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NCST Advisory  
Committee Meeting

# **NCST Technical Investigation of Hurricane Maria's Impacts on Puerto Rico: Preliminary Project Plan for Evaluation of Critical Building Performance**

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**Goal 2: The Performance of Representative Critical Buildings,  
and Designated Safe Areas in those Buildings,  
Including their Dependence on Lifelines**

## Project: Performance of Critical Buildings

**Objective:** To characterize the performance of critical buildings in Hurricane Maria by (1) documenting failures of structural systems, building envelopes, and rooftop equipment, along with the resulting intrusion of wind-driven rain, interior damage, and loss of function for a representative sample of hospitals and schools, (2) identifying dependencies in loss of function on lifelines, (3) characterizing wind loads on building envelopes and rooftop equipment through wind tunnel testing for a subset of these hospitals and schools to correlate with observed damage, and (4) evaluating the adequacy of existing selection criteria and design requirements for storm shelters.

# Background

Observations from preliminary reconnaissance of engineered buildings:

- Limited ***structural*** damage to reinforced concrete and concrete-block buildings with concrete roofs
- Some failures of non-concrete roofs (wood or steel frame) on reinforced concrete and concrete-block buildings
- Wind-induced damage to and failure of metal building systems, potentially due to corrosion





## Background

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- Damage to windows and doors





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- Failures of rooftop equipment
- Damage to roof coverings
- Rainfall ponding on the roof
- Damage to windows and doors
- Wind-driven rain penetration, even through undamaged cladding



# Preliminary Project Plan (1/4)

## Documenting Performance of Critical Buildings:

- Identify available data on characteristics and performance of hospitals and schools in Hurricane Maria in coordination with federal partners (through National Disaster Recovery Framework)
- Select a representative sample of hospitals (~15) and schools (~30) for detailed study, with consideration of available information on the buildings, the hazards, and social factors
- Perform detailed on-site evaluations of the selected sample of critical buildings:
  - Building characteristics; design criteria; construction, inspection, and maintenance practices
  - Structural and non-structural damage, loss of functionality, dependence on lifelines
- Where possible, collect samples of failed materials where further study may be warranted (e.g., corroded components and fasteners, polymeric materials with UV degradation)
- Select a subset of the critical buildings for forensic wind-tunnel testing
- Evaluate the performance of the critical buildings with consideration of:
  - Wind loads and other hazard levels encountered during Hurricane Maria
  - Code and standard requirements, including consideration of seismic hazards

## Preliminary Project Plan (2/4)

### **Identifying Dependences on Lifelines:**

- For buildings in the representative sample of hospitals and schools:
  - Identify the cascade in loss of function from the hazard to infrastructure systems and ultimately to the building
  - Identify the lifelines that defined the timing of the return to building function
  - Identify critical paths in recovery activities for restoration of lifelines
- Based on these findings, identify components of infrastructure systems that tend to be critical for the return of building functionality
- Document the physical performance of wireless communication systems with respect to hazard levels and applicable requirements for design and construction



# Preliminary Project Plan (3/4)

## **Forensic Wind Tunnel Testing of Selected Critical Buildings:**

- Wind tunnel testing is planned for a subset of the sample of critical buildings, where detailed characterization of the wind loads would be warranted for evaluation of building performance
- Buildings models will be extensively instrumented:
  - Pressure taps to measure pressures on the building envelope (e.g., roof, walls, windows, doors)
  - Pressure taps or force balances to measure wind loads on rooftop equipment
- Surrounding buildings and terrain will be included in area models
- Selected tests may be repeated with varying conditions:
  - With and without surrounding buildings, to quantify their effect on the resultant wind loads
  - With different configurations of rooftop equipment
- Directional pressure and force coefficients from wind tunnel testing will be combined with the time-dependent hurricane wind-field model to estimate wind load histories during Hurricane Maria, which will be used in evaluating building performance

## Preliminary Project Plan (4/4)

### **Evaluation of Storm Shelter Section Criteria and Design Requirements:**

- Collect relevant data on the hurricane shelter program in Puerto Rico:
  - Shelter selection criteria and process
  - Shelter facilities used during Hurricane Maria
  - Storm impact on these facilities, including damage and any injuries or fatalities
- Determine the hazard levels experienced at shelter site locations
- Evaluate shelter performance and selection criteria in consideration of:
  - Hazard levels experienced during Hurricane Maria
  - Code and standard requirements
- Develop findings and recommendations based on these results

## FY18 Planning Tasks

- Other agencies (e.g., FEMA, USGS) with information on the performance of schools and hospitals will be identified, and plans will be made on best ways to reach out
- A sampling strategy will be developed, and a representative sample of critical buildings will be selected for detailed study
- Contract specifications will be developed:
  - Local engineering support for evaluation of building performance
  - Forensic wind tunnel testing of selected critical building models
- Buildings will be identified where wind tunnel testing would be warranted for evaluating building performance
- Staff with GIS expertise may be hired or detailed to assist the Team