven to be life-saving and cost-effective, such as strapping down water heaters or bolting houses to foundations, and neglect to buy hazard insurance – even when the federal government provides substantial subsidies. While financial concerns play a role, Kunreuther found that the main problem is people believe disasters may affect others, but not themselves.
Disasters by Design: A Reassessment of Natural Hazards in the United States
http://www.nap.edu/books/0309063604/html/

The Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) is conducting groundbreaking atmospheric research that complements the efforts of NCAR, CSWR and others.
www.casa.umass.edu

Three NSF Engineering Research Centers support earthquake research:
Multidisciplinary Center for Earthquake Engineering Research (MCEER)
http://mceer.buffalo.edu/
http://www.erc-assoc.org/factsheets/m/html/erc_m.htm

Pacific Earthquake Engineering Research Center
http://peer.berkeley.edu/
http://www.erc-assoc.org/factsheets/n/html/erc_n.htm

Mid-America Earthquake Center
http://mae.cee.illinois.edu/

Additional highlights of NSF disaster research can be found in the full-color text America’s Investment in the Future, also available online, and the Disasters and Hazard Mitigation section contained within.

Selected NSF news stories related to storms and flooding:
Population and Wealth, More Than Climate, Drive Soaring Costs of U.S. Flood Damage

New England Lakes May Hold Clues to Future Storms and Floods
#second

Complex Weather Study to Target Summer Storm Forecasting

Selected NSF news stories related to tectonics and volcanism:
Researchers Attempt to Identify When, Where Volcanoes Will Erupt

Seafloor Observatories to Monitor Tsunamis, Earthquakes
http://www.nsf.gov/od/lpa/news/02/tip020604.htm#third

Volcanic Eruption Detection

Earthquake Study Produces New Depiction of Fault Zones
http://www.nsf.gov/od/lpa/news/02/tip021001.htm#second

Selected NSF news stories related to wildfires:
Researchers Receive Funds to Create High-Tech Wildfire Fighting Solutions
cntn_id=100365

Aircraft, Ground Instruments to Track Carbon Dioxide Uptake Along Colorado's Drought-Plagued Front Range
cntn_id=100373

Next: Preparing for the Worst
Preparing for the Worst

**Designing an environment that does not yield**

Events beyond our control may trigger disasters, but careful preparation is our responsibility – and often within our means.

Beyond learning which factors put us at risk, we can look to cutting-edge research for tools that can help keep us safe.

**View Video** (*Video no longer available.*)

The terrorists who attacked the Pentagon and the World Trade Center on Sept. 11, 2001, used fuel-laden airplanes as missiles. Few (if any) building engineers had considered such a threat. The Pentagon damage was severe, and researchers have been studying the attack to learn what design elements can help engineers protect against similar threats. This simulation, created by Purdue University researchers, breaks down the factors that caused the most severe damage during the 0.25 seconds from the plane’s impact to its destruction. Additional information is available at [Purdue release on Pentagon simulation](#).

Credit: Department of Computer Sciences and Computer Graphics Technology, Purdue University
On Feb. 7, 2003, a bomb demonstrated the critical benefits of solid construction when El Nogal social club in Bogotá, Colombia, withstood a devastating blast. Terrorists had used approximately 600 pounds of ammonium nitrate and chlorate mixed with fuel oil to create an enormous explosive device, placed within an automobile parked on the fourth floor of a 12-story building. At the time of the blast, 750 people were in the building; 38 were killed and 170 were injured. However, because the building remained standing, fatalities were minimized.

El Nogal, composed of the 12-story structure and an adjacent, smaller four-story structure, was designed to withstand seismic shaking. Luis García of Universidad de Los Andes, Colombia, and Santiago Pujol of WJE Associates studied El Nogal to determine how a modern building designed to sustain earthquakes responds to an explosive blast.

The researchers compared the Colombia event in February 2003 to a comparable event in Oklahoma City in April 1995, when the Murrah Federal Building (which was not designed for earthquakes) was eviscerated by an enormous truck bomb placed there by Timothy McVeigh.

...because the building remained standing, fatalities were minimized.

For engineers, similar concerns apply to both earthquakes and explosions, and engineers intend to use seismic design concepts to produce structures that address both threats. Specifically, the structures must be redundant (able to retain integrity after a component fails) and tough (able to retain integrity through cycles of stress).

Researchers found that reinforcing details, which were integrated into the structure of El Nogal and were required by Colombia's seismic code, were critical in preventing total collapse of the building. Such details helped minimize a tragedy not foreseen by engineers, who designed the structure to withstand only the forces of an earthquake.
Buildings are not the only structures vulnerable to physical assault. Power stations, water mains, roads and myriad other components of modern infrastructure would be vulnerable to failure if not for engineering codes and new technologies in place throughout disaster-prone regions of our country.

The university network that comprises 15 of NSF’s $81.8 million George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) are linking their laboratories into one integrated system to study the effects of seismic events on national infrastructures.

From an enormous laboratory wave basin that creates small tsunamis at Oregon State University to a Cornell University facility for testing the resilience of electrical, water and other lifelines, distant researchers can interact with each other—and each other’s equipment—to study the impact of seismic waves on full-scale structures. Experiments can originate at any of the sites across the nation thanks to Internet2, a heartier offspring of the original Internet.

NEES researchers at the University of California, San Diego, are conducting a test during fall 2005 that takes full advantage of another unique tool. ... they will subject a seven-story building to the actual seismic
Using one of the world's largest outdoor shake tables, they will subject a seven-story building to the actual seismic motion (in terms of both direction and strength) of the Northridge earthquake.

Such studies may soon develop an international scope. On Sept. 11, 2005, NSF Director Arden L. Bement, Jr., and Tetsuhisa Shirakawa, Japan's Deputy Minister of Education, Science and Technology, signed the "Memorandum Concerning Cooperation in the Area of Disaster Prevention Research" in Kyoto, Japan.

The agreement will enable earthquake engineering researchers from both countries to participate in joint experiments at laboratories in both nations, ultimately allowing researchers from either country to use testing facilities on both sides of the globe.

Such efforts and their findings will likely spawn a new generation of prevention mechanisms, further securing not just buildings, but entire communities.
Preparing for the Worst >> Ensuring Cybersecurity

Not all threats target concrete and steel. Some target the electronic infrastructure of the Internet. From the purchasing of airline tickets to the coordination of emergency responders, the Internet is at the core of how our society functions in the 21st century.

To learn how to detect and combat ever-more potent cyberattacks, researchers are developing broad test-beds to watch how computer worms and viruses spread, and to develop new tools to safeguard against them.

In collaboration with the U.S. Department of Homeland Security, NSF is funding the networking of nearly 1,000 computers into a system that, while isolated from outside electronic traffic, is a dynamic model for the Internet. Called the Cyber Defense Technology Experimental Research Lab (DETER), the $5.46 million system is the workbench upon which researchers at the University of California, Berkeley, and the University of Southern California in Los Angeles will craft novel cyber attacks and better security solutions.

A $5.34 million companion project will subject these solutions to rigorous tests. Researchers at Pennsylvania State University, the University of California, Davis, Purdue University and the International Computer Science Institute will drive the testing effort, dubbed Evaluation Methods for Internet Security Technology (EMIST).

Next: Preparing for the Worst >> Defending Against Weather

*These links may no longer be available.
While cybersecurity breaches can knock out infrastructure, so can one of the most devastating and perhaps most enduring threats we face: the weather.

Major research efforts are targeting the inner workings of devastating storms (see Understanding Disasters) and helping to devise earlier warnings to prepare for the worst. Parallel research is uncovering ways to prevent severe damage to buildings and other immobile structures that remain to face the brunt of an assault.

The threat of wind damage cannot be underestimated; much of a storm’s destruction can be caused by wind. The investigators designing defenses against these barrages are called wind engineers, and Bogusz Bienkiewicz of Colorado State University (CSU) helped to pioneer this field.

For 10 years, Bienkiewicz and his colleagues at CSU and Texas Tech University ran NSF’s Cooperative Program in Wind Engineering, which combined research at the enormous CSU wind tunnels—up to 88 feet long—with field experiments at Texas Tech. The teamwork has led to improvements in the American Society of Civil Engineers Standard No. 7, an extensive guideline that helps communities determine appropriate building codes. Researchers around the globe, from Europe to Japan, learned from this research and have since begun similar experimental studies.
In this video clip, Bill Spencer of the University of Illinois discusses a building-scale shock absorber that may help structures resist the shaking of earthquakes. The shock absorbers use a special magnetic fluid that thickens to a dense, almost solid paste in a magnetic field. Additional information on this research is available at http://sstl.cee.illinois.edu/. 

Video no longer available

**Preventing the Worst >> Related Links**

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<tr>
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<td>Dave Weggel</td>
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<td>Bill Spencer</td>
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**Related Links**

- [Dave Weggel](http://cee.uncc.edu/faculty-directory/faculty-profiles/96-weggel-david.html) and his colleagues study structural damage from suicide bomber attacks, specifically the effects of small, backpack-sized explosives on industrial facilities. 

**Partha Sarkar**, Iowa State University

Sarkar and his colleagues study high-speed, rotating tornadic winds and powerful microbursts—downdrafts that have been responsible for bringing down aircraft. The researchers have created one of the largest tornado simulators in the world, designed for engineering research. 

[http://www.aeem.iastate.edu/Faculty/Sarkar.html](http://www.aeem.iastate.edu/Faculty/Sarkar.html) 

**Bill Spencer**, University of Illinois at Urbana-Champaign

Spencer and his colleagues research protective systems, such as magnetic fluid braces. The braces contain liquids that become rigid in a magnetic field, a property that can work to offset earthquake forces in a building. 

[http://sstl.cee.illinois.edu/](http://sstl.cee.illinois.edu/) 

**Simulating Disasters to Save Lives**


**Tomorrow's Materials: Lighter, Tougher, Faster**

[http://www.nsf.gov/about/history/nsf0050/materials/tomorrow.htm](http://www.nsf.gov/about/history/nsf0050/materials/tomorrow.htm) 

**Selected NSF news stories related to cybersecurity**


**A Surveillance System for Cybersecurity Attacks**


**NSF Announces Two Cybersecurity Centers to Study Internet Epidemiology and "Ecology"**


**Data Mining Pinpoints Network Intrusions**

Immediate Response

The front lines of a catastrophe are marked by frenetic activity amid myriad hazards. Survival in such an environment can hinge on lessons and technologies resulting from disaster research – such as sensors to detect victims in rubble, safety equipment to neutralize toxins, modern building codes to withstand bomb blasts and a carefully planned emergency response to minimize aftereffects.

When a major disaster strikes, rapid-response researchers can arrive on site within days to collect data before it is lost to erosion, vandalism or reconstruction. After the Indian Ocean tsunami of 2004, U.S. researchers rushed to the devastated regions to assess the wave damage, study reconstruction efforts and determine how to rebuild to withstand future tsunamis.

Such response is familiar to the research community. From Hurricane Camille to the 2001 terrorist attacks to Hurricane Katrina, researchers have raced to disaster sites to learn important lessons before the clues vanish.

Many NSF rapid-response researchers not only study disasters, but also play an active role in rescues by providing both technology and field expertise.

In the aftermath of the 2001 attacks, researchers used rescue robots to search for victims in the demolished buildings in New York. After Hurricane Katrina in 2005, members of that same research team participated in the search and rescue effort in Mississippi.

Whether searching for victims, setting up communications equipment or helping to rescue pets, members of the research community can have a direct and vital role in disaster response while gathering valuable information to apply to future crises.

Next: Immediate Response >> Communication
Editor’s Note: High Performance Wireless Research and Education Network (HPWREN) cameras and communications continue to prove useful in combating wildfires. On June 30, 2006, several HPWREN cameras captured real-time visuals of a wildfire at the Riverside/San Diego county line that shut down portions of a busy California freeway and threatened the Santa Margarita Ecological Reserve. The California Department of Forestry and Fire Prevention extinguished the blaze before it turned into a large-scale disaster. For an HPWREN press release about newly updated cameras and how they captured the June 30 wildfire on film, see: http://hpwren.ucsd.edu/news/20060712/.

Reliable communication is essential at disaster sites, particularly for local, state and federal agencies that have lost access to phone lines, power stations and roads.

In July 2003, lightning touched off the Coyote wildfire in a remote corner of San Diego County, Calif. The resulting blaze eventually scorched 19,000 acres. In response, the California Department of Forestry and Fire Protection (CDF) deployed 1,700 firefighters, 10 helicopters and several bulldozers.

To link the power of the Internet to the isolated operations camp, CDF called upon researchers from the San Diego Supercomputer Center and Scripps Institution of Oceanography, both at the University of California, San Diego, and San Diego State University (SDSU), all collaborators on a project known as the High Performance Wireless Research and Education Network (HPWREN).

Researchers arrived at the wildfire scene within hours to deploy a high-speed wireless link. This invisible lifeline carried information more than 70 miles, from the San Diego Supercomputer Center to the emergency crews. With the wireless access, firefighters were able to receive weather data and other intelligence in real time and send incident information to the state’s emergency response agencies.

Since 2003, HPWREN has supported several major California fire responses, including the Eagle Fire of May 2004 and the Mataguay Fire of July 2004. The Eagle Fire response was the team’s first nighttime, ad-hoc deployment of communications for emergency support.

Meanwhile, researchers are continually developing new methods and devices including a real-time early warning system to alert firefighters to dry, dangerous weather conditions, and a new procedure for helicopter-based deployment of an ad-hoc data-communications relay site.
In the last week of August 2007, Robin Murphy, director of the Center for Robot-Assisted Search and Rescue (CRASAR), and her team brought search and rescue robots to Crandall Canyon mine, just outside Huntington, Utah, where six miners have been trapped since Aug. 6. While the muddy, rugged conditions within the mine made robotic searching difficult, the technology will allow the search effort to continue without risk to other miners.

To address disasters in more urban environments, CRASAR (at the University of South Florida has conducted training workshops and field exercises to help researchers improve the latest generation of search and rescue robots.

The need for such tools was apparent at the World Trade Center following the 2001 terrorist attacks. CRASAR researchers coordinated the use of robots at the site, deploying devices that helped rescue crews remotely explore the acres of collapsed buildings.

The CRASAR efforts have expanded since 2001. In 2005, the team participated in several search and rescue efforts, including the response to the La Conchita, Calif. mudslides of January 2005. During investigations of two damaged houses, the researchers evaluated their robots and identified new mobility challenges for them. This real-world experience resulted in new data for the scientific community and their partners in industry, which in turn became a valuable asset for engineers designing improved models.

In 2005, CRASAR also joined forces with industry, the University of Minnesota and undergraduate-focused colleges to form the NSF Safety Security Rescue Research Center (SSRRC).

The SSRRC combines research efforts in robotics and robotic vision and in the aftermath of Hurricane Katrina in 2005, team members searched for survivors in Mississippi. The researchers used unmanned aerial vehicles to search several hazardous areas. They reported back to emergency responders that no survivors were trapped in the destroyed buildings and that floodwaters from the cresting Pearl River posed no additional threat to people in the vicinity.

Furthering such efforts, researchers at the University of Minnesota, the University of Pennsylvania and Caltech...
are working to create **coordinated robot platoons** for search-and-rescue operations. To enhance their value at disaster sites, robot teams need to work together to sense biochemical hazards, to explore and map a site, accomplish simple tasks without a human operator and to communicate effectively with that operator if necessary.

**Murphy** says, "My hope is that in five years, when you see a disaster or earthquake on television, you're just going to expect the rescue to have robots. It's going to be that standard."

*Next: Immediate Response >> Containment*
Immediate Response >> Containment

Emergencies seem unavoidable, but they need not provoke apprehension and fear. Continuing efforts from engineers and scientists across the country are ensuring that first responders will have the tools and skills needed to manage a crisis as it unfolds.

Decades ago, Kenneth Klabunde of Kansas State University developed a unique material with an uncanny ability to trap and destroy a variety of chemical warfare agents and industrial waste products.

Working with researchers at NanoScale Materials, Inc. of Manhattan, Kan., Klabunde helped create the FAST-ACT family of chemicals. Composed of harmless, naturally occurring minerals made from magnesium, titanium and oxygen, FAST-ACT grabs onto VX gas, hydrochloric acid and other toxins and tears them apart – usually in less than two minutes.

The secret to FAST-ACT’s effectiveness is the way researchers engineered the material using nanoscale manufacturing processes that cause changes at the atomic level.

The resulting product is not only cheaper than its laboratory predecessor, it also has a much larger, highly reactive surface area. One ounce of the white powder has the same surface area as a football field, in about the volume of a shot glass.

Next: Immediate Response >> Related Links
Immediate Response >> Related Links

**NSF Press Briefing: Beyond September 11th: An Account of Post-Disaster Research**
Includes presentations from rapid-response researchers who deployed to the disaster sites.

**NSF Special Report: After the Tsunami**
Highlights rapid response research following the 2004 Indian Ocean tsunami.

**Natural Hazards Research and Applications Information Center (NHRAIC)**
A clearinghouse for social science disaster research and information at the University of Colorado in Boulder. Collects and shares research and experience related to disaster preparedness, response, recovery and mitigation. (Participant, Beyond September 11th event)
http://www.colorado.edu/hazards/

**Institute for Civil Infrastructure Systems (ICIS)**
A partnership with Cornell University, Polytechnic University, the University of Southern California and the Robert F. Wagner Graduate School of Public Service at New York University. (Participant, Beyond September 11th event)
http://www.icisnyu.org/

**Disaster Research Center**
http://www.udel.edu/DRC/

*These links may no longer be available.*
A natural or accidental disaster is certainly traumatic. But when a disaster is caused by human malevolence, the impact can seem even more intense. In addition to its focus on natural disasters, the National Science Foundation (NSF) is also engaged on several fronts in the fight against terrorism.

NSF’s core mission is basic research—that is, long-term or fundamental research aimed at gathering knowledge, not necessarily a specific result. Sometimes, the value of cutting-edge research is not obvious until public attention focuses on it.

In the case of Sept. 11, scientists and engineers quickly joined the response. Those who were experienced with earthquakes, floods and other natural devastation converged on the World Trade Center site to help. Some searched for victims or studied how buildings collapsed. Others digitally mapped the disaster site. Still others monitored the coordination of responders from across the nation.

Scientists also measured emotions and public opinion, both immediately after Sept. 11 and over following years. The complex array of responses ranged from trauma and grief to a need to help. Such studies suggest that in some situations, strengthened emotional responses can be as critical to survival as strengthened physical structures. Researchers hope that by learning more about those feelings, we can react with greater resilience if or when disaster strikes again.

Here are some examples of NSF’s responses to Sept. 11.

Next: NSF And 9/11 >> Searching for Victims
Abolhassan Astaneh-Asl of the University of California, Berkeley and a colleague collected data on the mechanical and structural properties of the World Trade Center towers, focusing on how steel is affected by heat, fire and impact. Working with collaborators at MSC Software Corporation, the researchers have developed a simulation of the aircraft impact and are applying the findings to study how other building designs would react to a similar attack.

Credit: A. Astaneh-Asl, Z. Zhao, J. Son, University of California, Berkeley; C. Heydan, V. Tunga, MSC Software Corporation
NSF And 9/11 >> Searching for Victims

On Sept. 12, 2001, robotics expert Robin Murphy from the Center for Robot-Assisted Search and Rescue (CRASAR) was at Ground Zero.

Over the next 11 days, she and her CRASAR team from the University of South Florida (USF) helped search for victims of the collapsed World Trade Center towers. During those critical first days, the team guided the robots through five insertions into the rubble and debris.

Since the attacks, the CRASAR team has continued to help with emergency response, sending teams to Punta Gorda, Fla., following Hurricane Charley in 2004; the La Conchita, Calif., mudslides in 2005; and, most recently, in response to Hurricane Katrina as part of the new Safety Security Rescue Research Center.

This center is an NSF Industry-University Cooperative Research Center that combines robotics and robotic vision research efforts from researchers in industry and at USF, the University of Minnesota and undergraduate-focused colleges such as Augsburg College in Minneapolis, Minn., and Berea College in Berea, Ky.

Next: NSF And 9/11 >> Identifying the Anthrax Bacterium
In the months following the Sept. 11 attacks, scientists played a critical role in analyzing materials from the first known victim of the 2001 mailed-letter assault that exposed 22 people along the East Coast to Bacillus anthracis, the bacterium that causes anthrax.

Experts at The Institute for Genomic Research (TIGR) and Northern Arizona University identified genetic markers that distinguished the Florida Bacillus from closely related strains, pioneering the use of genomics for forensic analysis of microbes. Previous analyses of genetic markers focused on a limited number of DNA segments rather than the entire microbe genome.

Led by Timothy Read and Claire Fraser, the scientists discovered that the Florida Bacillus came from a 1981 strain found in a Texas cow—a strain that researchers had later used in experiments at the U.S. Army Medical Research Institute for Infectious Diseases in Fort Detrick, Md.
A team from Georgia Tech, led by engineer David Frost, collected damage data near Ground Zero using an innovative system that included Palm handheld computers. Frost and his colleagues originally developed the system, known as PQuake, for earthquake response.

PQuake allows many researchers to simultaneously collect and input Global Positioning System coordinates, digital data and photos into one format. This capability ultimately produces near-real-time mapping of the extent and severity of damage at a disaster site. The small devices generate detailed maps in hours rather than days, giving recovery workers critical information that applies to planning, operations and safety.
The National Opinion Research Center (NORC) at the University of Chicago documented Americans’ resilience after the attacks, registering large increases in national pride, confidence in government institutions and faith in both religion and community. However, months later, the continuing study found that some groups (such as residents of New York) were more likely to be worried about future terrorist attacks.

The researchers also compared responses to Sept. 11 and to the assassination of President John F. Kennedy. People reported a large drop in their normally positive feelings toward life after the Kennedy assassination, but reported few similar responses after Sept. 11. However, the study found a much stronger feeling of anger after Sept. 11 than after the 1963 assassination.

Across the Atlantic—on March 11, 2003—Spain experienced a terrorist attack that was carefully timed to occur just before the Spanish national election. Tom W. Smith and Kenneth A. Rasinski of NORC used NSF support to commission of the Analisis Sociologicos Economicos Y Politicos to study the emotional aftermath.

According to Smith, the study found that residents of Madrid were angrier about the event and more fearful for their own lives and safety than were those who lived elsewhere in Spain. Those in Madrid and those in the rest of the country did not differ in the belief that Spain had brought the attack on itself. Overall, the Spanish citizens who did believe this expressed less satisfaction with the government, and fewer said that they would vote for the pro-U.S. incumbent government.
Several NSF-funded surveys extended beyond the United States. In a study of Egypt, Monsoor Moaddel of Eastern Michigan University and his colleagues surveyed Egyptian attitudes and values before and after Sept. 11. Their results indicated increasing concern about “Western cultural invasion,” but more favorable views towards democracy.

When asked if the Western cultural invasion was a very serious problem, 63 percent of Egyptian respondents said yes before Sept. 11; 71 percent said yes after Sept. 11. Meanwhile, the percentage of those who strongly agreed that democracy is better than any other system also increased—from 56 percent before Sept. 11 to 69 percent after Sept. 11.

The researchers also found similar changes in Morocco, where “before” and “after” Sept. 11 survey data are also available. On the issues of religion, politics and gender relations, Moroccans (like Egyptians) became more favorable toward gender equality and democracy, but less favorable toward the involvement of religion in politics.

As the war in Iraq unfolded, the researchers continued to collect data from the Middle East, ranging from studies of pessimism among the various Iraqi ethnic groups to the religious practices of different nations.

For example, in Iraq, 77 percent of Sunnis surveyed in 2005 responded that “these days, life is unpredictable and dangerous in Iraq” – compared with 41 percent for Shi’as and 17 percent for Kurds. Regarding religious practices, a survey showed that only 27 percent of Iranians participated in religious services once a week (the same as for Saudi Arabians) compared to 33 percent for Iraqis, 42 percent for Egyptians, 44 percent for Jordanians and 45 percent for respondents in the United States.

A study of Russian views also showed strong opinions following Sept. 11, notably about the war in Afghanistan. John O’Loughlin of the University of Colorado-Boulder, Gerard Toal of Virginia Tech University and Vladimir Kolossov of the Russian Academy of Sciences in Moscow found that in April 2002, the Russian population was almost evenly split between those who thought the fight against the Taliban was correct and those who thought it was incorrect. However, Russian Muslims were far more likely to see the war as incorrect.

In a related finding, Russians surveyed also thought that
U.S. efforts to form an alliance with Russia and expand the war on terror in central Asia were efforts to advance American interests and influence in the area—at Russia’s expense.

Next: NSF And 9/11 >> Assessing Risk Perception
Risk is a fact of life—but how we perceive risk can influence our emotional state. Fear and anger are key components.

Jennifer Lerner Baruch Fischhoff of Carnegie Mellon University—along with Roxana Gonzalez and Deborah Small, graduate researchers at the time—examined how emotions affect our assessment of risk. Although we may like to think that our judgments about risk are entirely objective, this study demonstrated that emotional responses to the Sept. 11 terrorist attacks could affect not only a person's judgment of risk for future attacks, but also risk estimates for other types of hazards.

Participants exposed to media clips that induced fear held more pessimistic perceptions and were more risk-averse, while participants exposed to media clips that induced anger held more optimistic perceptions and were more risk-seeking. The same research found that respondents felt public health officials had failed to communicate easily understood (and desired) facts about terrorism.

Fear also impacted a study conducted by Leonie Huddy of the State University of New York at Stony Brook and her colleagues. They found that among those who perceive future terrorist attacks to be likely, people who were fearful and anxious after Sept. 11 were less likely to support aggressive military action, opting instead for isolationist policies. More recently, the researchers found that anxious people also had greater difficulty learning factual information about countries such as Afghanistan and Iraq, that have been affected by U.S. foreign policy—despite the survey participants’ greater attention to related news coverage.
A well-known behavior after a disaster is “convergence”—when people come to the scene of the disaster to help. Seana Lowe of the University of Colorado and Alice Fothergill of the University of Vermont interviewed volunteers in New York City after the terrorist attacks.

Volunteers performed a wide range of activities such as counseling, blood donation, cleanup assistance or simply cheering up workers. The study, discussed in a presentation at NSF, found that these actions gave volunteers a sense of solidarity, a feeling of being appreciated, a measure of personal healing and a sense of empowerment.
To help understand the emotional impact of Sept. 11, psychologist Roxane Cohen Silver (now on the Academe and Policy Research Senior Advisory Committee for the Department of Homeland Security) and her colleagues at the University of California at Irvine conducted the only longitudinal national investigation of emotional, cognitive and social responses to the Sept. 11 terrorist attacks. They began collecting data within two weeks of the attacks, conducted a follow-up survey two months later, and then followed up at six month intervals for three years.

The researchers found that the attacks have had a widespread impact on people across the country—whether or not they were directly affected. Each individual’s response depended upon certain factors, such as prior traumatic life experience, traumas experienced in the years after the attacks, strategies for coping with the attacks and their aftermath, and prior diagnosis of mental health difficulties. The study also suggested that people who responded to the Sept. 11 attacks with acute stress were likely to respond similarly to the war in Iraq.

Despite the negative impacts of Sept. 11, many people also reported unexpected positive consequences, including closer relationships with family members and a greater appreciation of the freedoms offered in the United States.

From interviews with people who were not themselves victims of the terrorist attacks, Suzanne Thompson of Pomona College in California and her research team learned that many people continued to experience anxiety, fear of flying and fear for safety two years later.

Those who took steps to reduce their risk of being a victim in the future had higher levels of distress than those who focused on understanding why the attacks happened and why their future personal risk was low.

To better understand the impact of continuing stress, Lisa Feldman Barrett of Boston College and Michele Tugade, now of Vassar College, studied why certain people are particularly resilient under the stresses of an ongoing threat. The scientists found that positive emotions after Sept. 11 predicted greater emotional complexity—the tendency to experience discrete emotional states, as opposed to broader positive or negative moods—in response to other traumatic events.
Barrett and Tugade found that people who express a broad array of emotions have a broader repertoire of behavioral and coping responses available to them, and are more likely to be resilient in the face of stress. Based on this study, the researchers believe that emotional complexity may be an important factor associated with resilience, positive emotions and emotion regulation.
**NSF 9/11 >> Related Links**

**9/11: Ten Years Later**
On the tenth anniversary of 9/11, NSF interviewed several of the scientists and engineers who were on site soon after the attack to learn about their experiences and the impacts of their research efforts.


**NSF and Homeland Security**
NSF news, speeches, reports and grants relating to Homeland Security, organized by year.


**Beyond Sept. 11**
All told, NSF and the NSF-supported Natural Hazards Center at the University of Colorado made more than 150 awards in the weeks following the attacks. The report *Beyond September 11th: An Account of Post-Disaster Research* documents results from many of the projects. For more information on the NSF briefing surrounding the report, see *Critical Lessons from September 11th*. The agenda features links to video of the researchers presenting their findings.

**Disaster Research Center**
For forty years, this social science research center has studied crisis ranging from the Sept. 11 attacks to the 1992 riots in Los Angeles.

http://www.udel.edu/DRC/

**National Academy of Engineering: Fact Sheets on Terrorist Attacks**
The National Academies has prepared, in cooperation with the Department of Homeland Security, fact sheets on four types of terrorist attacks.


*Linda Skitka, University of Illinois at Chicago*
Skitka and her colleagues studied anger and fear as factors in political intolerance.

http://tigger.cc.uic.edu/~lskitka/poltol.pdf

*Brian D. Silver and Darren W. Davis, Michigan State University*
Silver, Davis and their colleagues studied people’s willingness to trade off certain personal freedoms for greater security from terrorist attacks.

http://www.ippsr.msu.edu/Publications/PBCivilLiberties.pdf

*George Bonanno, Columbia University*
Bonanno and his colleagues studied personal strategies to cope with Sept. 11 by observing positive and negative effects when people chose to either express or conceal emotions.

http://www.fathom.com/feature/122422

**Multidisciplinary Center for Earthquake Engineering Research at SUNY, Buffalo**
This center has conducted a number of post-Sept. 11 studies. Researchers collected perishable data to learn the event’s impact on both engineering and organizational systems. In addition to perspective on the damage from terrorist attacks, the studies also have many implications for earthquake disasters.
Related National Security Links

http://govinfo.library.unt.edu/nssg/

National Strategy for Homeland Security
http://www.whitehouse.gov/homeland/book/

National Strategy for the Physical Protection of Critical Infrastructures and Key Assets
http://www.whitehouse.gov/pcipb/physical.html

National Research Council report, “Making the Nation Safer: The Role of Science and Technology in Countering Terrorism”
http://www.nap.edu/books/0309084814/html/


NSF director testimony before Senate Subcommittee on Disaster Prevention and Prediction
http://www.nsf.gov/about/congress/109/alb_homelandsec060805.jsp

A Special Report: The Sensor Revolution

A Special Report: Cyberinfrastructure

A Special Report: Robotics
THE CRITICAL ROLE OF RESEARCH

Many NSF-supported projects address immediate and obvious disaster needs, such as improved emergency communications or earthquake protection for buildings. However, fundamental, long-term research also plays a critical (but less visible) role in driving future advances in disaster response and prevention. The following descriptions showcase the diverse range of these projects.

Materials
James Mark and colleagues at the University of Cincinnati devised a technique to strengthen silicone rubber with transparent nanoscale particles. The standard techniques currently used often leave the material clouded, which complicates its use in such products as protective masks for emergency responders and medical tubing in hospitals.

Earlier methods enhanced silicone strength by adding silica particles—the same material found in quartz. The new technique infuses silicone rubber with silica nanoparticles up to five times smaller than those from competing methods. The result is a material with enhanced strength, yet pristine clarity and implications for improved emergency and medical response.

Computer Software
Mark Goldberg, Malik Magdon-Ismail and William “Al” Wallace of Rensselaer Polytechnic Institute tackled the need to root out terrorist communications on the Internet.

The researchers apply statistical methods, social theories and other techniques to create software that detects communication patterns in email, newsgroups, chatrooms and other Internet forums frequented by suspected terrorists. The researchers hope the tools will alert law enforcement to suspicious message patterns without the need for an agent to first read or understand the messages.

Earthquake Prediction
Terry Tullis and David Goldsby of Brown University in Providence, R.I., and Giulio Di Toro of the University of Padova in Italy discovered a mineral gel created when rocks abrade each other. The gel creates a slick surface that may amplify the energy that earthquakes transmit through the planet’s crust.

The researchers sheared quartz-rich rocks against each other under controlled conditions, simulating several aspects of a geologic fault.
environment. At the highest shearing speeds, resistance between the rocks approached zero.

Scanning electron microscope images revealed the possibility that the mineral powder generated during the abrasion is combining with water from the atmosphere to form the lubricating gel. If confirmed with field observations, these findings could apply to computer earthquake models and may help scientists and emergency personnel better predict the magnitude of strong ground motions that damage man-made structures.

**Economic Game Theory**

Over the last two decades, economists Todd Sandler of the University of Southern California and Walter Enders of the University of Alabama in Tuscaloosa have been applying economic theories such as game theory to identify unintended consequences of U.S. counterterrorism policies. Game theory looks at mutual responses between two thinking agents such as governments and sophisticated terrorist groups.

The researchers have found that at the time of the study (in 2003), the likelihood of death or injury from terrorism had increased—despite a decline in the number of terror incidents. High on the list of reasons for this trend: The way governments respond to terrorist threats and the changing face of terrorism (to involve more religious groups and so-called “amateurs”).

Since the early 1980s, Sandler and Enders have looked at various strategies in hostage-taking incidents, antiterrorism agreements between governments and effective government responses. A paper for *The American Political Science Review* in 1993, and other writings based on the project, led the Department of State’s security office to consult the researchers about current U.S. policy.

**Alternative Energy**

Bruce Logan and colleagues at Pennsylvania State University have developed a bacteria-driven fuel cell that generates electricity as microbes clean wastewater. On a larger scale, such a fuel cell might produce both electricity and potable water at disaster sites. Recently, the researchers created a similar wastewater treatment cell that produces hydrogen instead of electricity.

A hydrogen-making catalyst developed by James Dumesic and colleagues at the University of Wisconsin at Madison points to a cheaper, cleaner chemical process that could help produce fuel for portable devices such as military equipment and batteries.

**Hazard Detection**

Rick Weber and colleagues at Containerless Research, Inc. developed a new family of glasses that may bring higher power to smaller packages in lasers and optical devices—at a lower cost than alternatives. Applications might include communications devices, medical lasers and sensors to detect explosives and toxins.

**A Special Report: Disasters**
Disasters can vary in type, cause and impact. Disaster can follow a hurricane or an earthquake, a blackout or a terrorist attack. While natural disasters are more frequent, the human factor is an increasing concern. A disaster's effects may last months or years, and may affect one city or several nations. One factor common to all disasters is the role of knowledge. Knowledge is the most critical defense in understanding, preparing for, and responding to disasters. NSF is dedicated to disaster research and works with the Administration and other federal agencies in a coordinated effort to anticipate and minimize the worst effects of disasters.

The most recent NSF disaster-research news and feature stories are linked below.
U.S.-Taiwan Constellation of Satellites Launched
Released April 12, 2006
Press Release

Collaboration Will Investigate Vulnerabilities of Rapidly Growing Internet Phone and Multimedia Systems
Released April 4, 2006
Press Release

Large Centrifuge Helps Researchers Mimic Effects of Katrina on Leves
Released March 21, 2006
Press Release

Scientists Issue Unprecedented Forecast of Next Sunspot Cycle
Released March 6, 2006
Press Release

New NSF Aircraft to Probe Hazardous Atmospheric Whirlwinds
Released March 2, 2006
Press Release

Study of 2004 Tsunami Forces Rethinking of Giant Earthquake Theory
Released March 1, 2006
Press Release

Instruments on Alaska's Augustine Volcano Provide New Insights into Volcanic Processes
Released February 9, 2006
Press Release

Outbreak: Rapid Appearance of Fungus Devastates Frogs, Salamanders in Panama
Released February 6, 2006
Press Release

Climate Change Drives Widespread Amphibian Extinctions
Released January 11, 2006
Press Release