



# Windstorm Impact Reduction Implementation Plan

A Report of the National Science and Technology Council



# Report Documentation Page

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# 1. EXECUTIVE SUMMARY

The tragedy caused by Hurricanes Katrina and Rita in August and September 2005, the unprecedented hurricane season of 2004 in which five hurricanes made landfall in Florida, and the May 1999 outbreak of damaging tornados in Oklahoma underscore the significant and growing risks to our society due to wind hazards. Public Law 108-360, known as the National Windstorm Reduction Act of 2004, was signed into law by President Bush to reduce the risk wind hazards pose to life and property. The law increased national attention on wind hazard reduction efforts, which will require significantly improved cooperation and coordination between Federal agencies, improved coordination with states and local governments and increased, focused Federal investment to reduce wind hazards.

Although there are current and ongoing activities related to, or focused on, wind hazards it is clear that these efforts are more often merely small parts of larger efforts and are not coordinated among the agencies. For example, the National Oceanic and Atmospheric Administration (NOAA) makes weather predictions regarding several physical parameters of which wind is only one part; the National Institute of Standards and Technology (NIST) studies structural hazards ranging from earthquakes to fires, and winds are only one component; and the Federal Emergency Management Agency (FEMA) conducts evacuation planning studies, promotes wind preparedness activities, and advocates enhancements to the nation's model building codes as part of multi-hazard programs.

Each agency's effort toward wind hazard reduction is detailed in Appendix C. There appears to be virtually no duplication of effort among the agencies but there are gaps in knowledge, implementation and coordination.

In accordance with the legislation, a coordinated Federal effort, in cooperation with other levels of government, academia, and the private sector, will improve the understanding of windstorms and their impact, and develop and encourage implementation of cost-effective mitigation measures to reduce those impacts while promoting community resilience. We recommend a coordinated, comprehensive multi-agency, multi-disciplinary group be established as a working group of the National Science and Technology Council's Committee on Environment and Natural Resources Subcommittee on Disaster Reduction to reduce the impact of wind hazards by facilitating better communication among agencies, effectively allocating collective resources and operating within a common framework. This working group shall meet at least quarterly, report to the Subcommittee on Disaster Reduction annually and work with state, local officials and non-government organizations as appropriate. All Federal agencies contributing to this document shall be members of the working group and the chair of the working group will rotate between NIST, NSF, NOAA and FEMA with each Agency serving a two-year term as chair.

A coordinated portfolio that builds on current efforts in research and mitigation activities should be developed including:

- Assessing individual and community capability to respond to wind events, including vulnerability analyses, risk perception, risk communication, risk management, communication of wind warnings and public response, evacuation capability, and public knowledge of appropriate protective actions for wind events, especially among vulnerable populations

- Evaluating the response of the built environment and critical infrastructure to wind events by investigating aerodynamic response, load path, ultimate capacity and the performance of the building envelope
- Assessing the impact of wind and windborne debris or wind and water/ice/snow
- Examining the interaction between wind and storm surge to determine the impact on building foundations and critical infrastructure
- Exploring the near-ground and channeling/shielding effects of winds on buildings through testing and instrumentation
- Developing new technologies and ground, airborne and satellite based observing systems to improve knowledge and understanding of windstorms and the wind variability within those storms
- Measuring the response of bridges and other highway structures to wind events, including stability, serviceability and functionality leading up to and through extreme events
- Developing and implementing technologies for rapid repair and restoration of critical infrastructure and critical services

There could be improvements in and enhancement of:

- Windstorm prediction
- Local, state, regional and federal coordinated response capabilities following wind hazard events, including field validation and data collection capabilities for buildings, critical infrastructure and essential facilities
- Windstorm damage and loss estimation modeling tools
- Standards and technologies that will enable cost-effective, state-of-the-art windstorm-resistant provisions to be adopted as part of state and local building codes

These improvements and enhancements would enable more effective:

- Local, state, regional and federal coordination in response to wind hazard events
- Evacuations through more informed planning and annual drills
- Local and regional preparedness through public-private partnerships fostering outreach and technology transfer programs
- Windstorm impact reduction practices through training and outreach programs that enhance state and local capabilities

## 2. PURPOSE AND SCOPE

Public Law 108-360, Title II, known as the National Windstorm Impact Reduction Act of 2004, was signed into law by President Bush on October 25, 2004. This law seeks to measurably reduce the loss of life and property from windstorms. The law states that,

*No later than 90 days after the date of enactment of this Act, the Director of the President's Office of Science and Technology Policy shall establish an Interagency Working Group consisting of representatives of the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), the National Institute of Standards and Technology (NIST), the Federal Emergency Management Agency (FEMA), and other Federal agencies as appropriate. The Interagency Working Group will be responsible for the planning, management, and coordination of the Program, including budget coordination.*

- *NIST shall support research and development to improve building codes and standards and practices for design and construction of buildings, structures, and lifelines.*
- *NSF shall support research in engineering and the atmospheric sciences to improve the understanding of the behavior of windstorms and their impact on buildings, structures and lifelines.*
- *NOAA shall support atmospheric sciences research to improve the understanding of the behavior of windstorms and their impact on buildings, structures, and lifelines.*
- *FEMA shall support the development of risk assessment tools and the effective mitigation techniques, windstorm-related data collection and analysis, public outreach, information dissemination, and implementation of mitigation measures consistent with the Agency's all-hazards approach.*

The Act further stipulates that not later than one year after the date of enactment of this title, the Interagency Working Group shall develop and transmit to Congress an implementation plan for achieving the objectives of this Program. This document is that plan.

## 3. INTRODUCTION

### 3.1 COSTS OF STRUCTURAL WIND DAMAGE

The 2005 hurricane season brought storms that wreaked havoc, causing large-scale damage from wind and water across many states. It was the most costly hurricane season in U.S. history. Hurricanes Katrina, Rita and Wilma demonstrated in dramatic fashion how costly these events can be, both in lives lost and property destroyed. The costs of wind damage to the built environment from wind hazards continue to increase, even when adjusted for inflation. These devastating events were only the most recent examples of the worldwide impact of windstorms.

According to a report published by RAND<sup>1</sup>, windstorms caused almost two-thirds of the \$145B total 2004 uninsured losses. The State of Florida was struck by four hurricanes in 2004, and uninsured losses there alone reached \$42B. Losses due to windstorms include damages from wind, storm surge and flooding. The RAND report indicates that, in the United States, losses due to hurricanes and tornadoes total \$6B per year.

Although these losses show an increasing trend over the last decade, improvements in forecasts, preparation and mitigation have significantly reduced the number of lives lost over the last century. Deaths and injuries from wind-hazard extreme events, as estimated before Hurricane Katrina, average about 100 deaths and 1,250 injuries per year. Social vulnerability analysis has shown that demographic subpopulations, including those of lower socioeconomic status, are at higher levels of risk from wind events.

### 3.2 PREVIOUS WIND IMPACT REDUCTION EFFORTS

Improved wind forecasting, wind characterization, wind engineering and design, improved building standards and codes, and mitigation activities, have led to a better understanding of wind hazards, and helped reduce their effects on the built environment.

Social sciences, research for the past fifty years has focused upon producing more effective hurricane and tornado warnings and protective actions on the part of local officials and individuals. Research has led to significant strides in understanding the warning process and implementing effective risk communication. Improved hurricane evacuation planning is the direct result of research over the past thirty years. Thousands of lives may have been saved by improvements in warning and evacuation to date. But, given the devastating impacts of the 2005 hurricane season, clearly more improvements must be made.

Research into individual protective actions also has improved public response to tornadoes. Decades of research on community emergency preparedness and response have produced more effective state and local capabilities. It is an ongoing process to maintain effective capabilities at the state and local level.

Key Federal agency players include:

- Federal Emergency Management Agency (FEMA)
- National Oceanic and Atmospheric Administration (NOAA), Department of Commerce
- National Science Foundation (NSF)
- National Institute of Standards and Technology (NIST), Department of Commerce
- Federal Highway Administration (FHWA)

- Housing and Urban Development (HUD)
- National Aeronautics and Space Administration (NASA)
- U.S. Army Corps of Engineers (USACE)

Also playing a critical role are:

- State governments
- County governments
- City governments
- State-supported public universities

Finally, non-government organizations also continue to play significant roles:

- American Association of Wind Engineers (AAWE)
- American Society of Civil Engineers (ASCE)
- Institute for Building and Home Safety (IBHS)
- Private universities

### **3.3 RECENT PREPAREDNESS AND MITIGATION ACTIONS**

Hurricane Katrina set records for a single disaster event and early indications are that preparedness and mitigation prior to this event were not adequate. The State of Florida had a record hurricane year in 2004 emphasizing the fact that, while some progress has been made in mitigation measures to protect lives and property, much remains to be done. A recent survey conducted by IBHS found that more than half of Florida's homeowners have taken action to protect their homes from hurricanes and an even larger number recognize the importance of the state's building codes in reducing property losses from these events. Many think the codes should be even stronger. States, such as Texas, are adopting hurricane coastline wind load building codes and these are being implemented at the county and city levels. NOAA All-Hazards Radio and the National Weather Service's StormReady program are encouraging preparedness. Advances in wind engineering and design are increasing the effectiveness and popularity of affordable shelters, such as in-residence tornado shelters, based on design and construction guidance developed by FEMA.

## **4. CURRENT ACTIVITIES AND CAPABILITIES**

Several Federal agencies have missions and mission capabilities that are essential to achieving the objectives of the National Windstorm Act. (See Appendix C for Federal agency-specific contributions.) It is difficult to estimate the amount of money that Federal agencies invest in wind hazard related activities alone because of the broad nature of agency missions.

Understanding wind events, assessing wind damage, reducing the impacts and enhancing community resilience are often part of larger efforts to understand severe weather, hurricanes, building safer structures, etc. These larger efforts have myriad purposes, of which wind is often a tiny piece, and almost never the primary motivator. Therefore, the total investment by Federal agencies that can be explicitly and solely applied to wind hazard reduction is quite small in relation to the magnitude of losses and the national impact of those losses.

### **4.1 UNDERSTANDING, PREDICTING AND FORECASTING WINDSTORM HAZARDS**

Federal agency efforts to understand, predict, design for, and forecast windstorm hazards range from basic research funded by NSF and operational forecasts provided by NOAA to evacuation studies jointly funded by FEMA and USACE. NIST and FHWA focus on research aimed at understanding, predicting and designing for wind effects on structures, critical infrastructure, and creating the knowledge needed to develop improved design code provisions. NASA's work provides satellite based observational data and develops new observing systems that help underpin and improve wind predictions and forecasts. FEMA provides State and local governments the tools and products to enhance their capability to effectively manage loss reduction programs.

The focus on understanding and predicting of windstorm hazards and risks within any one of these agencies is minimal at this time. Wind is only one relatively small component of a broader suite of hazards addressed by each agency. For example, the observations of NOAA and NASA and the forecasts from NOAA address temperature, precipitation, moisture, air pressure and wind. However, the wind measurements taken are seldom at the small space and time scales required by engineers. In addressing hazards, FEMA, NIST and FHWA address issues related to buildings and public infrastructure for mitigating earthquakes, floods, fires, wind and other hazards making wind just one small component of their overall responsibility.

Nevertheless, efforts by these agencies have led to some improvements in the understanding and prediction of the winds themselves and in the development of programs for mitigating their effects. The spatial and temporal scale of wind predictions are decreasing and becoming more accurate. There has been a gradual increase in the understanding of structural response to winds, but progress has been uneven, particularly in the area of high winds combined with storm surge, flying debris, and ice loading on structures, among others. Another area where more attention is needed is the transfer of current research and knowledge into effective guidance and practice, including cost-effective mitigation.

### **4.2 ASSESSING THE IMPACT OF WIND HAZARDS**

The investigation of wind-induced damage to buildings and critical infrastructure should happen immediately following a wind-hazard event. These assessments of wind impacts are essential to providing new knowledge about how wind behaves at varying elevations and

around differing structural envelopes. To assess impact of wind hazard loadings on structures and to gain better understanding of the impact of winds and windstorm on their performance, it is essential to gather data through instrumentation before and field data collection after the hazard event. Through these types of efforts new or enhanced test procedures, tools for predicting structural response to wind and models for computer simulation of wind/structure interaction and loss estimation and improvements in design can become available. Damage assessment is also a focus of social science research as well as household, business and community recovery, but is not necessarily wind related.

### **4.3 REDUCING THE IMPACT OF WIND HAZARDS**

Successfully reducing the impact of wind hazards requires that actions be taken, directly or indirectly, to change or enhance existing building practices, infrastructure resilience, social behavior patterns and evacuation processes. Improvements in warning systems, evacuation planning and building technology have reduced the threat of windstorms to people even while the total number of people, buildings and critical infrastructure exposed to windstorms has grown dramatically. The result is that even while the threat of injury or death is being reduced, the total amount of damage and loss continues to rise. Many improvements have been implemented but much more needs to be done. Techniques have been developed to estimate wind effects that account realistically for wind directionality characteristics. Further, estimation methods have been developed to help assure higher safety levels for tall buildings that experience dynamic effects. The continuing improvement of the Nation's model building codes and standards with respect to improved design and construction provisions for wind resistance have had a significant impact on building and infrastructure performance. Ongoing efforts to develop performance based approaches to building design, especially critical and essential facilities, promise to bring further improvements. The additional development and use of innovative computer-intensive, user friendly methods to quantify wind loading can reduce errors in the estimation of wind loads by as much as fifty percent and can result in stronger structures built for lower costs. This is of interest to the private sector, state and local government, as well as Federal agencies, including FEMA and USACE, which are focused on increasing building survivability through optimized designs, building in hostile environments, and in hurricanes and other wind storms.

New designs that are evaluated in wind tunnels to ensure safety and performance are reducing the impact of winds and windstorms on highway structures. Efforts also have been made to promote structural health monitoring which permits evaluation of changes within a structure over time as a way to determine degradation before a catastrophic event and to incorporate monitoring instrumentation into major new structures.

### **4.4 PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE**

Preparedness is the advance capacity to respond to the consequences of a hazard event. This means having emergency plans in place concerning what to do and where to go if a warning is received or a hazard is observed. FEMA, in partnership with NOAA and USACE, develops the tools and products to develop effective State and local plans for evacuation and sheltering. NSF undertakes basic research on warning, evacuation, emergency planning and response, and vulnerability analysis.

Community resilience, especially in vulnerable populations, can be enhanced through a variety of means including outreach and awareness programs, partnerships with Federal and State agencies to improve the resilience of buildings and infrastructure, increased

preparedness exercises, effective mitigation planning efforts, and through improvements in local building code adoption and enforcement activities.

Numerous informational and educational materials exist on protection of individuals and property in high wind events, including hurricanes, tornadoes and straight line winds from thunderstorms. This information is repeated in brief during severe weather warnings. Coastal regions impacted by wind are encouraged to be prepared, have mitigation plans in place and establish sound building practices.

Within NOAA's National Weather Service, an outreach and education program called StormReady (<http://www.stormready.noaa.gov/>) has now reached communities in all 50 States. StormReady helps arm America's communities with the communication and safety skills needed to save lives and property— before and during the event. Working with local emergency managers, the Weather Service helps communities strengthen local safety programs. All potential weather risks to a community are included. Wind is usually a significant risk to life and property in most locations.

In addition, social science research that includes social vulnerability analysis as well as organizational and community emergency preparedness and response has been sponsored by NSF.

## 5. GAPS

### 5.1 UNDERSTANDING, PREDICTING AND FORECASTING

There are a number of areas where additional knowledge and action may reduce the impact of windstorms. Among these are enhanced full-scale wind measurement and structure performance with more sites and broader distribution, better and more robust instruments and networking, improved coordination between agencies and jurisdictions and setting standards for sensors, deployment, measurements and data storage.

Fundamental research on the meteorological aspects of wind hazards is continuing under support from NSF and other agencies. The interagency U.S. Weather Research Program has placed a high priority on improved knowledge of hurricane dynamics and developing improved forecasts of hurricane intensity. Major gaps in this research arena include the need for better understanding of the influence on intensity of: ocean heat content; environmental wind and thermodynamic structures and internal hurricane dynamics, such as the impact of hurricane eye wall and rain band interactions.

Improved prediction of wind storms is essential, but almost totally lacking are observations and understanding of the small scale wind structure in time and space to which the built environment responds within a larger windstorm event. Simulation of such detailed wind structure in wind tunnels is useful, but observations in the real environment near full-scale buildings must be obtained. These observations will provide necessary information on the interaction between individual structures and various types of complex built environments on the one hand and high winds on the other.

Methods and tools for wind hazard exposure predictions are required for structural design purposes. Improved methodologies for site-specific wind climate models and more refined and locally-detailed wind speed/hazard maps are therefore a critical need.

### 5.2 ASSESSING THE IMPACT OF WIND HAZARDS

Tools for assessing the impact of wind hazard events should be developed and improved. A greater effort must be made to study and learn from the aftermath of wind events and investigations of wind-impacted structures should be enhanced by including a broader spectrum of structures, including critical infrastructure. More comprehensive data on wind and windstorms should be collected and data exchange on damage and loss should be encouraged. New methods to predict the risk or loss and damage due to windstorms should be developed with appropriate simulation and modeling tools. Improved understanding of the effects of wind-borne debris on structures as well as the additional risk to structures from wind-driven rain, ice and hail are other important issues. For instance, the wind (speed and turbulent structure) and icing thresholds of danger to these buildings and infrastructure is not well understood.

Social scientists should examine the impact of wind hazards on individuals, businesses and communities, including vulnerable populations, by leveraging National Science Foundation funding to universities and non-government organizations.

Improved methods for assessing social and economic costs are also needed. Inclusion of detailed loss data from the insurance industry in this assessment effort is of vital importance.

### **5.3 REDUCING THE IMPACT OF WIND HAZARDS**

New, more accurate methods of understanding and assessing risk perception, risk communication, risk management, and designing for wind will reduce the impact of wind hazard events. Systematic establishment of design and retrofitting requirements should continue and a closer partnership between the design, construction and industry communities should be established to allow exploration, development and application of innovative technologies. Another area of emphasis should address ongoing programs to ensure that State and local knowledge and capabilities regarding wind hazards are high. Improvement in building code provisions and in wind loading provisions such as those contained in the ASCE 7 Standard is a central part of the impact reduction effort. Improved enforcement of new and existing building code requirements in areas of high risk to wind-borne hazards is equally important. Improved enforcement and inspection by local building officials is a very effective way to decrease the potential for damage from improper construction. Attention to damage generated by wind driven missiles and debris on building envelopes and glazing systems is needed.

### **5.4 PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE**

Information regarding risk and preparedness should be broadly distributed in a coordinated fashion. Gaps include the lack of sufficiently effective decision making tools for warning and evacuation; increased understanding of household and community adoption of preparedness measures; improved understanding of the role of improvisation and resilience in emergency preparedness and response; increased understanding of community physical, economic and social recovery from wind related disasters.

Additional work is needed to understand how individuals, especially those in vulnerable populations, perceive their risk to wind hazards and how they might best receive warning messages. This knowledge will help individuals understand their likelihood of preparedness and the potential need to target messages to specific audiences and geographical locations.

As with any other kind of disaster, community resilience is further determined by how quickly essential services are restored after a wind event. Damage resistant infrastructure must be designed and new technical methods must be developed for rapid repair of damaged infrastructure and restoration of services. Without restoration of essential services, like electricity and gas for cooking, potable water for drinking or telephone lines for communication, extreme community disruption will occur.

## 6. RECOMMENDATIONS

In accordance with the legislation, a coordinated Federal effort, in cooperation with other levels of government, academia, and the private sector, will improve the understanding of windstorms and their impact, and develop and encourage implementation of cost-effective mitigation measures to reduce those impacts while promoting community resilience. We recommend a coordinated, comprehensive multi-agency, multi-disciplinary working group be established as a working group of the National Science and Technology Council's Committee on Environment and Natural Resources Subcommittee on Disaster Reduction to reduce the impact of wind hazards by facilitating better communication between agencies, effectively allocating collective resources and operating within a common framework. This working group shall meet at least quarterly, report to the Subcommittee on Disaster Reduction annually and work with state, local officials and non-government organizations as appropriate. All Federal agencies contributing to this document shall be members of the working group and the chair of the working group will rotate between NIST, NSF, NOAA and FEMA with each Agency serving a two-year term as chair.

A coordinated portfolio of research and other activities should build on existing efforts and should include:

- Assessing individual and community capability to respond to wind events, including vulnerability analyses, risk perception, risk communication, risk management, communication of wind warnings and public response, evacuation capability, and public knowledge of appropriate protective actions for wind events, especially among vulnerable populations
- Evaluating the response of the built environment and critical infrastructure to wind events by investigating aerodynamic response, load path, ultimate capacity and the performance of the building envelope
- Assessing the impact of wind and windborne debris or wind and water/ice/snow
- Examining the interaction between wind and storm surge to determine the impact on building foundations and critical infrastructure
- Exploring the near-ground and channeling/shielding effects of winds on buildings through testing and instrumentation
- Developing new technologies and ground, airborne and satellite based observing systems to improve knowledge and understanding of windstorms and the wind variability within those storms
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- Developing and implementing technologies for rapid repair and restoration of critical infrastructure and critical services

There could be improvements in and enhancement of:

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- Windstorm damage and loss estimation modeling tools
- Standards and technologies that will enable cost-effective, state-of-the-art windstorm-resistant provisions to be adopted as part of state and local building codes

These improvements and enhancements would enable more effective:

- Local, state, regional and federal coordination in response to wind hazard events
- Evacuations through more informed planning and annual drills
- Local and regional preparedness through public-private partnerships fostering outreach and technology transfer programs
- Windstorm impact reduction practices through training and outreach programs that enhance state and local capabilities

# APPENDIX A: ELEMENTS OF DISASTER RISK REDUCTION AND HAZARD MANAGEMENT

The hazard research and management community employs a range of terminology to describe its activities, but no definitive, comprehensive list of these terms and their definitions exists. However, hazard risk reduction and disaster management activities can be grouped largely under nine broad concepts: research and development, hazard identification, risk assessment, risk communication, prediction, mitigation, preparedness, response, and recovery. Each of these rubrics includes critical science and technology elements, and, taken together, they form the nation's toolbox for reducing vulnerability to disaster risk.

**1. Disaster Process Research and Development (R&D)**—the science activities dedicated to improving understanding of the underlying processes and dynamics of each type of hazard. R&D includes fundamental and applied research on geologic, meteorological, epidemiological, and fire hazards; development and application of remote sensing technologies, software models, infrastructure models, organizational and social behavior models; emergency medical techniques; and many other science disciplines applicable to all facets of disasters and disaster management.

**2. Hazard Identification**—determining which hazards threaten a given area. This includes understanding an area's history of hazard events and the range of severity of those events. The continuous study of the nation's active faults, seismic risks, and volcanoes are included in this category, as are efforts to understand the dynamics of hurricanes, tornadoes, floods, droughts, and other extreme weather events.

**3. Risk Assessment**—determining the impact of a hazard or hazard event on a given area. This includes advanced scientific modeling to estimate loss of life, threat to public health, structural damage, environmental damage, and economic disruption that could result from specific hazard event scenarios. Risk assessment takes place both before and during disaster events.

**4. Risk Communication**—public outreach, communication, and warning at every stage of hazard management. Risk communication includes raising public awareness and effecting behavioral change in the areas of mitigation and preparedness; the deployment of stable, reliable, and effective warning systems; and the development of effective messaging for inducing favorable community response to mitigation, preparedness, and warning communications.

**5. Mitigation**—sustained actions taken to reduce or eliminate the long-term risk to human life and property from hazards based on hazard

identification and risk assessment. Examples of mitigation actions include planning and zoning to manage development in hazard zones, storm water management, fire fuel reduction, acquisition and relocation of flood-prone structures, seismic retrofit of bridges and buildings, installation of hurricane straps, construction of tornado safe rooms, and flood-proofing of commercial structures.

**6. Prediction**—predicting, detecting, and monitoring the onset of a hazard event. Federal agencies utilize weather forecast models, earthquake and volcano monitoring systems, remote sensing applications, and other scientific techniques and devices to gather as much information as possible about the what, when, and where of a potential hazard, as well as the severity of each threat.

**7. Preparedness**—the advance capacity to respond to the consequences of a hazard event. This means having plans in place concerning what to do and where to go if a warning is received or a hazard is observed. Communities, businesses, schools, public facilities, families, and individuals should have preparedness plans.

**8. Response**—the act of responding to a hazard event. Hazard response activities include evacuation, damage assessment, public health risk assessment, search and rescue, fire suppression, flood control, and emergency medical response. Each of these response activities relies heavily on information and communication technologies.

**9. Recovery**—activities designed to restore normalcy to the community in the aftermath of a hazard event. Recovery activities include restoring power lines, removing debris, draining floodwater, rebuilding, and providing economic assistance programs for disaster victims. As with response, the recovery process relies heavily on the availability of up-to-date data and information about the various community sectors, and on the technology to obtain and communicate that information.

## APPENDIX B: REFERENCE

1. Meade, C. and Abbot, M., “Assessing Federal Research and Development for Hazard Loss Reduction”, RAND Report, 2003, 65pp.

## APPENDIX C: CURRENT AGENCY ACTIVITIES

	NIST	NSF	NOAA	FEMA (DHS)	NASA	USACE	FHWA
<b>Understanding, Predicting and Forecasting</b>							
Enhancing knowledge, information and data on severe winds	Uniform description of wind increase with height; work on wind turbulence; post-event documentation and damage analyses.	Better understanding of atmospheric dynamics of straight-line winds	Wind observing systems and analysis	Post-event building performance assessments	Experimental and modeling research to improve understanding of severe storm development and lifecycle	Effects of wind on water and storm surge	Monitored and evaluated wind conditions at bridge sites; deployed weather stations along highways
Improving prediction of hazardous wind events	Developed extreme wind climatological models	Tornado genesis and tornadic vortex structure	Wind speed and direction forecasts		Work with NOAA to develop new technologies and use existing scientific satellite observations to improve wind storm prediction		Evaluated wind data and characterized wind and storm conditions at bridge sites
Understanding and quantifying wind loading	Developed novel static and dynamic wind loading estimation techniques	Improved understanding of fundamental physics that control hurricane intensity		Post-event building performance assessments			Measured wind conditions and structural response; studied wind/structure interaction
Understanding the perception of wind hazard risk		Studies of hazard risk perception		Outreach and training	Satellite observations provide global context to illustrate wind storm hazard risk to the public		Studied user/owner perception of risk
Mapping wind hazards	Developed techniques for improved extreme wind speed maps	Investigation of straight-line winds	Wind speed and direction analysis for input to HAZUS and other tools		Satellite observations from Landsat, EOS provide capability to map potential high risk regions		
<b>Assessing Impacts</b>							
Investigating wind resistance of buildings, structures and critical infrastructure	Pioneered studies of structural ultimate capacity and dynamic response under fluctuating wind loads. Post-event damage analyses.	Rapid-response field investigations of structural and societal damage		Post-event building performance assessments			Conducted aerodynamic assessment of new bridge designs in the laboratory; evaluated structural performance through full scale measurements
Developing improved tools for component- and structure-level simulation and numerical modeling of wind effects	Developed technology for computer-intensive use of pressure time histories for structural design	Development of instrumentation for the observational study of atmospheric winds					Developed methods for simulations in laboratory; developed numerical models for predicting bridge response

	NIST	NSF	NOAA	FEMA (DHS)	NASA	USACE	FHWA
<b>Assessing Impacts</b> (continued)							
Developing improved tools for loss assessment of wind hazards	Assisted the State of Florida in developing such tools	Design analyses for storm surge, wave actions, and wind speed on structures		Developing hurricane loss estimation model (HAZUS)	Ground, air and satellite based scientific observations provide capability to assess pre- and post-storm impact	Empirical models for debris volume estimation	
Assessing social costs		Economic analyses of wind disaster impacts		Benefits of mitigation study; developing indirect economic loss model			

<b>Reducing Impacts</b>							
Assessing and communicating risk	Incorporated effect of uncertainties on safety margins for wind loads	Basic research on warning and risk communication	Airborne photos and Lidar data for damage assessment; watches and warnings for high wind events; NOAA all hazards radio	Developing hurricane loss estimation model (HAZUS); Design and construction guidance			Developed new procedures for performing aerodynamic assessments
Developing prototype structural requirements		Improved modeling of wind effects upon structures		Consensus design standard input		Guidelines and requirements for standing seam metal roofing, building survivability, and optimized design	Identified details important to structural performance in winds
Demonstration, education, training and outreach on improved codes and building guidelines	Participates in the ASCE 7 Standard Committee on Wind Loads; trains future wind engineers	Research on Code enforcement and code design analyses		Develop design and construction guidance; Outreach and training		Snow fence construction to reduce wind impacts in cold regions	Demonstrated issues to visitors at laboratory; presented findings at major conferences
Guidance on retrofitting	Provides research; sponsored workshop	Analyses of effectiveness of structural retrofitting		Develop design and construction retrofit guidance			Evaluated structures demonstrating wind problems; developed retrofit solutions
Innovative technologies	Developed Database-Assisted Design methodologies; estimated ultimate capacities through non-linear analysis	Structural health monitoring				Wind noise mitigation	Investigated streamlining of structural form, aerodynamic treatment of structural surfaces, use of dampers and damping materials, use of active/passive control systems
Land use measures and cost effective construction practices		Research on effectiveness of non-structural mitigation		Develop/promote wind-resistant construction guidance		Design guidance on structural issues	

	NIST	NSF	NOAA	FEMA (DHS)	NASA	USACE	FHWA
<b>Preparedness and Enhancing Community Resilience</b>							
Developing tools for community preparedness to wind hazards		Research on community emergency preparedness and response capabilities,	StormReady community program	Develops tools for effective State and local evacuation and sheltering plans; implementation and training for design and construction guidance including HAZUS			
K-12 and college education needs	Trains future wind engineers	Research on emergency management education	Tornado and hurricane educational materials	Develop public outreach materials; materials for university courses; HAZUS training	NASA Earth science educational outreach programs increase understanding and awareness of wind storm hazards and impact		Conducted demonstrations and tours for students visiting the laboratory; presented seminars at universities as requested
General public awareness and outreach	Issues recommendations for wind engineering research	Surveys of public risk perception and knowledge of protective actions	Pre-tornado and pre-hurricane season public awareness campaigns	Develop public outreach materials; materials for university courses; HAZUS training			
Evacuation Planning		Evacuation Research and Decision-Tool development		Develops tools for effective State and local evacuation and sheltering plans		Cooperative evacuation route development	Participate with the State Highway Agencies in evacuation planning for all hazards
Enhancing disaster-resistance of Building Codes and Standards		Code analysis and studies of enforcement		Facilitate improvements to national model building codes and standards			
Building public and private partnerships				Maintaining and enhancing partnerships with Agencies, Universities, and private sector		Involvement with TISP and other public-private groups	
Conducting emergency response exercises		Basic research on emergency response		Emergency response and preparedness exercises thru FEMA Preparedness Division		Active exercise program	Conduct regular emergency response exercises for all hazards

## APPENDIX D: AGENCY SUMMARIES

### NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY UNDERSTANDING, PREDICTING AND FORECASTING

NIST researchers have proposed a uniform description of the variation of wind speeds with height to supersede two descriptions currently in use: the logarithmic law, used by meteorologists, and the power law, used by the ASCE 7 Standard. The current dichotomy makes it difficult to transfer knowledge from the meteorological community to the structural engineering community. NIST has also performed work on wind turbulence spectra, and has shown that efforts to develop overly detailed turbulence descriptions may be unnecessary for a broad class of structural calculations.

NIST conducts research aimed at developing extreme wind climatological models, both non-directional and directional, aimed at estimating extreme speeds with long mean recurrence intervals.

NIST develops and uses innovative computer-intensive, user-friendly methods to quantify wind loading, e.g.: NIST has developed database-assisted design, an advanced approach to defining wind loads on buildings which is based on information obtained in wind tunnel tests. This is expected to reduce errors in the estimation of wind loads by up to 50% and to result in stronger structures at lower costs. In addition, these methods are used in conjunction with nonlinear structural analysis techniques to develop the technology required for ultimate capacity-based design that could save up to 10% or even more in construction steel consumption nationwide while reducing expected losses due to winds. This development is of potential interest to those entities with an interest in “greener” building technology and embodied energy reduction. NIST develops techniques for the estimation of wind effects that account realistically for wind directionality characteristics, and develops estimation methods to help assure higher safety levels for tall buildings that experience dynamic effects.

Through its extreme wind climatological work NIST has contributed to efforts to improve the mapping of hazards due to non-hurricane winds, hurricanes, and tornadoes.

### ASSESSING IMPACTS

NIST investigates wind-induced damage that can provide new knowledge or recommendations for improvements to codes, standards, and practices that will reduce public risk and economic losses in future. The post-disaster investigations conducted by NIST have led to changes in practices, standards, and codes to enhance the health and safety of the American public. Examples include:

- Improvements to the wind speed requirements for coastal and near coastal regions and anchoring provisions for manufactured (mobile) homes in the Department of Housing and Urban Development national regulatory standards following Hurricane Andrew which struck Florida in 1992 and Hurricane Camille which struck Mississippi in 1969.

- An investigation following the Jarrell, TX, tornado of 1997 led to the development of an enhanced Fujita (EF) scale for tornado intensity (used to estimate wind speed based on observed damage to physical structures) by the Working Group for Natural Disaster Reduction/Post-Storm Data Acquisition in the Office of the Federal Coordinator for Meteorology (which includes NIST as a member) and subsequently has received approval by the National Weather Service for implementation during the Spring 2006 severe weather season.

Further, NIST's program for Hurricane Reconstruction in the Dominican Republic after Hurricane Mitch and Georges (1998), in partnership with USAID and HUD, led to the development of (1) a guide for constructing disaster-resistant housing in the informal sector, and (2) a manual for evaluating the disaster resistance of critical facilities (especially concrete buildings). To disseminate this work among practitioners, training workshops were conducted for local builders on the application of the housing guidance and for local engineers on the application of the facility assessment manual.

As part of its broader mission to meet the measurement and standards needs of the building and fire community, NIST is engaged, singly or in cooperation with other institutions, including NOAA, in wind speed measurements, specialized use of existing data, modeling, and prediction. These efforts are aimed at characterizing the wind environment and the wind climatology near the Earth's surface that are needed for realistic engineering assessments of structural safety, dispersion of fire products, and fire growth and spread. NIST also develops software for the user-friendly utilization of NOAA's ASOS data to create sets of wind speeds in formats suitable for extreme value analyses, and develops and disseminates the most advanced techniques for such analyses. The techniques are validated by using Monte Carlo simulations to estimate the effect of non-asymptotic behavior. NIST also assists the ASCE 7 Standard Task Committee on Wind Loads in developing realistic, updated U.S. wind hazard maps.

NIST is part of the team that develops the Florida Public Loss Prediction model at the request of the Florida Department of Financial Services. Through nonlinear analysis, NIST also develops novel algorithms for prediction of incipient wind-induced structural collapse or damage to building envelope components.

NIST has conducted studies of ultimate capacities of structures under fluctuating wind loads which, if continued, will facilitate safer structures while at the same time reducing material costs and embodied energy.

NIST investigates the systematic use of database-assisted design wherein pressure time histories throughout the building envelope are recorded in electronic form for use in the design process. NIST also has the capacity to develop computational fluid dynamics tools for use in wind engineering.

## **REDUCING IMPACTS**

NIST has capabilities in the area of risk assessment, and has worked on the development of appropriate safety margins for wind loads.

NIST is represented and active in the ASCE 7 Standard Committee on Wind Loads, and provides training to several high-school, undergraduate, graduate students, and postdoctoral research associates per year in the area of wind engineering.

NIST has supported the development of retrofitting guidance both through its research and by holding a workshop on the subject.

NIST has developed several innovative technologies in wind engineering, e.g., Database-Assisted Design methodologies, estimation of ultimate capacities through non-linear analysis, methods for simultaneously taking into account the directionality of the extreme wind climate, of the building's aerodynamic and dynamic response.

### **PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE**

Through its investigations NIST has issued recommendations for research and implementation of existing knowledge in a variety of wind engineering areas. For example, NIST's investigation of the World Trade Center towers' collapse of 9/11 found that there were discrepancies on the order of 40% between wind tunnel testing laboratories which estimate wind loads on tall buildings. The labs that were compared were independent labs that are widely used by industry. NIST has recommended that nationally accepted performance standards be developed for: (1) conducting wind tunnel testing of prototype structures based on sound technical methods that result in repeatable and reproducible results among testing laboratories; and (2) estimating wind loads and their effects on tall buildings for use in design, based on wind tunnel testing data and directional wind speed data.

NIST has also recommended that an appropriate criterion be developed and implemented to enhance the performance of tall buildings by limiting how much they sway under lateral load design conditions (e.g., winds and earthquakes).

NIST provides training to several high-school, undergraduate, graduate students, and postdoctoral research associates per year in the area of wind engineering.

## **NATIONAL SCIENCE FOUNDATION**

### **UNDERSTANDING, PREDICTING AND FORECASTING**

The National Science Foundation (NSF) invests a considerable amount of resources in support of competitive peer-reviewed research aimed at defining the wind environment physically and statistically. NSF has awarded grants for research related to hurricanes, tornados, cyclones, and wind. This research is mainly undertaken by the Directorates of Engineering, Geosciences and Social, Behavioral and Economic Sciences.

The Division of Atmospheric Sciences at NSF supports research that covers a broad range of activities relevant to wind hazards. Current research activities include: developing improved understanding of the fundamental physics that control hurricane intensity; research on tornado genesis and tornadic vortex structure; investigations of strong straight line winds from thunderstorms. Better understanding of the atmospheric dynamics of straight-line winds was one of the foci of the Bow Echo and Mesoscale Convective Vortices Experiment (BAMEX) held in the Spring of 2003.

### **ASSESSING IMPACTS**

In addition to research in atmospheric dynamics, the Atmospheric Sciences Division supports development of instrumentation (e.g. mobile and airborne Doppler radars) that is required for the observational study of atmospheric winds.

Structural Engineering research funded by NSF has examined the immediate impact of hurricane and tornado activity by funding damage assessment teams to visit disaster areas for post-event triage of structures. These studies are valuable in identifying not only specific anecdotal damage examples but also issues that require further study. For example, uneven damage patterns were observed by NSF-funded teams responding to Hurricane Isabel in 2003. The damage patterns suggest that the peak winds speeds were highly variable as the storm moved inward from the Atlantic Ocean. NSF-funded research is currently developing models for the storm surge and wave actions generated by severe storms and hurricanes. Other research is focused on detailed wind tunnel studies of structures under a variety of wind environments to determine the adequacy of current design and modeling approaches.

Social science research at NSF has supported quick-response research efforts to assess community damages, infrastructure disruption, and individual, organizational, and community social, political and economic impacts. The research attempts to develop damage assessment tools for use by emergency response officials.

### **REDUCING IMPACTS**

Development of improved modeling of wind effects on structures is a primary outcome of NSF-funded Structural Engineering research. Present design standards, such as ASCE 7, have benefited greatly by Federally-funded research into wind and its effects on structures. The current versions of these consensus standards are more comprehensive than previous versions. However, at the present time, most large structures including longer span bridges are subjected to detailed wind tunnel studies to determine the impact of winds on the structure and how to optimize their performance. It is the goal of NSF-funded research to improve the modeling and analysis capabilities in the Engineering community so that in the future, these detailed experimental studies will not be required. This will require on-going improvements in computational systems as well as in the modeling and analysis of the aeroelastic effects of wind. Training of the next generation of Wind Engineers is another aspect of NSF funding that is important. As the founding generation of Wind Engineers has retired, it has become an urgent need to continue the training of young Engineers so that the Wind Community will be able to meet the challenged posed by society in reducing wind effects on the built environment. NSF support for universities engaged in Wind Engineering research is a key component in building of the next generation of Engineers.

## **PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE**

NSF has a long history of supporting social science research on risk communication, warning systems and processes, evacuation planning and effectiveness, and individual, organizational and community protective actions undertaken prior to impact. In addition, research on factors facilitating societal adoption of structural and non-structural mitigation measures has been supported for over two decades. Research has also been supported that focuses upon such elements of community preparedness and capabilities improving our understanding and developing tools to measure social vulnerability and damage assessment, and household, business and community recovery from wind disasters.

## **NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION UNDERSTANDING, PREDICTING AND FORECASTING**

NOAA maintains an investment, on the order of \$600M in its operational numerical weather prediction and forecasting activities within the National Weather Service (NWS). These products include wind forecasts and severe weather outlooks up to 2 and 3 days. In addition, NOAA funds research to improve numerical modeling and forecast decision support systems (about \$20M). Much of the research is done within NOAA research laboratories in close collaboration with the NWS, and includes work to improve detection, diagnosis, real-time and retrospective analysis, and forecasts of hurricanes, tornadoes and thunderstorms. The NOAA H\*WIND product provides a contoured map of analyzed surface winds for hurricanes before, during and after landfall. In support of its modeling, prediction, and forecasting efforts, NOAA supports and maintains an array of surface wind sensors, radar and satellite observation systems, and mobile tornado tracking, observation, and measurement systems, including the WSR-88D Doppler radars operated with the FAA, and the COOP network. In addition, NOAA research develops and tests new observing capabilities, including airborne microwave wind sensors, GPS sounding technology, Doppler wind Lidar, and radar wind profilers. A new extreme turbulence probe uses pressure ports to measure high velocity winds at high frequency, which has been successfully used during 2004.

## **ASSESSING IMPACTS**

NOAA provides photographic and on-the-ground damage surveys immediately following a disaster to determine the severity of the impact of each storm and to provide information that assists in response and recovery. These surveys are particularly useful to correlate the measured winds with the degree of damage. The NOAA Sea Grant program funds real-time hurricane wind measurements and instrumented test homes in coastal environments, assessments of building practices and plans in coastal regions that include wind effects, and education and outreach concerning preparedness and mitigation practices.

## **PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE**

Within NOAA, the National Weather Service provides numerous informational and educational materials on protection of the general public and property in high wind events, including hurricanes, tornadoes and straight line winds from thunderstorms. This information is repeated in brief during severe weather warnings. The Sea Grant program, through extension agents, offers education and outreach concerning best construction practices and siting of coastal development.

## **FEDERAL EMERGENCY MANAGEMENT AGENCY\***

### **UNDERSTANDING, PREDICTING AND FORECASTING**

Mitigation Assessment Team (MAT) studies of building performance following hurricanes have been frequently and successfully used to assess and understand the impacts of wind storms on the built environment. Those lessons learned have been translated into improvements in design and construction practices and changes to the nation's consensus design standards and national model building codes which directly improves the wind-resistance of construction in high-wind areas. Through the use of a state-of-the-art wind field computer model, the HAZUS loss estimation tool allows states and communities to conduct vulnerability analysis which leads to an improved understanding of how windstorms affect the built environment and their risk from those hazards. Also, ongoing outreach and training on wind hazards enhances the knowledge and capability of all groups to make informed decisions.

### **ASSESSING IMPACTS**

Detailed results of HAZUS analysis provide communities, emergency managers, planners, and decision-makers with critical information regarding community vulnerability and likely impacts impending or future hurricanes. This information can have a significant impact on the decision-makers who are responsible for determining what, if any; will be taken before, during, and after hurricanes. Specific assessment activities include:

- Conduct post-hurricane building performance assessments
- Develop HAZUS hurricane wind loss estimation modeling tool
- Conduct a study on the benefits of mitigation; and
- Develop an indirect economic loss model for hurricanes.

### **REDUCING IMPACTS**

A critical, and effective, way to reduce the impacts of hurricanes on the built environment is to have strong, disaster-resistant building codes and in place which effectively enforced. FEMA has worked for over a decade to develop partnerships and successfully advocate for the adoption of wind-resistant provisions to the nation's model building codes and standards. A part of that effort includes participation consensus committees such as ASCE 7 (Design Loads for Buildings and other Structures) Wind Load Task Committee and developing design and construction guidance (new and retrofit) for design professionals, State and local officials, contractors, and the public. We also conduct outreach and training to improve understanding and promote the use of wind-resistant design and construction in high-wind coastal areas.

### **PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE**

FEMA works to promote the concept of having emergency plans in place concerning what to do and where to go if a warning is received or a hazard is observed. In partnership with NOAA and USACE, FEMA develops the tools and products to develop effective State and local plans for evacuation and sheltering. In addition, we: provide support for the development and exercise of community and regional evacuation planning; develop and implement state-of-the-art design and construction guidance; train and educate using materials designed for communities, designers, and contractors; develop public outreach materials; establish and maintain partnerships, grants and cooperative agreements with a wide range of Agencies, trade organizations, universities, and private-sector groups; and

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\* Specific organizational units may vary because of pending reorganization.

carry out a robust program of emergency response and preparedness exercises through the FEMA Preparedness Division.

## **FEDERAL HIGHWAY ADMINISTRATION UNDERSTANDING, PREDICTING AND FORECASTING**

A significant component of the FHWA wind research program has been the development of technology and capabilities to collect site-specific information on winds and windstorms to gain better understanding of the wind environment. A select number of sites have been instrumented and monitored by the Aerodynamics Laboratory for periods ranging from weeks to decades to characterize the wind conditions and study impact on structures.

Roadway Weather Stations have been deployed on many of their major highway routes to monitor wind as well as general roadway conditions.

### **ASSESSING IMPACTS**

FHWA is specialized in the assessment of impact of winds and windstorms on the performance and safety of highway bridges, especially long span bridges, and other highway structures. The agency's Aerodynamics Laboratory has been the primary facility in the U.S. for conducting aerodynamic assessment of new bridge designs and evaluations of existing structures sensitive to wind. Many bridge assessments are also performed at private and public laboratories in Canada, and the results are usually reviewed by FHWA staff. The FHWA Laboratory has been active in developing new or enhanced test procedures, tools for predicting structural response to wind, and models for computer simulation of wind/structure interaction. The Aerodynamics Laboratory also performs full scale measurements on highway structures, in conjunction with wind measurements, to gain better understanding of the impact of winds and windstorms on their performance.

### **REDUCING IMPACTS**

The FHWA wind research program has been working toward reducing the impact of winds and windstorms on highway structures. New designs have been evaluated in the wind tunnel to ensure safety and performance, while retrofits have been identified and implemented for structures with wind problems. Some studies have been initiated to conduct benchmark tests on new structures to establish initial performance characteristics. In addition, efforts have been made to promote structural health monitoring and to incorporate monitoring instrumentation into major new structures. Guidelines are being developed to mitigate wind-induced vibration of cables on long span bridges. Through Transportation Research Board's (TRB) National Cooperative Highway Research Program (NCHRP), AASHTO guidelines for wind related design of highway support structures (signs, signals, luminaries, etc.) have been periodically updated. No national guideline or specification currently exists for the wind resistant design of long span bridges. The FHWA wind research program has just initiated a small project to prepare a synthesis of wind load criteria for long span bridges. Studies are planned to address areas of risk and reliability due to all hazards, including wind.

### **PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE**

The FHWA wind research program has attempted to provide some training and awareness to students by providing access to and tours of its research facility in McLean, Virginia. A new demonstration wind tunnel has recently been added to the laboratory to assist in this outreach activity. Some seminars have been presented at selected universities as opportunities arise. More than two dozen graduate students have had the opportunity to perform research in our Aerodynamics Laboratory under the umbrella of the Eisenhower

Fellowship Program with the hope of stimulating interest in pursuit of a career in Wind Engineering. FHWA has provided demonstrations and tours of its facility to groups of engineers, industry representatives, public officials, and the general public when requested. Findings of our investigations are presented in a variety of venues including workshops, seminars, national meetings, and international conferences. FHWA also engages in developing predictive traffic analysis tools for planning and traffic management to improve mobility in times of crisis. Models are being tested which allows engineers to perform critical transportation infrastructure analyses and evaluate different incident management strategies during and after any event. Additionally it participates with State highway agencies in evacuation planning and response for all hazards.

## **NATIONAL AERONAUTICS AND SPACE ADMINISTRATION UNDERSTANDING, PREDICTING AND FORECASTING**

NASA operates a number of scientific satellites, including the three flagship satellites Terra, Aqua, and Aura, as part of the Earth Observing System. The EOS instruments provide unique global observations of atmospheric, land and ocean processes that can augment the operational observations of NOAA to improve our understanding of the generation and lifecycle of the large storm systems that produce hazardous wind conditions. NASA satellite observations, when assimilated into operational models, can significantly improve the forecast and prediction of these storms. For measurements of high impact and importance NASA works closely with NOAA and DoD to transition these new measurement capabilities into the next generation of operational weather satellites. Beyond EOS, NASA is also developing new technologies and instruments, including space based precipitation radar and Doppler wind Lidar which will further advance our understanding and capability to predict these events. In addition, NASA is developing advanced global models that can be used for weather prediction and climate simulation; operates, plans, and considers the development of satellite observing systems contributing significantly to the understanding and prediction of windstorms, including space-based Lidar wind profile measurement systems, and the Global Precipitation Mission. NASA performs Observing System Simulation Experiments, typically in collaboration with NOAA, to evaluate the potential of proposed observing systems to contribute to improved forecasts and to design the most effective global observing system.

### **ASSESSING IMPACTS**

NASA land and ocean observing systems such as Landsat, MODIS, and SeaWiFs provide the 'big picture' space based view of the impact of large windstorms in affected areas. This big picture view can allow rapid assessment of the effects on the built environment and have the potential to be used for planning and deployment of available resources to the most heavily impacted regions. Other unique ground and airborne instruments can be employed to determine the patterns and magnitudes of coastal change caused by erosion and destruction of buildings and infrastructure following a windstorm. For example, through a cooperative research program NASA, NOAA, the U.S. Geological Survey and the U.S. Army Corps of Engineers are exploring the use of innovative airborne laser mapping systems to quantify coastal change along the entire coastline affected by Hurricane Katrina.

## **UNITED STATES ARMY CORPS OF ENGINEERS**

### **UNDERSTANDING, PREDICTING AND FORECASTING**

Following Hurricane Katrina, ERDC was contacted to provide calculations relative to the effects of wind on water and surge, key information that can be leveraged into future wind mitigation studies.

### **REDUCING IMPACTS**

USACE is presently concerned with building survivability, optimized building and facility design, building in hostile (particularly cold) environments, and in hurricanes and storms. Research proposals addressing structural issues related to wind have been developed for all three services.

USACE has developed guidelines and requirements for standing metal seam roofing and the Corps' Engineer Research and Development Center has recently conducted research in areas of wind/noise mitigation techniques and techniques for constructing snow fences to reduce the impacts of wind in cold regions.

### **ASSESSING IMPACTS**

Following Hurricane Andrew in 1992, the USACE participated in a reconnaissance effort related to damage at Homestead Air Force Base and lessons learned as a result of that storm. The Corps' Engineer Research and Development Center (ERDC) participated in an effort for federally owned and leased buildings as part of the Seismic Hazard Reduction Program that involved estimating the number of buildings at risk and probable annual loss and the projected cost to mitigate the existing seismic deficiencies in federal buildings. The knowledge gained in the seismic program can be leveraged for a new wind-focused program. A group within USACE is also working on empirical modeling of debris volume created by wind storms and the associated rain.

### **PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE**

USACE participates in cooperative evacuation route development and maintains an active program conducting emergency response exercises.

## APPENDIX E: LIST OF ACRONYMS / DEFINITIONS

AASHTO	American Association of State Highway and Transportation Officials
AAWE	American Association of Wind Engineers
ASCE	American Society of Civil Engineers
ASOS	Automated Surface Observing System
ASTM	American Society for Testing and Materials
BAMEX	Bow Echo and Mesoscale Convective Vortices Experiment
COOP	Cooperative Observer Program
DOD	Department of Defense
EOS	Earth Observing System
ERDC	Engineer Research and Development Center
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
HAZUS-MH	HAZUS Meteorological Hazards
H*WIND	Hurricane Wind
HUD	Department of Housing and Urban Development
IBHS	Institute for Business and Home Safety
ICC	International Code Series
MAT	Mitigation Assessment Team
NASA	National Aeronautics and Space Administration
NCHRP	National Cooperative Highway Research Program
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OSTP	Office of Science and Technology Policy
USACE	United States Army Corps of Engineers





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