Task 26.4 DEVELOPMENT OF NIST MEASUREMENT SCIENCE R&D ROADMAP: WINDSTORM AND COASTAL INUNDATION IMPACT REDUCTION
A Literature Review of Existing Resources and Past Workshops on Identifying Research Needs

The references at the end of this report are indicated with a [letter]. Any information in the references that addressed research related to one of the five program elements is listed under the appropriate program element. There has been no effort made at this point to synthesize the list as there is some value in seeing how many times certain subjects are considered by various groups at various times.

Subject Area 1: Systematic support of the windstorm and coastal inundation code development process.

Program Element 1: Provide technical support for windstorm and coastal inundation engineering practice and code development process.

- [3] Develop simulation techniques for wind modeling
- [3] Develop database and knowledge-based model for wind loading on structures
- [3] Develop simulation techniques for modeling of wind loading on structures
- [3] Develop techniques for modeling effects of wind hazards
- [3] Improve characterization of properties of severe winds
- [3] Develop instrumentation and data transfer/processing infrastructure for wind data acquisition
- [3] Develop computational methods for simulating wind loading
- [3] Develop databases and visualization tools for simulation of wind effects
- [4] Modeling of wind-structure interaction, including effects of integral wind loads on structural systems, components and cladding, effectiveness of retrofitting schemes, effects of structural fatigue and impact by wind-generated missiles, design of cost effective tornado shelters and shelters for hurricane zones to minimize evacuation
- [4] Application of effective numerical schemes using computational fluid dynamics to determine the wind environment and wind loading on and response of buildings, structures, transportation systems and other critical components of civil engineering infrastructure, and to mitigate these effects
- [5-a] Study the possibilities of using wind database-assisted design techniques
- [5-b] Study the possibilities of using wind database-assisted design techniques
- [5-b] Need new gust loading factors, including 3-D gust loading factors
- [5-c] Need wind design methodology for photovoltaic systems
- [5-d] Investigate shape coefficients for more roof shapes than currently exist in ASCE 7
- [13] Develop tools to simulate aging of components including corrosion
- [13] Develop methods for assessing load path continuity
- [14] Provide the technical basis for revised codes and standards for critical infrastructure and essential facilities by using risk and vulnerability assessment tools
- [16] Increase the number of building shapes available in the codes and standards

Program Element 2: Develop the technical basis for performance-based windstorm and coastal inundation engineering by supporting problem-focused, user-directed research and development.

[1] Interaction of hurricanes with engineered structures.
[2] 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
[2] Assessing the impact of wind and windborne debris or wind and water/ice/snow
[3] Improve understanding of wind-borne debris
[3] Define performance measures
[4] Research in debris impact potential in windstorm and development of impact resistant building components
[5-a] Research the transition in turbulence from Exposure D to Exposure B at landfall
[5-b] Serviceability thresholds for wind motion in tall buildings is needed
[5-c] Wind-borne debris needs to be researched
[8] Develop and implement performance-based approaches for the design of wood structures
[11] Develop reliable methods to design structures to meet specific performance levels under increasing level of hazard intensity
[12] Establish design criteria that reflects system reliability as opposed to component reliability
[13] Determine characteristics of wind-borne missiles. Better define the geographical boundaries where missile impacts should be taken into account in design. Determine the correlation between missile size, weight and impact speed with wind speed.

Subject Area 2: Improve windstorm and coastal inundation design and community resiliency.

Program Element 3: Support the development of technical resources (e.g., guidelines and manuals) to improve windstorm and coastal inundation engineering practice.

[2] Exploring the near-ground and channeling/shielding effects of winds on buildings through testing and instrumentation
[2] Measuring the response of bridges and other highway structures to wind events, including stability, serviceability and functionality leading up to and through extreme events
[3] Improve knowledge on behavior of structural and non-structural components
[3] Improve understanding of response of structural systems
[3] Improve damage and fragility models for structures
[3] Improve indirect loss estimation models for wind hazards
[3] Develop real-time loss estimation tools
[4] Study of internal load paths, performance of structural systems, and effectiveness of connections between structural components
[6] Develop ADCIRC model for operational use
[6] Improve determination of storm water levels
[6] Develop techniques to show flood depth above ground
[11] Improve loss assessment methodologies and decision support tools to include multiple hazards based on existing tools developed for earthquake engineering
[13] Improve probabilistic treatment of the variability in loads and resistance

[14] Develop probabilistic inundation hazards prediction and methods to effectively quantify and communicate risk

Program Element 4: Make evaluated technology available to practicing professionals in the windstorm and coastal inundation design and construction communities.

[1] Improved in situ observations.
[1] Understanding air-sea interaction.
[2] 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
[2] Examining the interaction between wind and storm surge to determine the impact on building foundations and critical infrastructure
[3] Improve mapping of wind hazard
[3] Develop tools for real-time monitoring of wind hazards
[3] Continue to develop remote-sensing technologies for damage assessment
[3] Develop retrofit techniques for new and existing materials, systems and subsystems, components
[3] Demonstrate application of new tools in post-event setting
[4] Collection of wind speed data using robust instrumentation and state-of-the-art technology to map detailed structure of the wind, topographic effects, and long-term climate effects
[4] Development of effective techniques for collection and rapid archiving and dissemination of data acquired during post-disaster investigations
[4] Development of cost-effective retrofit techniques to enhance wind resistance of existing structures
[4] Mapping of wind climate in urban areas
[4] Simulation of hurricanes and their wind fields and other extreme wind effects for statistical analysis of wind, wind loads, and wind-induced response of structures and their components
[5-a] Study the variations of results of wind tunnel studies
[5-b] Damping technology for tall buildings
[5-d] Effects of exposure and terrain on wind pressures at buildings needs study
[5-d] Study the effects of building size and shape on attenuating wind pressure
[5-e] Study the flow around buildings from tornado vortex to determine pressure requirements for design
[7] Improve storm surge modeling by coupling five other coastal models to CSTORM-MS
[13] Develop long-term performance of glues, adhesives and coatings
[14] Examine the interaction between wind, storm surge and shallow water waves to determine the impact on building foundations, critical infrastructure, and vegetation
[14] Evaluate capabilities of radar for swell/wave and deformation measurements
[14] Develop coastal wind/wave climate maps and shoreline coastal process models to better understand and predict aspects of coastal erosion and inundation
[14] Determine climate scale factors that relate to sea level variability and rise
[15] Improve quantitative predictions of coastal erosion

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[15] Improve understanding of the physics of tropical cyclones or coastal ocean conditions at the land-water interface
[16] Study the effects on structures of wind loading caused by various wind event types
[16] Study the effects of building surroundings on structural reliability and risk of damage caused by wind loading
[16] Establish a program of real-time wind monitoring of buildings

Program Element 5: Develop the technical basis for windstorm and coastal inundation engineering to support community resilience within an all-hazards framework.

[1] Predicting hurricane intensification and size, and reducing the uncertainty associated with where and when hurricanes will make landfall.
[1] Economic and social impact of hurricanes and mitigation measures.
[1] Assessing and improving the resilience of the built environment.
[2] Developing and implementing technologies for rapid repair and restoration of critical infrastructure and critical services
[2] 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
[3] Develop methodologies and assessment of effectiveness in enhancing community resilience to wind hazard
[4] Development and application of reliable techniques for cost-benefit analysis of wind hazards mitigation measures and other socio-economic evaluations
[5-c] Need to study interface between wind engineering and green building design
[8] Develop next generation wood systems including maerials, connections, assemblies and products.
[8] Develop advanced design and construction methodologies using combined materials (hybrid construction)
[11] Identify mitigation strategies and technologies that can provide simultaneous protection against more than one hazard for a single cost
[11] Develop technologies to prevent cascading failures of complex lifeline systems

Literature Reviewed

[1] Hurricane Warning: The Critical Need for a National Hurricane Research Initiative, National Science Board of the National Science Foundation, January 2007
High Priority Issues: (included in 5 program elements)
Medium Priority Issues:

- Understanding the relationship between hurricanes and climate.
- Fundamental hurricane predictability.
- Hurricane modification through human intervention.
- Computational capability.

- Training and education programs related to hurricane impacts.

[2] Windstorm Impact Reduction Implementation Plan, National Science & Technology Council, April 2006

Gaps in Understanding, Predicting and Forecasting:

- Full scale wind measurement and structure performance
- Influence on intensity of ocean heat content
- Internal hurricane dynamics
- Understanding of the small scale wind structure in time and space to which the built environment responds
- Improve methodologies for determining site-specific wind climate
- Need more refined and detailed wind speed/hazard maps

Gaps in Assessing the Impact of Wind Hazards

- Develop tools for assessing wind damage to buildings
- Develop simulation and modeling tools for predicting wind damage to buildings
- Improve the understanding of wind-borne debris and wind-driven rain, ice and hail on structures
- Social scientists should study the impact of wind hazards on individuals, businesses, and communities including vulnerable populations.
- Improved methods are needed for assessing social and economic costs of losses caused by wind hazards.

Gaps in Reducing the Impact of Wind Hazards

- Need methods for understanding and assessing risk
- Need more accurate methods for designing for wind
- Need to built stronger partnerships between design, industry and construction communities to explore innovative technologies
- Need further improvement in building codes and wind load standards
- Need improved building code enforcement in at-risk high wind areas

Gaps in Preparedness and Enhancement of Community Resilience

- Lack of sufficiently effective decision making tools for warning and evacuation
- Understanding of household and community adoption of preparedness measures
- Understanding of role of improvisation and resilience in emergency preparedness and response
- Understanding of how to recover from wind related disasters
- Improve understanding of how wind risk is perceived by individuals
- Develop new technical methods to speed up repair and thus recovery of damaged infrastructure, services, and/or critical facilities

[3] Wind Engineering Research and Outreach Plan, American Association of Wind Engineers and ASCE, May 2004

The issues presented in this report are organized into four categories similar to the *Windstorm Impact Reduction Implementation Plan* shown above. In each category, there are needs defined for research and for outreach.

Gaps in Understanding Wind Hazards

Research: (included in 5 program elements)

Outreach:

- Incorporate knowledge into codes and guidelines
- Disseminate codes and guidelines to practicing professionals
- Develop surge/flood mapping and warning

Assessment of Impact of Wind Hazards

Research: (included in 5 program elements)

Outreach:

- Develop consensus guidelines for deployment of sensors and use in operation of buildings including interfaces with emergency management
- Create new models for representing behavior of components in simulation software
- Develop standards for development of wind loading simulation software
- Develop strategy to utililize computational resources including engineers in the strategy development
- Develop loss estimation models utilizing simulation technologies

Reduction of Impact of Wind Hazards

Research: (included in 5 program elements)

Outreach:

- Develop guidelines, standards of practice and codes for wind-resistant design of structures
- Develop products for implementation of performance-based design
- Develop publicly accessible database of wind damage
- Integrate loss estimation tools with real-time information on wind hazards
- Develop methodologies to update post-evenjt loss estimates with post-event real data on losses

Enhancement of Community Resilience

Research: (included in 5 program elements)

Outreach:

- Develop process for improving regulatory system
- Develop demonstration efforts for target audiences

[4] New Opportunities to Reduce Wind Hazard Losses and Improve Quality of Life in the USA, American Association for Wind Engineering, August 1997

[5] Proceedings of International Workshop on Wind Engineering Research and Practice: Current State of the Art and Future Needs/Plans, Chapel Hill, NC, May 2010

[a] Hurricane winds on low-rise buildings: full-scale measurement and scale model comparisons, Gurley, Prevatt, Masters, Liu, and Aponte-Bermudez
[b] Tailoring contemporary tall buildings for wind effects, Kareem
[c] Contemporary architectural aerodynamics and the future of wind engineering, Cochran
[d] Wind effects on buildings: Understanding of wind design standards and codes of practice, Stathopoulos
[e] PIV and PSP Techniques and their applications for wind engineering studies, Hu, Yang, Sarkar

[6] NOAA's Storm Surge Roadmap: Transition Research to NWS Operations, Jesse Feyen, July 2010

[7] Coastal Storm Modeling – System Integration, US Army Corps of Engineers, Massey, Wamsley, Cialone, Date

[8] Wood Engineering Challenges in the New Millennium – Critical Research Needs, ASCE-SEI, Gopu, April 2008

[9] Performance Based Design Extreme Wind Loads on a Tall Building, The Structural Design of Tall Buildings, Jain, Srinivasan, Hart, August 2000

[10] Toward the Probabilistic Simulation of Storm Surge and Inundation in a Limited-Resource Environment, Davis et al, American Meteorological Society, 2010

[11] Grand Challenges for Disaster Reduction, National Science and Technology Council, Subcommittee on Disaster Reduction, 2005

[12] Proceedings, Workshop on Research Needs in Wind Engineering, NISTIR 5597, National Institute of Standards and Technology, 1995.

[13] Windstorm Mitigation Initiative, Retrofit Workshop Report, Texas Tech University, December 1999

[14] Grand Challenges for Disaster Reduction, National Science and Technology Council's Subcommittee on Disaster Reduction (SDR), 2008

[15] Coastal Hazards Colloquium, Department of Homeland Security, Science and Technology Directorate, University of North Carolina, December 2008

[16] Wind Engineering Research Needs, Dr. Peter Irwin, ASCE Technical Council on Wind Engineering, 2011

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