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Multi-Hazard and Resilience Research at Rensselaer

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ATC U.S.-Japan Workshop
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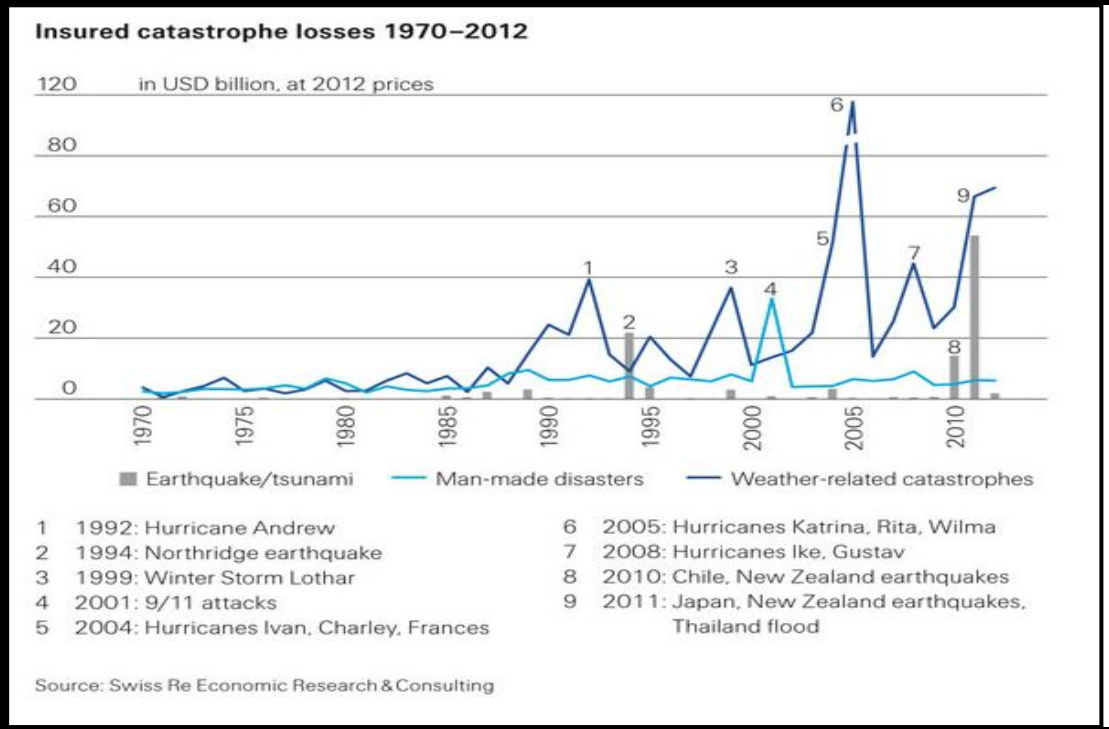
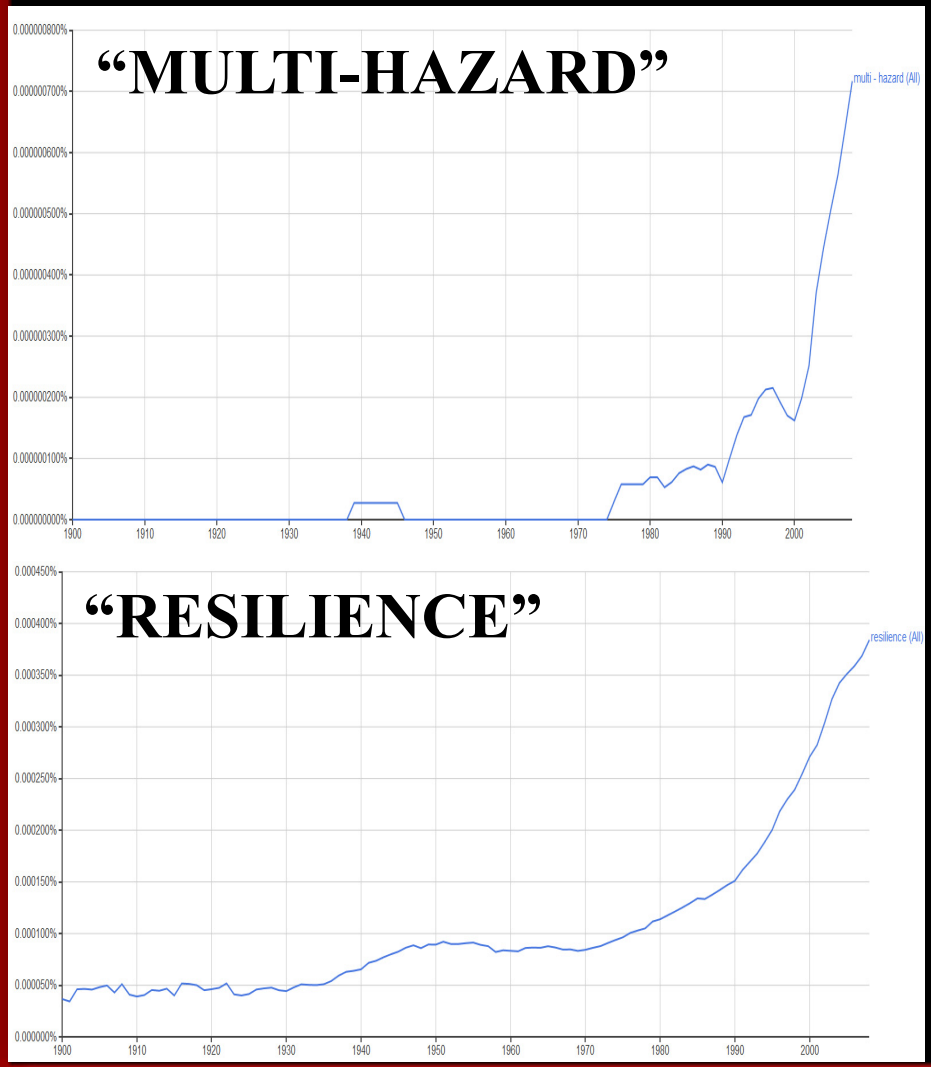
Introduction/Background

- $2.5T losses in 21st Century induced by natural hazards and increasing
- Multiple Hazards
  - Tohoku Earthquake and Tsunami (2011)
  - Hurricane Sandy – wind and storm surge (2012)
- Prompted increased 'Resilience' discussion



Multi-Hazard and Resilience Push

- **Increased awareness of multi-hazard and resilience concepts**



NIST Community Resilience Center of Excellence

DHS Center of Excellence in Resilience

NSF Themed Programs and Proposal Solicitations:

Resilient and Sustainable Infrasturctures

Decision Frameworks for Resilient and Sustainable Buildings (RSB)

Resilient Interdependent Infrastructure Processes and Systems (RIPS)

Tenure-Track Job Announcements:

"...Candidates with specific research expertise in resilient and sustainable civil infrastructure systems are particularly encouraged to apply"

"Research thrusts relevant to this position include, but are not limited to, autonomous and adaptive systems, sustainability, and **resilience**"

"**Resilient Systems**"....Infrastructure systems and projects face a multitude of hazards that must be assessed, communicated, and managed appropriately. We are interested in candidates who develop high-performance computer simulation and advanced visualization tools to conduct risk assessments at the citywide scale, considering **multiple hazards** such as earthquakes, tsunamis, flooding, and fires.

"… Research areas of interest include structural design to mitigate impacts of natural and man-made **hazards**; sustainability in structural design; **resilient infrastructure systems**; infrastructure interdependencies and cascading effects; multi-scale experimental testing; and innovative infrastructure materials.

"… It is expected that these positions will add to existing strengths in interdisciplinary research thrusts such as energy, **resilience** and sustainability, structures and materials, geo-engineering, and civil engineering systems. .."

"… candidates that have significant depth in structural engineering and take a modern view of how to apply that technical depth to solve problems such as creating **resilient structures** for extreme environments or under **multiple hazards**; improving the sustainability of buildings and other infrastructure components;

"… position in the area of **resilient infrastructure** for extreme events at the assistant professor level."

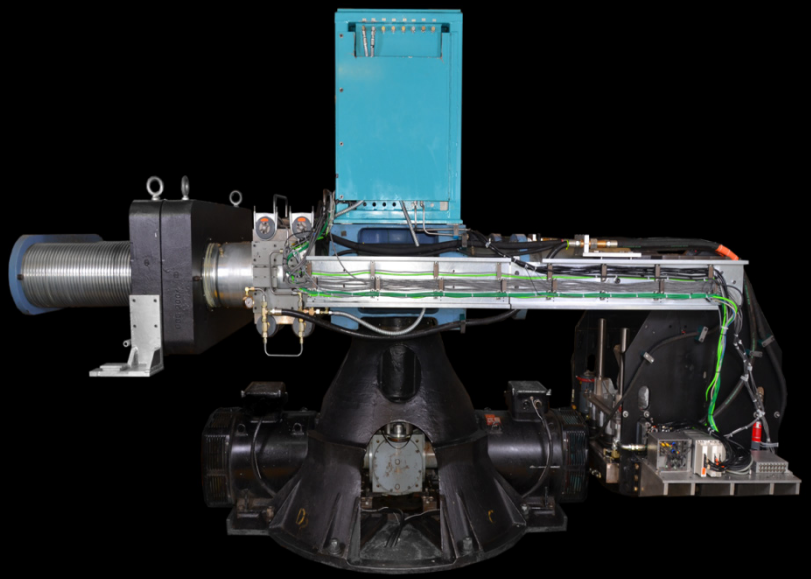
"… Targeted areas of interest include, but are not limited to, sustainability, big data, **multi-hazard mitigation**, risk assessment/reliability (including transportation infrastructure), system design, digital design and construction, and critical infrastructure systems."

Rensselaer/Presentation Overview

- Located in Troy, New York – Founded in 1824
- Oldest CEE department in the United States
- Number of CEE researchers involved multi-hazard and resilience topics
- Other disciplines involved as well – Industrial and Systems Engineering and Computer Science
- Discuss briefly current and preliminary projects in these areas – how tied together

Centrifuge Modeling

- Part of NEES facility from 2000-2014
- Soil-structure interaction
- Focus was initially earthquake hazards but has expanded to include flooding hazards
- Major finding when studying New Orleans floodwall system



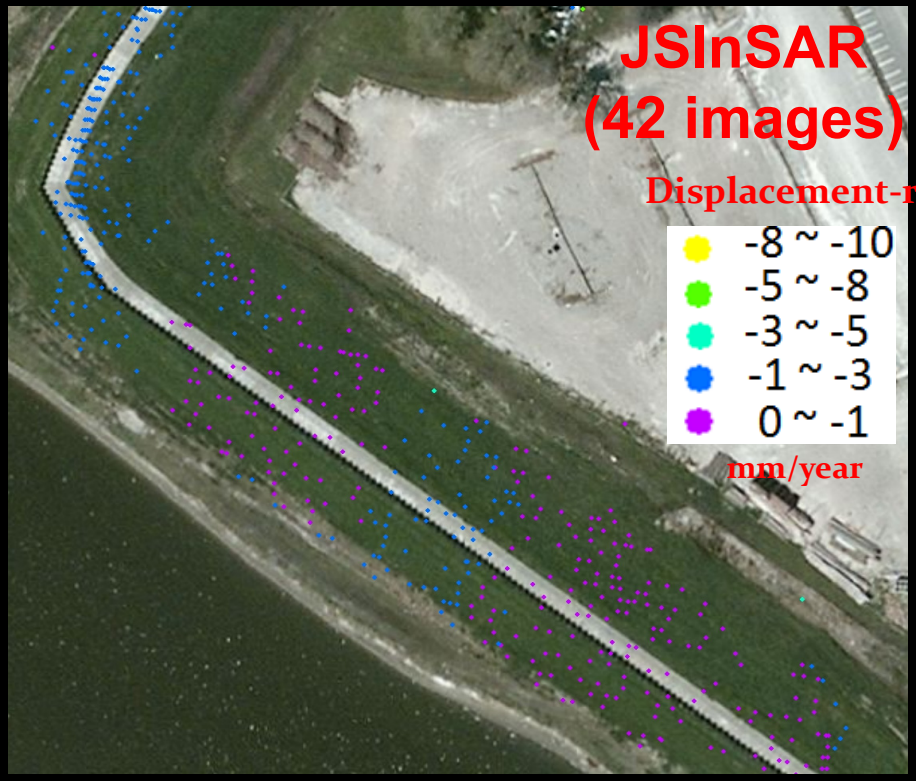
New Orleans Levee Centrifuge Models
17th Street Test

Rensselaer Polytechnic Institute
CEES Center
http://nees.rpi.edu/

Contact: Tarek Abdoun (abdout@rpi.edu)

Levee Displacement via SAR

- SAR (Synthetic Aperture Radar) → space-based system



- Radar system and processing gives accurate displacement of area around levee (London Ave. Canal – New Orleans)

Contact: Victoria Bennett (bennev@rpi.edu)

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Soft-Story Earthquake Damage

- Loma Prieta Earthquake (1989) – weakness in “corner buildings”
- Multi-story residential → “soft-story”
- Many mitigation techniques – fluid viscous dampers
- NEES-Soft project revealed reduction in inter-story drift and damage in upper floors

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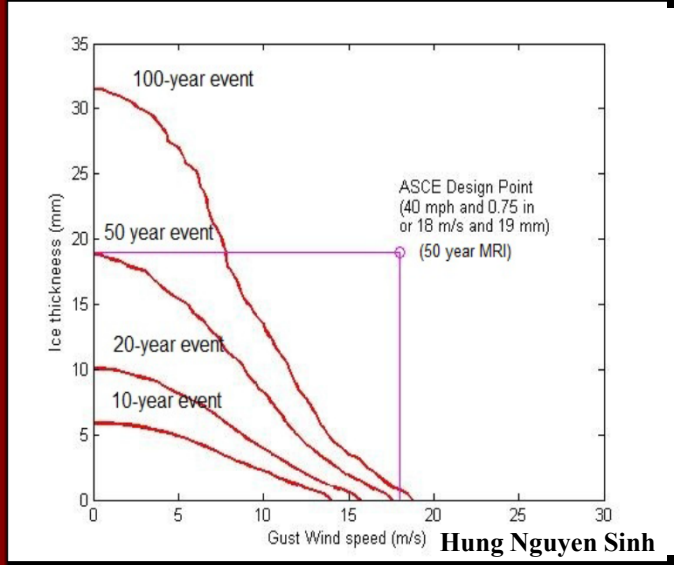
Probabilistic Analysis of Multi-Hazards

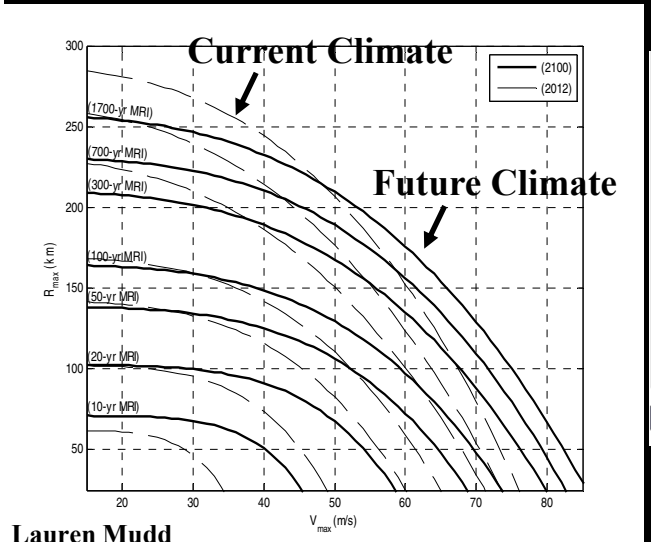
- Design typically considers hazards independently
- Combined hazards caused significant losses
  - Wind/Other Hazards (uncertainties, climate change projections)
- Results show that joint hazards are important to consider

Wind/Ice



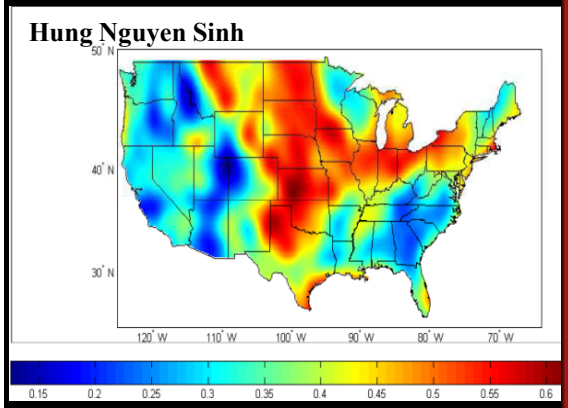
Hung Nguyen Sinh

Wind/Storm Size



Lauren Mudd

Wind/Snow



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Joplin, MO Tornado

- 161 fatalities – deadliest tornado in the official record
- 7,500 – 8,000 structures damaged or destroyed (7,000 residential)
- $600M loss at St. Johns Hospital (FM Global)
- Allowed researchers to study in detail (w/ NIST and U. Florida)

Key finding toward push for tornado-based codes and standards ⟶

- **F9:** Regardless of construction type, buildings were not able to provide life–safety protection. Of the 161 fatalities, 135, or 84%, were related to building failure

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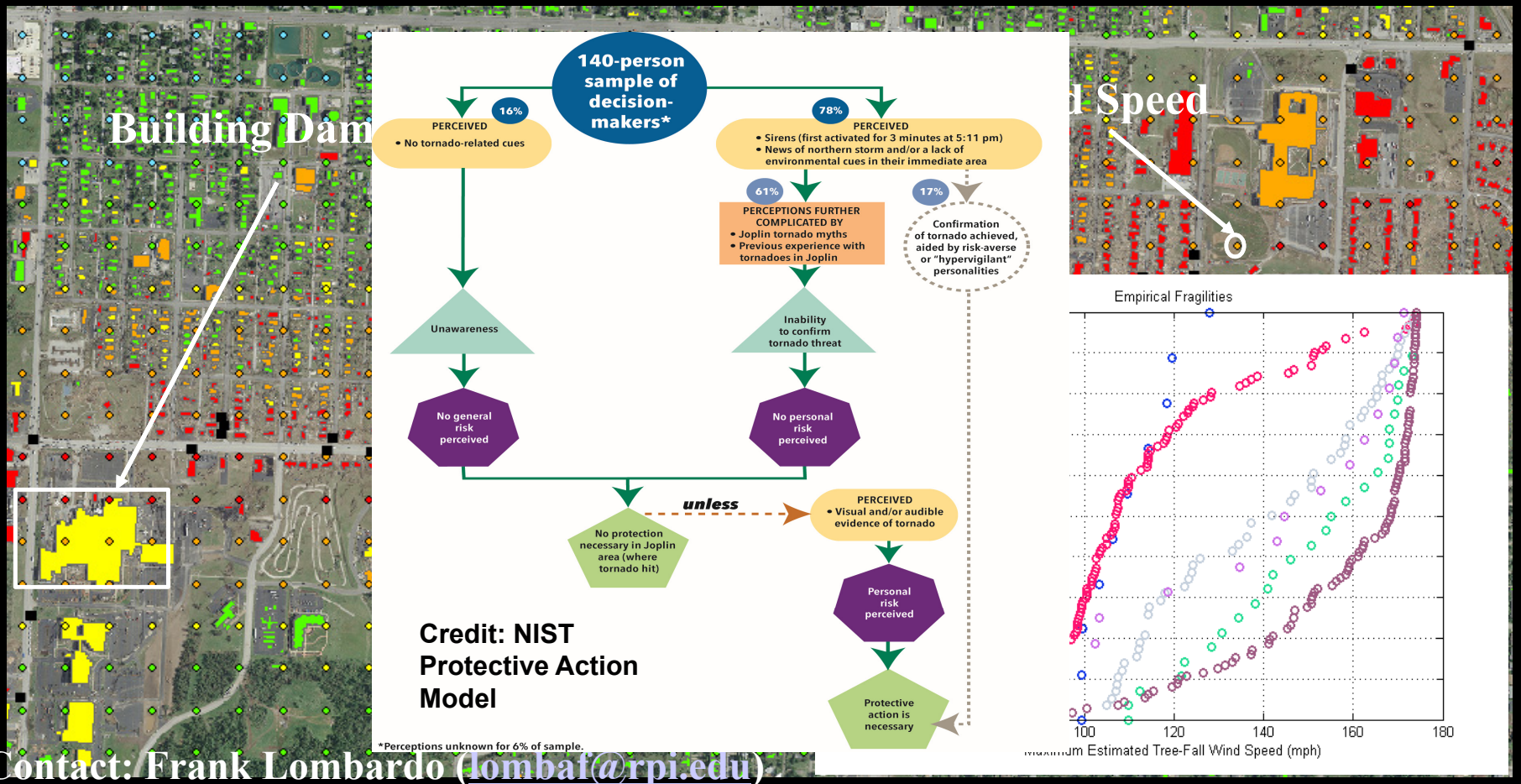
Joplin, MO Tornado

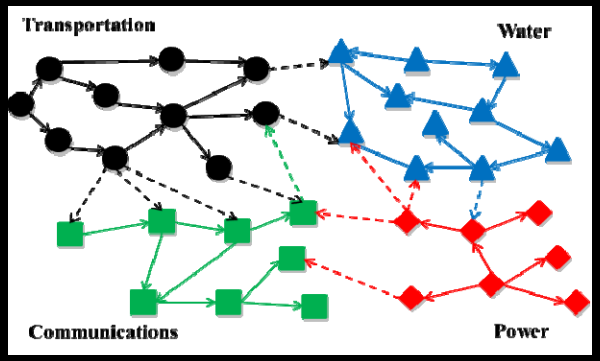
- Estimated wind speeds from tree-fall patterns, structural damage, fatalities/injuries → all geo-located
- 77% of interviewees within tornado path did not take immediate action



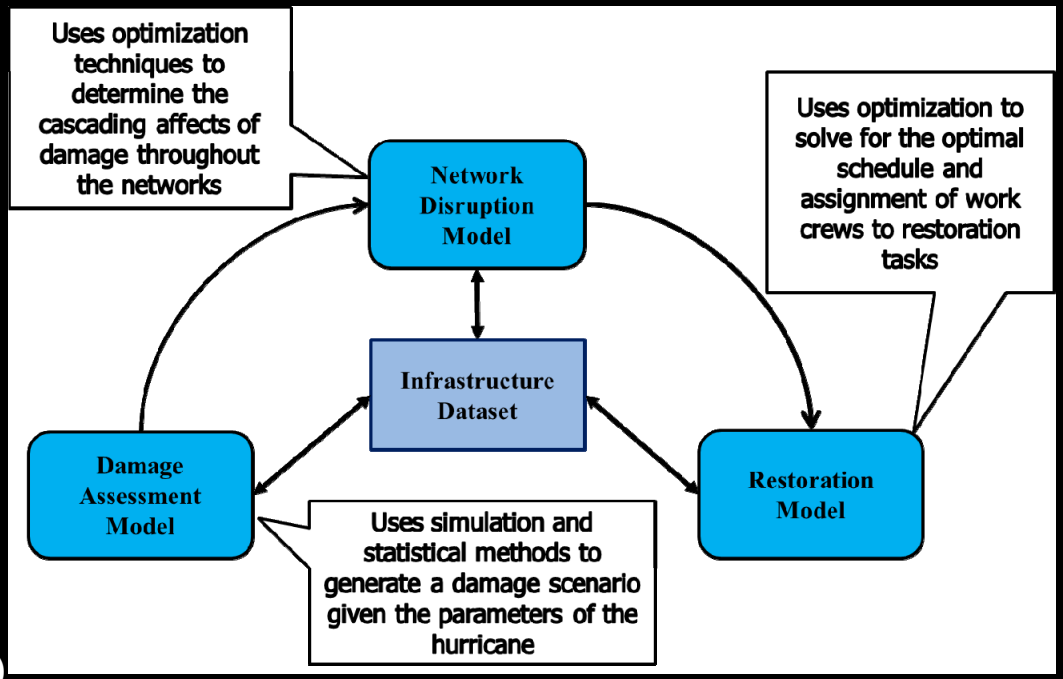
Contact: Frank Lombardo (lombaf@rpi.edu)

Infrastructure Interdependencies

- **Physical and Social Interdependencies**



- MUNICIPAL is a decision technology designed for emergency managers and managers of civil infrastructure systems



Contact: Al Wallace (wallaw@rpi.edu)

Post-Disaster Debris Removal

- 8M m^3 debris from 2011 Alabama tornadoes

- Explain debris removal *team* performance
- Simulate *system* performance given incentive and resource strategies

- Turnover negatively impacts team performance
- Increased size positively impacts effectiveness
- Eliminating payment bonus results in better system performance

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Big Data and Disasters

- "Human-Sensor" Data (e.g., Twitter)
- Comp Sci, Industrial Eng, DPRI – Kyoto U. (Japan)

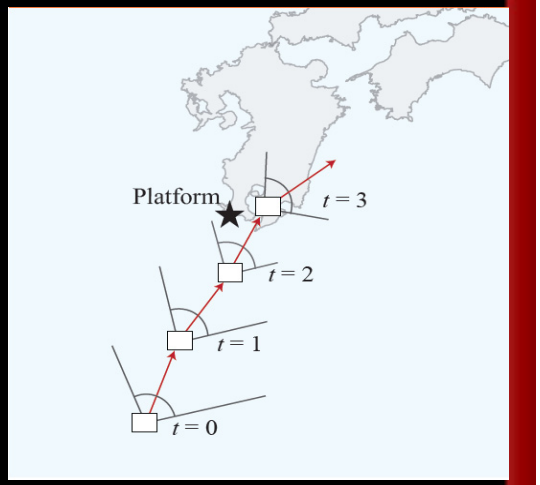
"I'm really freaked out by this hurricane, It's **not here yet** in NJ but I keep watching the trees move like crazy with wind"

"Most of Gowanus in **Evacuation** zone. Canal **already** at high tide. Storm surge to push water over edge.

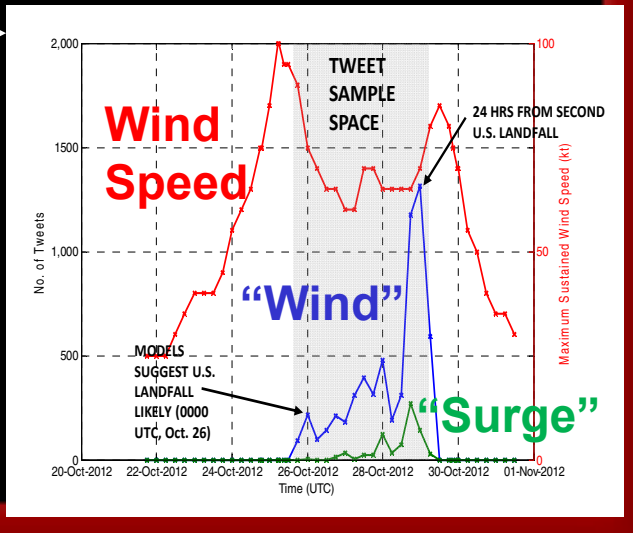
HAZARD LOCATION ENVIRONMENT CONDITION MAGNITUDE

NLP

Decision Making



Hazard/Risk



SNA

Diffuser: Controls information flow/sends messages
Broker: High access/high visibility
"Leaders"

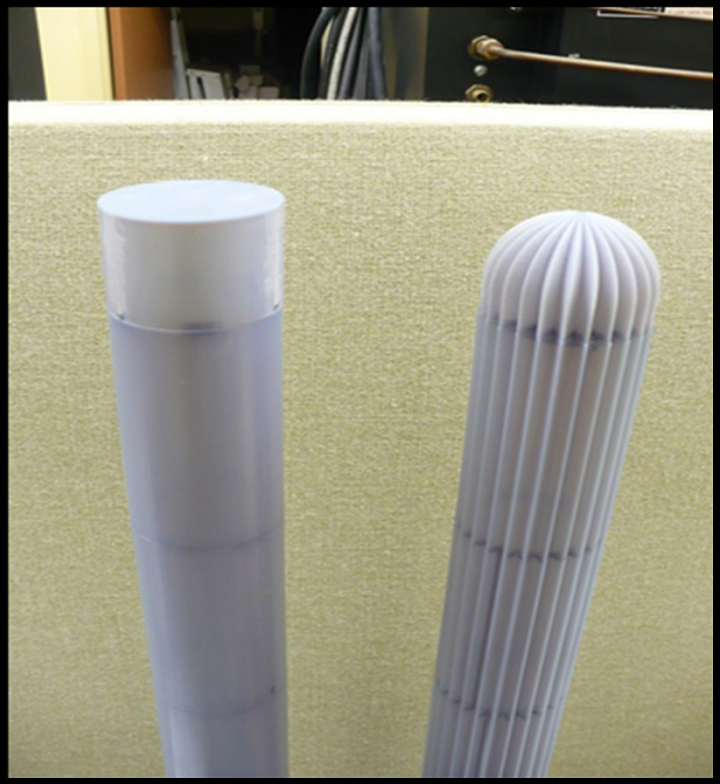
Community ID	Diffuser/Gatekeeper	Broker
2	NHCAtlantic	WSJweather
19	Fema	BarackObama

Warning Response Process:
1) Hear Warning
2) Seek Information
3) Take Action

Contact: Heng Ji (jih@rpi.edu)

Biomimicry

- Mother Nature is the most resilient system known to man
- As urbanization increases, tall and slender buildings more common
- Tested a ‘cactus-like’ shape in the wind tunnel v. smooth cylinder



- Drag and along-wind moment ~20% lower than smooth cylinder
- Cross-wind loading showed little difference
- ‘Cactus-like’ shape most important for day-to-day growth

Contact: Chris Letchford (letchc@rpi.edu)

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Thanks!

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Course Development

- ***Natural Hazards Engineering*** **– Fall 2013**

- **Hazard Assessment (Data Mining, Probability and Statistics, Mapping, Simulation)**
- **Vulnerability and Risk**
- **Disasters**
- **Forensic Engineering/Post-Disaster Survey**
- **Resilience**

Ten (10) Engineering-Based Case Studies:

- **The Event, Damages, Treatment of Loading, Lessons Learned, Mitigation**

- **Tornado – Joplin, MO – Building Damage**
- **Hurricane – Katrina and Sandy – Levee; Wind/Water; Debris Clean Up**
- **Tsunami – Japan 2011 – Building Damage**
- **Snow – NE U.S. 2011 – Building Damage**
- **Earthquake – Loma Prieta 1989 – Building/Infrastructure Damage**
- **Thunderstorm – Dallas 1985 – Aviation Crash**
- **Ice – Quebec/NY 1998 – Energy System Damage**
- **Flood – Upstate NY 1987 – Bridge Collapse**