Challenges in Disaster Resilience

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The Americas Are At Risk From Diverse Natural Hazards

**Earthquake**

Collapsed stories due to vertical irregularities in Torre O’Higgins during the 2010 Bio Bio earthquake in Chile. Credit: NIST

**Wildfire**

Bridge decks failure due to storm surge and wave action in Hurricane Katrina. Credit: NIST

**Hurricane**

Hurricane Irma, Florida Keys. Credit: NIST
...and From Technological and Manmade Events

San Bruno, CA Natural Gas Explosion

World Trade Center

Credit: NOAA September 23, 2001

Credit: NOAA September 23, 2001
Over Time, Event Impacts are Increasing in Number

Billion-Dollar Disaster Event Types by Year (CPI-Adjusted)

Source: Adam Smith NOAA/NCEI
But, Progress IS Possible!

Historical Perspective - Addressing the Urban Fire Problem

America Burning


Among other things, this Act created what have become the U.S. Fire Administration and the National Fire Academy. The Act built on existing fire responsibilities at the National Bureau of Standards (NBS) by creating the NBS Center for Fire Research (CFR).

In 1976, the U.S. experienced 2.9 million fires and 8,800 fatalities.
Basic Approach: Understand the Impacts, Understand the Hazard, Improve Resilience

- **National Fire Incident Reporting System** – fire fighters report data on structure fires, enabling a basic understanding of parameters from ignition to outcomes

- **Heat and Visible Smoke Release Measurements** – enabling fundamental heat release rate measurements worldwide via improved standard test method

- **Fire Dynamics Models** – enabling transformation from prescriptive to performance standards through tools to accurately predict the spread of fire, smoke, and toxic products

- **Fire Fighter Protective Equipment** – enabling safer and more effective fire fighting through performance metrics and standards for thermal imagers and personal alert safety systems and positive-pressure ventilation techniques for fire fighting

- **Automatic Fire Sprinkler Standards** – enabling reductions in loss of life and property due to fire by developing installation and design standard for residential sprinkler systems
The Result - In 30 Years: Major Reductions in Fires, Deaths, and Injuries

In 1976, the U.S. experienced 2.9 million fires and 8,800 fatalities.
Do We Already have an *America Burning* for Resilience?

2005 the U.S Subcommittee on Disaster Resilience – Grand Challenges

1. Provide hazards information where and when it is needed.
2. Understand the natural processes that produce hazards.
3. Develop hazard mitigation strategies and technologies.
4. Recognize and reduce vulnerability of interdependent critical infrastructure.
5. Assess disaster resilience using standard methods.

Available at https://www.sdr.gov/docs/SDRGrandChallengesforDisasterReduction.pdf
NIST Disaster Resilience Program and Our Partners are Working to Achieve Major Measurable Impacts

- Community Resilience
- Structures / Infrastructure
- Materials

Hazards
- Chronic
- Acute

NIST Research and Investigations

NIST Partners
- NOAA
- NSF
- FEMA
- NWIRP
- USGS
- NSF
- FEMA

Resilience
Part 1: Much Work to be Done: Understand the Impacts

Example: Morbidity and Mortality in Disasters
Studies and Estimates of Morbidity and Mortality in Puerto Rico Vary Based on Methodology and Scope

• Puerto Rico’s Department of Public Safety certified 64* deaths related to the storm*, but later updated this estimate to 1,427** on June 13, 2018 and to 2,975*** on August 28, 2018.

• The New York Times and other news organizations estimate that the actual death toll could be over 1,000*, based on analysis of daily mortality data from Puerto Rico’s Vital Statistics Record Office.

• Letter to the Editor of JAMA provides an estimate of 1,139**** excess deaths through December 2017, using death counts from vital statistics records and updating a previous estimate.

• Harvard School of Public Health conducted a population-based survey and estimated 4,645***** deaths.

• George Washington University conducted a study of excess mortality, and estimate that there were 2,975****** excess deaths in Puerto Rico from September 2017 through the end of February 2018.

Draft NIST/COE Metrics for Resilient Communities Following a Disaster

- Population stability
  - % people in their homes
  - population count
- Economic stability
  - Household income
  - Employment rate
  - Earnings by sector
- Social Services stability
  - % staffed hospital beds / wait time
  - % attendance per school
  - Availability of social institutions
- Physical Services stability
  - % customers served utilities (electric power, telecom, water, wastewater)
  - % buildings functional
  - % transportation network functionality
Part 2: Much Work to be Done: Understand the Hazard

Hazard Measurement Science
Hurricane Maria subjected Puerto Rico to Multiple Hazards:

- High winds: peak gusts > 140 mph
- Storm surge: peak coastal inundation > 6 ft
- Rainfall, flooding: total rainfall of 5 - 40 inches
- Landslides: many hundreds occurred
Hurricane Maria - Rainfall Hazard Measurement

In addition to station reporting issues, NWS Radar suffered complete structural failure just prior to landfall.

Disparity in rainfall measurements dependent on choice of sensor and/or methodology – varied as much as 60 cm.

These measurements are a critical component of NWIRP post windstorm investigations.

Source: Bessette-Kinton et al, 2019 (With Permission)
Actual Wind Measurement Complicated by Enhanced Fujita Tornado Scale Using Damage Indicators, Not Direct Wind Speed Measurements

- No direct measurements of tornadic wind speeds near the ground.
- While *reported* as a range of wind speeds, the EF scale is a damage indicator.
- 28 damage indicators (targets) are indicative of wind strength based general observations.
- Biases in database:
  - Awareness / population bias
  - Target Damage
  - Can be based on single record
  - ...

<table>
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<th>EF Rating</th>
<th>Wind Speed (3-sec gust)</th>
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<tr>
<td>0</td>
<td>63-85 mph</td>
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<tr>
<td>1</td>
<td>86-110 mph</td>
</tr>
<tr>
<td>2</td>
<td>111-135 mph</td>
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<tr>
<td>3</td>
<td>136-165 mph</td>
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<tr>
<td>4</td>
<td>166-200 mph</td>
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<tr>
<td>5</td>
<td>Over 200 mph</td>
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</table>
Metrology in the Wildland-Urban Interface

- Post-fire study findings
  - Embers are a major cause of ignition
    - Witch Creek/Guejito Fire (California 2007)
      - 65% of structures ignited by embers
    - Waldo Canyon Fire (Colorado 2012)
      - 50% of structures ignited by embers
  - Embers can be lofted for more than 20 km
  - Exposure 1-2 hours occurs ahead of fireline
  - Vegetative and Structural firebrands

- Metrology Need
  - Emberometer –
    - Needed to measure ember flux
    - Number & Mass
Step 3: Much Work to be Done: Improve Resilience

Tools and Methods
Adoption and Enforcement
Functionality

Lost Functionality

A. Improvements

B. Aging System

Hazard Event

Administrative and construction solutions for community resilience

Time

Performance Goal: Time to Recovery of Function
Sometimes, we know what works.

Photo Credit: Google
NIST Investigations Can Lead to Changes in Codes/Standards

  U.S. model building codes changes adopted for fire proofing; fire resistance rating; structural integrity; occupant evacuation & fire service access elevators; active fire protection systems; emergency responder communications.

• **Station Nightclub Fire (2003 - 2005)**
  Requirements on automatic sprinklers, restricted festival seating in new and existing buildings, crowd managers for existing and new assembly occupancies, and egress inspection recordkeeping adopted in NFPA 101 (Life safety Code)

• **Joplin Tornado (2011 – 2014)**
  Recommendations for standard/code requirements for tornado-resistant design for buildings, code requirements for tornado shelters in many more buildings, and standards and codes for clear, consistent, and accurate emergency communications
Sometimes, we don’t know what works

“WUI” Fire Codes are not providing adequate protection –

- Focused on thermal radiation and flame contact
  - Firebrands-50% of the ignitions addressed only through ignition and fire spread resistance

- Firebrand exposure and penetration not adequately addressed
  - Igniting wood crib on roof does not adequately represent wind-driven firebrand exposure
  - Vegetative vs structural firebrands

- Weather – wind and wind-driven fire and firebrands are not addressed
  - Need to Understand Wind in Fire Severity Zones
  - Or else, Difficult to improve building design and materials
NIST Community Resilience Planning Guide Helps Communities Achieve Resilience

STAKEHOLDER QUOTE

"Actions to improve resilience can offer immediate dividends beyond resiliency. That's why we are planning now and moving forward in ways that reflect our community's priorities. The NIST Guide is a very helpful tool for doing just that."

- Gerry Horak, Ft. Collins Mayor Pro Tem

STAKEHOLDER QUOTE

"The performance goals were the number one thing we got out of using the NIST Guide. They kept conversations anchored."

- Justin Kates, Director of Emergency Management, City of Nashua
Economics Always Matters! – The NIST Economic Decision Guide

• Standard methodology for evaluating investment decisions to improve a community’s resilience

• Compliments the NIST Community Resilience Planning Guide—but can be used alone
  • Mechanism to evaluate and prioritize efficiency of resilience actions and to prioritize them

• Step-by-Step User Guide with example community resilience planning scenarios

• Tool now publicly available (beta version): https://www.nist.gov/services-resources/software/edge-economic-decision-guide-software-tool
How to Join Us at NIST

Summer Undergraduate Research Fellowship (SURF):
https://www.nist.gov/surf

*NIST Pathways Program* for currently enrolled students (high school through post-grad): https://www.nist.gov/ohrm/student-and-other-opportunities

*NIST NRC Postdoc Fellowship:
https://www.nist.gov/iaao/nist-nrc-postdoctoral-research-associateships-program

PREP (Professional Research Experience Program):
https://www.nist.gov/iaao/academic-affairs-office/nist-professional-research-experience-program-prep

Guest Researchers, and Sabbaticals

*Term Appointments and many others!*

* US citizens only
Back - up
Functionality

Lost Functionality

A. Improvements

B. Aging System

Administrative and construction solutions for community resilience

Hazard Event

Performance Goal: Time to Recovery of Function

Time