Hurricane Sandy: Cascading Events and the Impact on Emergency Response Capabilities

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Hurricane Sandy, which affected 24 U.S. states in October 2012, was the second-costliest hurricane in U.S. history. The storm resulted in particularly severe damage to coastal New Jersey, New York City, Long Island, and Connecticut. The cascading effects caused by the high winds and massive storm surge included prolonged and widespread power outages, communications network failures, flooding of road, rail, and subway tunnels, massive fires, loss of hospital infrastructure and structural building collapses. This paper and presentation will review the challenges faced by emergency management agencies and fire services as they respond to and recover from a catastrophic event of this magnitude. The lessons learned can be applicable to preparedness and resiliency efforts in any densely populated urban region.

Hurricane Sandy, which was also known as "Superstorm" Sandy, created tremendous challenges for emergency planners and first responders because of the region of the United States that it targeted. The East Coast of the United States is densely populated and is home to a significant amount of critical infrastructure upon which the entire country is highly dependent. The massive storm surge that occurred along the New Jersey and New York coastlines damaged or destroyed at least 650,000 homes. At least 147 direct deaths occurred across the Atlantic basin due to Sandy, with the mid-Atlantic and northeastern United States recording 72 of these fatalities. (NOAA)[1]

[1] National Oceanic and Atmospheric Administration

Outside of the United States, damage estimates (in USD) include $2 billion in Cuba, $750 million in Haiti, and $30 million in the Dominican Republic. (NOAA)

By definition, a hurricane is a tropical cyclone with maximum sustained winds of 74 mph (64 knots) or higher. A major hurricane is a tropical cyclone with maximum sustained winds of 111 mph (96 kn) or higher, corresponding to a category three, four or five on the Saffir-Simpson Hurricane Wind Scale. At its maximum, hurricane Sandy reached a sustained wind speed of 115 mph (one 85 km/h) and was classified as a Category Three hurricane on October 25, 2012.

According to the US National Weather Service, the Atlantic hurricane season runs from June 1 to November 30. The Atlantic basin includes the Atlantic Ocean, Caribbean Sea, and the Gulf of Mexico.

The following chart identifies the total number of tropical systems and hurricanes produced throughout the year in the Atlantic basin for the period 1966 – 2009. The curves represent the average cumulative production of all named tropical systems and hurricanes.

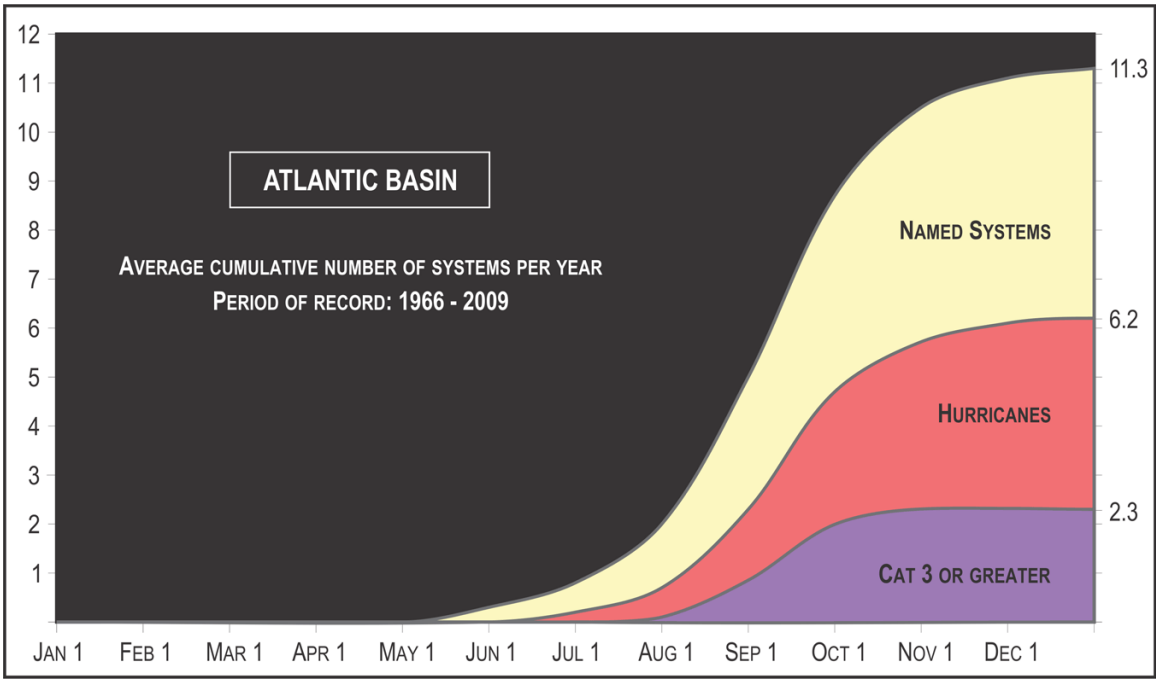


Figure 1. Atlantic Basin Storms

During the 2012 hurricane season, 19 named storms occurred in the Atlantic basin. The names tracks and dates of those storms are shown on the following chart.

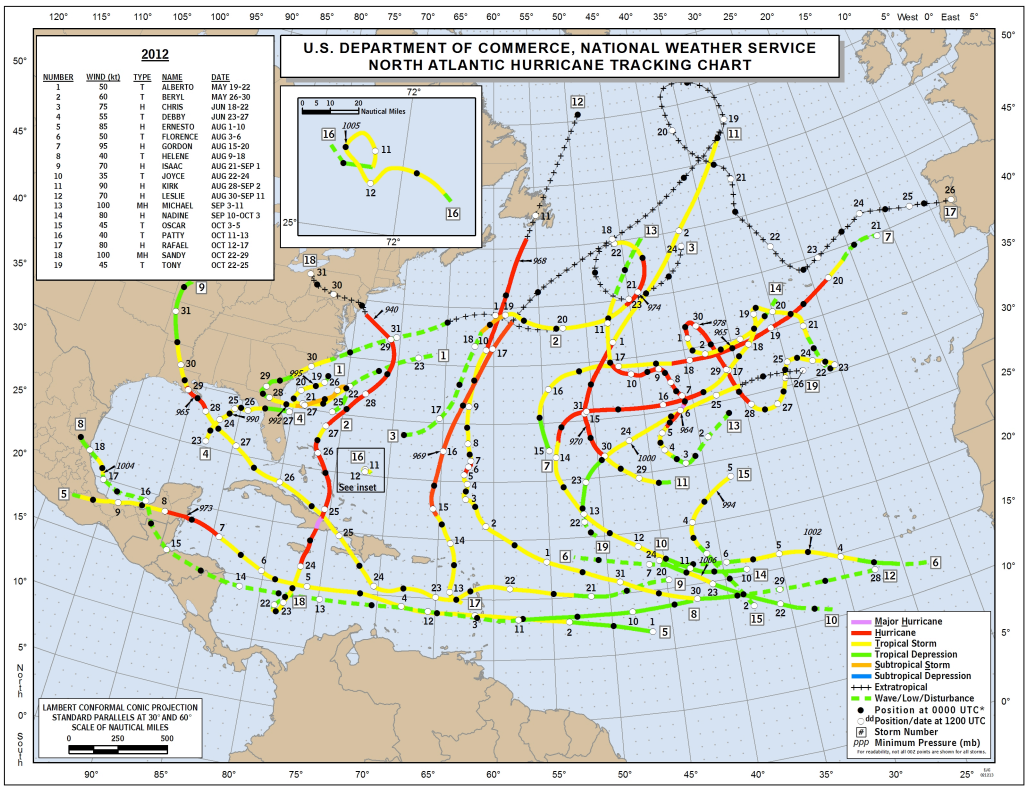


Figure 2. 2012 Atlantic Hurricane Season

The 2012 Atlantic hurricane season resulted in above average tropical cyclone activity with the formation of 19 tropical storms, of which 10 became hurricanes two of the hurricanes (Michael and Sandy) became major hurricanes (Category 3 or higher). Only four named storms actually made landfall in the mainland US, and only one hurricane (Isaac) made landfall at hurricane strength. Sandy also brought hurricane force winds to the US coast, but it had become post-tropical by the time it made landfall. (NOAA)

The US Emergency Management Structure

In order to appreciate the complexity and magnitude of the response to Hurricane Sandy in the New York-New Jersey region, it is helpful to understand the organization and structure of the emergency management system in the United States.

Emergency management in the U.S. is a "bottom-up" system with its roots in state and local government. Towns, cities and county fire, police, emergency medical agencies serve as the first responders to all incidents, including natural disasters. Local governments are responsible for emergency planning, resource allocation and coordination, evacuation and sheltering, and incident command. The extent to which such responsibilities are executed on a regional level (*e.g.*, county or regional government agencies) varies from state to state. As an event escalates, local government officials typically call upon the governor of the state to provide additional resources. The governor may exercise his/her legal authority to declare a state of emergency, which invokes special powers to manage the response and recovery effort.

State governments typically support local jurisdictions in their efforts to plan for the response to catastrophic events and to mitigate the impact of such incidents. The state emergency management agency provides the template for local emergency operations plans and can provide technical assistance and grants for developing the plan. Regional coordination of emergency management planning is often facilitated by the state emergency management agency. States provide training to local emergency managers and first responders, often under the auspices of the state fire training academy or police training academy. State government can also support specialized response capabilities, such as field communications units, hazardous materials response teams, public health response teams, and personnel and resources from the National Guard.

The following are examples of emergency management plans that are developed at the state government level:

- Emergency operations plan
- Emergency communications plan
- Hazard mitigation plan
- Statewide firefighting mobilization plan
- Statewide emergency medical services mobilization plan
- Statewide law enforcement mobilization plan
- Pandemic influenza plan
- Wildland firefighting plan
- Energy assurance plan

These plans ensure that state resources are coordinated with local and federal resources. State plans also depend on local capabilities for successful implementation, since that is where the nearly all first responder organizations are based. State emergency management plans depend upon previously established mutual aid agreements that provide for the sharing of law enforcement, fire service, EMS, public health and public works resources when local capabilities are overwhelmed.

The federal government provides overarching coordination and resource support for major disasters. Presidential Policy Directive (PPD) 8: National Preparedness defines five preparedness mission areas—prevention, protection, mitigation, response and recovery—and mandates the development of a series of policy and planning documents to explain and guide the national approach to for ensuring and enhancing national preparedness. These documents are known as the National Planning Frameworks.

Although the Department of Homeland Security (DHS) is the primary federal disaster response and coordination agency, a number of other federal agencies have been tasked with disaster response coordination responsibilities under the National Response Framework (NSF). For example, the Department of Energy is the primary agency responsible for implementing Emergency Support Function (ESF) #12, Energy. Likewise, the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) in the Department of Justice (DOJ) is the primary agency for ESF #13, Public Safety and Security.

The role of the National Guard in disaster response is worthy of explanation. The National Guard is both a federal military asset and a state asset; its function varies with each situation. The National Guard is a volunteer military organization that has its roots in the colonial patriots who formed volunteer militias during the American Revolution. During peacetime, each state has a National Guard contingent that can be mobilized by the governor to respond to disasters, civil unrest, wildfires or other major events that require highly trained and equipped personnel. When under state control, National Guard members can be authorized to enforce state laws and make arrests. When activated by the President for federal service, the National Guard serves under the Department of Defense and members are prohibited from enforcing state laws or making arrests because of a legal concept known as *posse comitatus*.

States and local governments have become highly dependent upon the ability of the federal government to provide financial support to emergency planning, emergency response, mitigation and recovery efforts. By providing financial incentives, disaster programs that have been established by Congress and by DHS have, in essence, become mandatory. For example, in order to receive grants from DHS, jurisdictions must commit to implementing the National Incident Management System (NIMS). Equipment purchased by fire, police and EMS agencies with grants provided by DHS must meet certain criteria for terrorism response. The federal government also provides funds for first responder training and for drills and

exercises that test the effectiveness of emergency response plans and the readiness of response organizations.

If a disaster reaches a certain threshold for damage, the federal government will reimburse states and municipalities for a percentage of the cost of the event (including some recovery costs) in accordance with the Stafford Act. Grants and low-interest loans can also be provided for businesses and individuals that have been impacted. In the case of Presidential declared disasters, the Federal Emergency Management Agency (FEMA) can also provide temporary housing for displaced families and individuals.

After a disaster, the federal government provides funding for mitigation projects that are intended to prevent damage from similar future catastrophic events in the region. Examples of mitigation projects include small-scale projects like increasing the size of a drainage pipe (culvert) under a roadway; large-scale projects like improving the levee system on the Mississippi River following a serious spring flood season; or removing hurricane blow-down debris in a forest that can eventually become the fuel for a major wildland fire.

The following table provides examples of the various responsibilities of local (municipal and/or county), state and federal governments.

LOCAL	STATE	FEDERAL
Firefighting Law Enforcement Emergency Medical Public Health Incident Command Emergency operations center (EOC) Emergency Planning Coordination with private sector Evacuation & sheltering Recovery Mitigation	Disaster/state of emergency declaration by governor Emergency operations center (statewide EOC) Coordination with federal government and other states Emergency planning Training Financial support pre- and post-event Specialized resources: communications, special response teams, etc. State Police National Guard Subject matter expertise on complex issues Major evacuation & sheltering coordination Coordination with private sector	Presidential disaster declaration Post-event recovery funds Specialized resources, including military assets Training Coordination of federal assets Federal law enforcement National coordination centers Coordination with private sector

Figure 3. Disaster Coordination Responsibilities

The private sector plays an essential role in disaster preparedness at the local, state and federal level. Because nearly eighty-five percent (85%) of critical infrastructure (CI) in the United States is privately owned, CI owners and operators are strongly encouraged to establish their own emergency management planning capabilities and to collaborate with government agencies on preparedness strategies. The vitality of the local, regional and national economy is highly dependent upon the ability of businesses of all sizes to recover quickly after an event. NFPA 1600, *Standard on Emergency Management/Disaster Preparedness and Business Continuity*

has been adopted as a national standard by DHS. NFPA 1600 provides the fundamental criteria for private and public sector organizations to develop, implement, assess, and maintain a program for prevention, mitigation, preparedness, response and recovery from a catastrophic event. It is available as a free download at www.nfpa.org/1600.

Incident Management System

One of the most important elements of U.S. disaster response capabilities is the National Incident Management System (NIMS). NIMS is based on the incident command system that was originally developed by the U.S. Forest Service to manage complex, large-scale wildland fire fighting operations. NIMS provides a systematic approach that enables departments and agencies at all levels of government, non-governmental organizations and the private sector to work together to manage incidents that involve all threats and hazards. The system is scalable in order to manage events regardless of cause, size, location or complexity.

NIMS ensures an effective span of control, assigns task and functions to specific sectors of operation, and is flexible enough so that incident command resources can be increased or decreased as the event evolves. It also facilitates cross-agency coordination under the concept of "unified command." For example, a major hazardous materials spill at the scene of a train derailment requires oversight by fire service, emergency medical services public health, law enforcement, railroad officials, and the National Transportation Safety Board (NTSB). Under the NIMS concept, a unified command system can be established to ensure that all critical functions (including proper notification to the public) can be performed in a well-organized, effective and safe manner.

The federal government does not have the authority to mandate the implementation of the NIMS system by state and local agencies or the private sector. However, in order to receive training, equipment and planning grants from DHS, a jurisdiction

must certify that NIMS has been implemented. This incentive has resulted in the widespread adoption of NIMS throughout the United States.

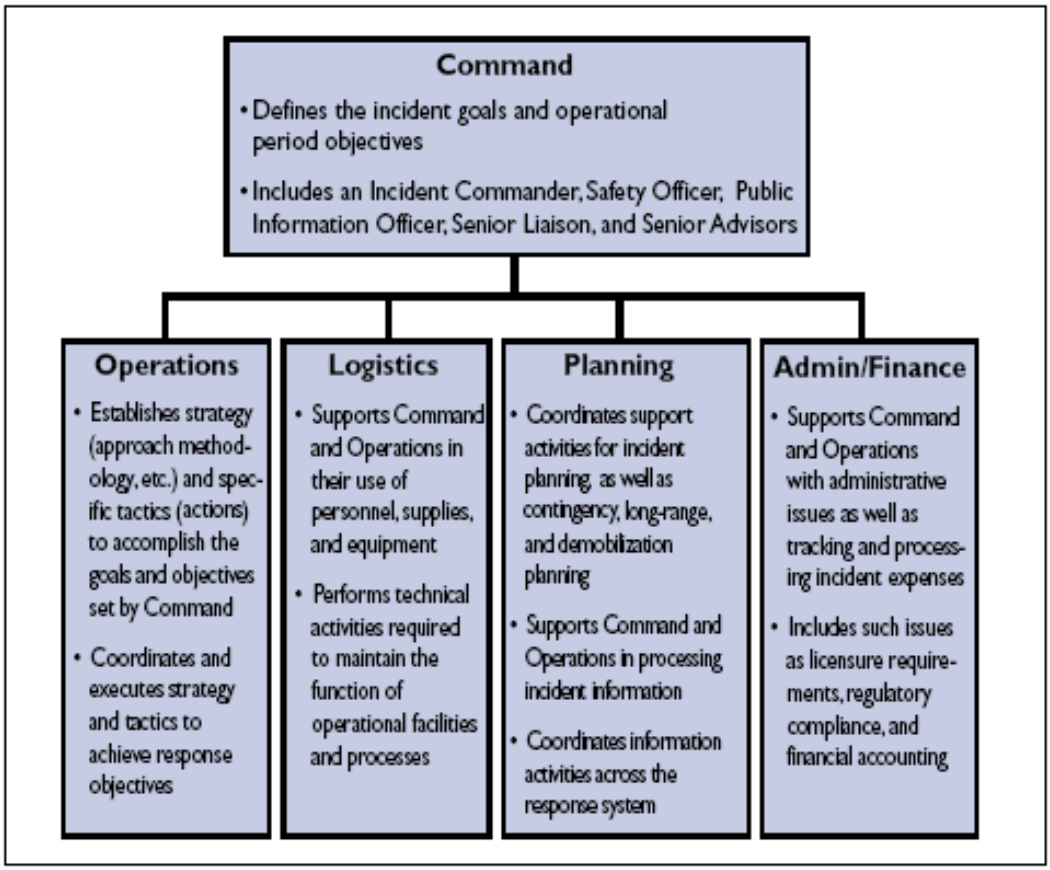


Figure 4. Typical Incident Command System (ICS)

US Policy Shifts Concerning Emergency Management

Over time, the U.S. approach to dealing with disasters has changed dramatically as the result of international events, domestic politics, and the type and frequency of catastrophic events. Congress provided financial assistance following a catastrophic fire in a town in my own home state of New Hampshire 1803, which was the first example of federal government involvement in a local disaster. In 1934, flood control legislation empowered the U.S. Army Corps of Engineers to design and build flood control projects. (Bullock, p. 2)

The perceived threat of nuclear attack during the Cold War in the 1950's and early 1960's focused the attention of the federal government on supporting a civil defense infrastructure. Fallout shelters were established in many cities, and plans were developed for the stockpiling and mobilization of essential materials and resources. School children practiced "duck and cover" procedures during "air raid" drills. During this period, state and local civil defense directors became the first recognized elements of emergency management in the U.S. (Bullock, p. 3)

Of course, the nation did experience a number of hurricanes and major floods during the 1950s. Congressional response consisted primarily of legislation that provided disaster relief funds to specific, affected areas rather than a systematic approach to emergency management.

In 1961, President John F. Kennedy created the White House Office of Emergency Preparedness to coordinate large-scale events, including earthquakes and hurricanes. However, civil defense responsibilities remained with the Department of Defense. In 1968, the National Flood Insurance Program (NFIP) was established so that homeowners and businesses in flood-prone areas would be insured against losses. Floods, earthquakes and hurricanes continued to increase in severity and frequency during the 1960s, resulting in an increased awareness of the vulnerabilities of US citizens to natural disasters. It became increasingly apparent that the fragmented and piecemeal approach to emergency management needed to change.

The tipping point for establishing a more unified emergency management system was the radiological accident at the Three Mile Island nuclear power plant in Pennsylvania. In 1979, President Carter established the Federal Emergency Management Agency (FEMA). A number of disaster preparedness programs were integrated into FEMA, including civil defense, federal disaster assistance, coordination of emergency warning systems, earthquake hazard reduction, dam

safety, and fire prevention and control. The director of FEMA answered directly to the President.

During the 1980s, FEMA was plagued with a series of organizational and management crises that resulted in an overall inability to respond effectively to a number of disasters, including Hurricane Hugo (1989, North and South Carolina), the Loma Prieta earthquake (1989, California) and Hurricane Andrew (1992, Florida and Louisiana). FEMA was eventually reorganized under a new leader, and new programs such as "Project Impact: Building Disaster Resistant Communities" were established to restore the credibility and effectiveness of the agency. Natural disaster preparedness finally became a major priority of the federal government.

The terrorist attacks of September 11, 2001 against the World Trade Center and the Pentagon heralded a dramatic shift in the focus of federal, state and local governments away from natural disasters to terrorism. The Department of Homeland Security (DHS) was established pursuant to the Homeland Security Act of 2002 (Public Law 107-296) and merged 22 existing federal agencies, including FEMA, into one cabinet-level organization. DHS now had responsibility for all emergency preparedness functions (focused primarily on terrorist events), border security, Coast Guard, critical infrastructure protection, and even Presidential security.

In August 2005, a massive hurricane struck the southeast United States. Hurricane Katrina eventually became the costliest natural disaster and one of the five deadliest hurricanes in the history of the U.S. Over 1,800 people died and total property damage has been estimated at $108 million, which is approximately four times the damage caused by Hurricane Andrew in 1992. The federal government, as well as state and local governments in Louisiana (and in particular, New Orleans) were woefully unprepared for the devastation caused by Katrina. While the U.S. Coast Guard performed admirably, FEMA's response was dismal at best. U.S. military

personnel were finally deployed to restore order and to manage the response effort. (Brinkley)

The analyses and critiques of emergency preparedness, response and recovery efforts that were employed during and after Hurricane Katrina resulted in a dramatic shift in public policy. While terrorism response is still an important component of emergency management planning, all levels of government now focus on an "all-hazards" approach. The all-hazards approach assumes that the *impact* of an event is essentially the same regardless of the cause—natural hazard, terrorist attack, or man-made technological event. Therefore, response and recovery capabilities can be quickly adapted to the particular situation using the same personnel, the same equipment and the same procedures.

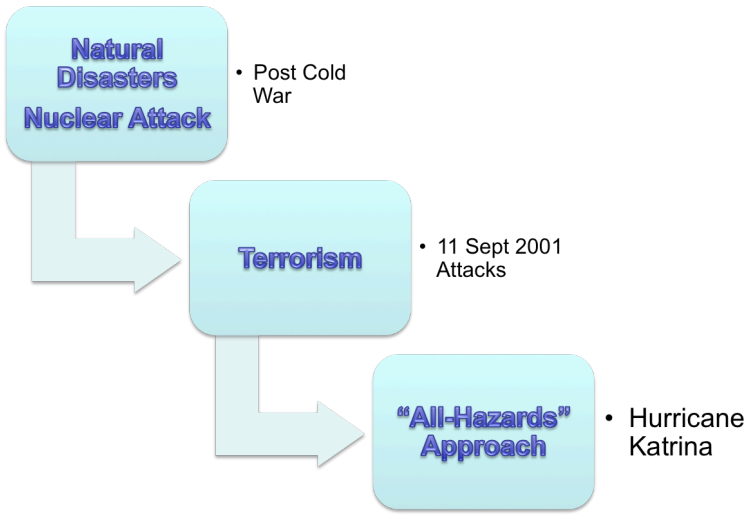


Figure 5. Federal Policy Shifts

A natural hazard event (hurricane, winter storm, earthquake, etc.) can result in power outages, building collapses, mass casualties, flooding, fires, disruptions in food and water supplies, and disruption of businesses and supply chains. The same is true of a terrorist attack or a technological event (such as an train derailment of dangerous chemicals in a highly populated area).

In addition to response efforts based on the all-hazards approach, emergency management policy now focuses on community resilience rather than simply trying to protect critical infrastructure and key assets. Community resilience incorporates business continuity concepts, redundancy, and robust recovery efforts along with the traditional emergency management concepts of planning, response, and mitigation.

Critical infrastructure protection is still a high priority under the resilience initiative. DHS has classified critical infrastructure functions in sixteen (16) different sectors and has promulgated the National Infrastructure Protection Plan (NIPP) as the basis for implementing a strategic, long-term public-private partnership to improve the robustness of the nation's critical infrastructure. However, Presidential Policy Directive (PPD) 21 instructs federal agencies to pursue initiatives that are based on the concept of resilience. *Resilience* has been defined in PPD-21 as:

"the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."

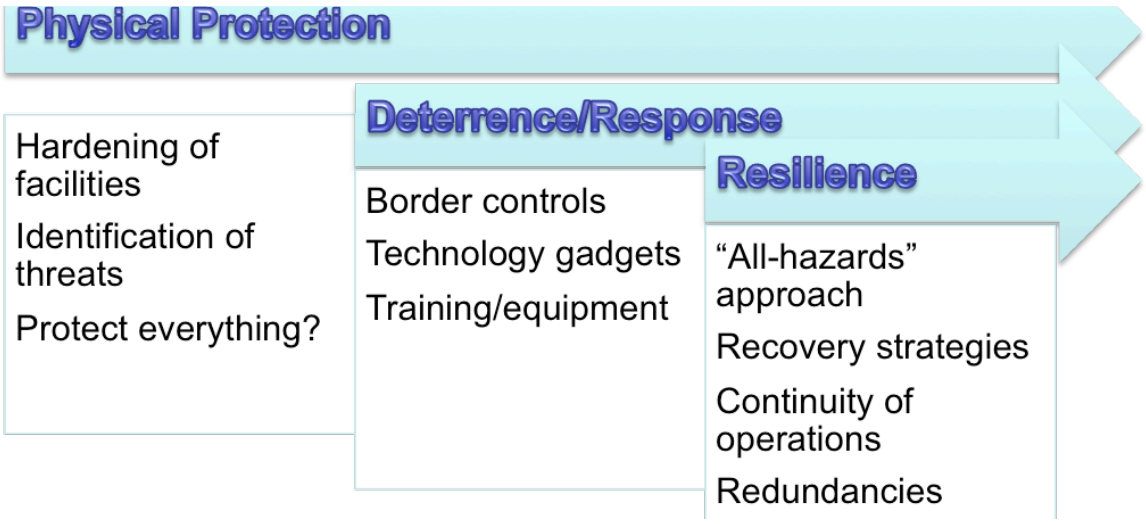


Figure 6. Components of Resilience

By shifting to the concept of resilience, policy makers have recognized that it is not possible to protect all facilities, buildings and assets from all threats and hazards all of the time. Storms, wildfires and earthquakes will continue to wreak havoc. Terrorists will still be able to launch attacks against their targets. The goal of resilience is to develop a well-balanced approach to detect, deter, mitigate, respond to, and recover quickly from even the most severe type of catastrophic event.

Critical Challenges During Hurricane Sandy

When Sandy made landfall on the New Jersey coast south of Atlantic City, it brought with it high winds, torrential rain, and most importantly, a storm surge that inundated many low lying areas in New York and New Jersey. The greatest impact of the storm surge occurred to the north of the storm in the New York City bay and harbor. The surge was more severe because of the spring high tide that was higher than normal because of a full moon.

A storm surge is defined as "an abnormal rise of water, over and above the astronomical tide, caused by a severe storm such as a tropical cyclone or nor'easter." Storm surge heights in the New York City area ranged from 9.4 feet (2.8 m) to 12.65 feet (3.86 m) above tidal predictions (FEMA, Mitigation Assessment Team report, Hurricane Sandy in New York and New Jersey)

According to FEMA, inundation (the total water level that occurs on normally dry ground as the result of a storm surge) was another major component of dramatic impact of Sandy. Coastal inundation levels recorded in New Jersey and New York ranged from 2 feet (.61 m) to 9 feet. The 9 foot (2.74 m) levels occurred in Monmouth and Middlesex counties (New Jersey) and Staten Island and Manhattan (two of the five boroughs of New York City).

The storm surge and inundation was anticipated, although not to the extent that actually occurred. Con Edison, the energy utility that serves New York City,

preemptively took the step of shutting of electricity to the southern end of Manhattan with the knowledge that underground utility services would be flooded. The Metropolitan Transit Authority moved its subway car fleet to high ground in so that it could restore service as quickly as possible. By contrast, New Jersey Transit moved its fleet of commuter trains to the low-lying Meadowlands area, resulting in millions of dollars in damage and lengthy outages of rail service throughout all of New Jersey in the following weeks. Fortunately, rail and subway service was suspended prior to the arrival of the storm which eliminated the need to rescue trapped passengers.

The impact of the storm surge and inundation on the region's transportation system cannot be underestimated. Flooding of local streets and major highways caused delays in responses to emergency calls. Those individuals who had not evacuated low lying areas were essentially trapped until the water subsided, and first responders resorted to small boats to perform rescues.

Large portions of the Rockaway section of Queens (a borough of New York City on the western tip of Long Island) was inundated, followed by a conflagration (massive fire) that destroyed numerous homes and businesses. The homes of a number of firefighters and police officers were also destroyed. Fire apparatus could simply not get close to the fire because of the flooded streets.

The high winds brought down trees and power lines throughout the region, resulting in widespread power outages. Because of the severity of the damage to significant parts of the electric utility grid in the region, power was not restored to some areas until months after the event. The cascading effects of the power outages included:

- Emergency facilities (fire and police stations) that were not equipped with standby emergency power were not functional.

- Gasoline stations could not supply customers
- Grocery stories could not operate refrigeration/freezer systems
- Traffic control signals and street lighting were out of service
- Schools were closed

Many facilities that were equipped with emergency generators experienced the failure of standby power systems for a variety of reasons:

- Generators and/or transfer switches were located at ground level or below ground level and were flooded by the storm surge and inundation.
- Fuel supplies were located at ground level or below ground level and were flooded.
- The time span of the power outage exceed on-site fuel supplies, and fuel delivery was not available or delayed
- Generator operation exceeded expected time frames and qualified maintenance personnel and/or supplies were not available

First responders were called upon to evacuate critical facilities that did not have electricity. For example, New York City lost ten percent (10%) of its hospital bed capacity, which placed a severe strain on the entire acute care hospital system. In addition, over a three-day period, 4,000 nursing home patients and 1,500 adult home residents were rescued from facilities that did not have power.

First responders throughout the region performed hundreds of rescues of individuals who were trapped in buildings and vehicles by the rising waters. In Manhattan, a large construction crane collapsed and was dangling over the street, posing an imminent threat to both people and other buildings. The façade of an apartment building also collapsed during the storm.



Figure 7. Crane Collapse, W. 57th Street, Manhattan



Figure 8. Building Facade Collapse, 8th Ave., Manhattan

The U.S. system of localized emergency response management and control does have its disadvantages. During a massive event such as Hurricane Sandy, the coordination of the hundreds of local, state and federal agencies can be an overwhelming task. Communications between response units, incident commanders, and high-level decision makers can fail quickly if not properly managed. Situational awareness during an event can be minimal due to inadequate

technology or conflicting and overwhelming amounts of data. Resources may not be deployed effectively if decisions are flawed. And if cascading events and interdependencies have not been anticipated and planned for, emergency response and recovery efforts can be quickly overwhelmed.

The Role of Standards in Resilience

Standards already play a critical role in establishing safe communities through the proper application of building, fire and electrical codes. Building codes mandate the criteria for seismic protection, resistance against high winds, snow loading, and fire protection. Fire and electrical codes establish measures for the control of hazardous processes, installation of equipment, maintenance of fire protection systems, and community fire protection strategies.

Guided by the National Institute of Standards and Technology (NIST), efforts are now underway in the United States to expand existing safety standards and to consider new standards that will define specific strategies to improve community resilience. It is hoped that the lessons learned and best practices that have evolved following catastrophic events can be developed into consensus standards.

NFPA is playing a major role in this effort. Many of our standards currently contain requirements that will improve resilience. For example, Article 708 of NFPA 70, *National Electrical Code*, specifies the requirements for protection critical operations power systems (COPS). NFPA's standards related to the wildland-urban interface also address resilience factors. The Fire Protection Research Foundation is currently conducting an assessment of NFPA's standards to identify those sections that address resiliency. This assessment will establish the baseline for further work in the area of resiliency standards.

Conclusion

First responders, emergency management officials, political leaders and legislative bodies throughout the world will continue to face serious challenges as they attempt to make their cities more resilient against both natural and manmade disasters. Climate change is having a well-documented impact on the frequency and severity of storms. People and buildings have encroached on forested areas, thus increasing the impact of wildfires within the "wildland-urban interface." Rebuilding and restoration occurs in areas that have been impacted by a disaster with the full knowledge and expectation that history will repeat itself. Terrorists are continually seeking new ways to breach vulnerabilities and cause fear and economic disruption. More work needs to be done to ensure that cities and nations focus their limited resources on efforts to improve resilience.

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